THE

THEORY AND PRACTICE

OF

HYGIENE

THE
THEORY AND PRACTICE
OF
HYGIENE

BY

J. LANE NOTTER, M.A., M.D. (DUB.),

FELLOW OF THE CHEMICAL SOCIETY; FELLOW AND MEMBER OF COUNCIL OF THE SANITARY
INSTITUTE OF GREAT BRITAIN; HON. MEM. OF THE HUNGARIAN SOCIETY OF
PUBLIC HEALTH; EXAMINER IN HYGIENE AND PUBLIC HEALTH
IN THE UNIVERSITY OF CAMBRIDGE, AND IN THE
VICTORIA UNIVERSITY, MANCHESTER;
EXAMINER IN HYGIENE, SCIENCE AND ART DEPARTMENT;
PROFESSOR OF HYGIENE IN THE ARMY MEDICAL SCHOOL, NETLEY;
BRIGADE SURGEON LIEUT.-COLONEL, ARMY MEDICAL STAFF.

AND

R. H. FIRTH, F.R.C.S.,

ASSISTANT EXAMINER IN HYGIENE, SCIENCE AND ART DEPARTMENT;
ASSISTANT PROFESSOR OF HYGIENE IN THE ARMY MEDICAL SCHOOL, NETLEY;
SURGEON MAJOR, ARMY MEDICAL STAFF.

LONDON
J. & A. CHURCHILL
7 GREAT MARLBOROUGH STREET
(*Removed from 11 New Burlington Street*)

1896

PREFACE.

THIS volume is founded on the well-known work of the late Dr E. A. Parkes, subsequently enlarged and edited by the late Professor de Chaumont, and latterly re-edited by one of us. The law of progress, to which all science is subject, however, causes any work of a scientific nature to become out of date in a few years, and this applies in a special manner to the very large number of subjects embraced in and closely connected with Hygiene or Public Health. It will readily be conceded that perhaps nowhere has the extraordinary activity exhibited in all branches of knowledge during the last twenty years been more marked than in the domain of Sanitation and Preventive Medicine, and this has borne fruit not only in the modification of old ideas as to the causes of disease and methods for their prevention, but also in the introduction of more perfect methods of research and the elaboration of more complete safeguards for the maintenance of the public and individual health.

On this account it was at one time deemed advisable to issue a new edition of "Parkes' Hygiene," but an examination of its general scheme of arrangement, combined with a somewhat extensive practical knowledge of the needs of students and others likely to use such a book, soon rendered it apparent that any attempt at mere revision or re-editing would be inadequate for the requirements of the times. We therefore determined to re-write the whole book, and to prepare a new work on the Theory and Practice of Hygiene, in which the historical portions of the original have been retained, but supplemented by a full statement of our present-day knowledge of the subjects discussed, with accounts of the methods, appliances, and legislative enactments introduced of late years in the application of Science to the Prevention of Disease and the Preservation of Health.

As regards the general range of subjects discussed, we have not departed greatly from traditional lines; while, in attempting to discuss each topic, we have endeavoured to explain it both theoretically and practically, in the hope that the book may be found thereby useful not only to the sanitary official but also to the student of public health work.

The subject of hygienic analysis is so intimately associated with the duties of the Medical Officer of Health, that special efforts have been made in the following pages to render the work in this respect a reliable guide for those who, while not being actually Public Analysts, are frequently called upon to express opinions necessitating an analyst's knowledge. In respect of special analytical methods, it has not been an easy task to decide as to what should be included and what omitted. In all cases we have given only such processes as experience has indicated to us to be reliable and of practical use for the Medical Officer of Health.

The analysis of water and air has necessarily been considered in some detail, not only from the chemical but also from the biological point of view; this latter aspect of the question has been so much developed during recent years as to constitute almost a distinct branch of study. In endeavouring to give explanations of methods for the bacteriological examination of water and air, we have adhered to the principle of advocating only such methods of research as come within the possibilities of the duties of a Medical Officer of Health, and which, in our hands, have been found to be practically useful.

The subjects of Ventilation and Heating have been considered at some length, and advisedly so, because experience has indicated to us that these are matters usually imperfectly treated in the majority of text-books, and are subjects, too, upon which students and others are inadequately informed.

The accounts of Scurvy and the dietetic value of Alcohol are given, with the exception of some minor verbal alterations, in much of the original language of Dr Parkes. Our knowledge upon these matters has been so little changed during recent years that it was felt that very little improvement could be made upon the original statements. Similarly, the chapters upon Exercise and Clothing have been but slightly altered by us.

One matter of great difficulty has been the question of Sanitary Law. While fully recognising the importance of every sanitary officer studying the various legislative enactments bearing upon the Public Health in their original form, and the difficulties in the way of either making a legal chapter interesting or profitable reading, we have endeavoured, in the section which deals with sanitary legislation, to overcome these objections and to construct a chapter which may be not only interesting but useful.

Special chapters have also been incorporated upon the subjects of

Offensive Trades, Disinfection, and the Infective Diseases. The latter has necessarily been somewhat compressed, as the subject is so constantly changing as to be difficult to keep up to date. The general principle adopted in this chapter has been to give merely such an outline of the natural history of each disease as may be readily supplemented by the reader's collateral reading, combined with a brief statement of our present knowledge upon immunity and of the general principles of disease prevention.

A chapter is devoted to the consideration of the life-history of Parasites; and for advice and much information on this subject we are indebted to Dr Patrick Manson. To him and to Mr Young J. Pentland we are indebted for the loan of photographic negatives and the use of drawings of certain parasites which illustrate the text.

Considerable pains have been taken to render the chapter on Vital Statistics intelligible and useful to the sanitary officer, without at the same time overloading it with redundant matter. The increasing importance attached to vital statistics, and the greater accuracy of our national enumerations, demand a careful study of this subject by all engaged in public health work. We do not profess to have succeeded in writing an exhaustive chapter on this subject, but hope that, if read in conjunction with special treatises and official reports, it may be found equal to the wants of the Medical Officer of Health and others. It is our regret that the delay in the publication of the Registrar General's Summary Report on the census of 1891 has precluded the insertion of the most recent facts and figures respecting occupations; but we think their omission will not materially affect the value of the statement of the general principles of vital statistics herein given.

We have, further, not been unmindful of the fact that much of the life-work of our predecessors, the late Drs Parkes and de Chaumont, was devoted to the amelioration of the sanitary conditions of soldiers and sailors, and that their writings, which admittedly form the nucleus of this volume, were primarily intended for the use of the sanitary advisers of the Army and Navy. Bearing this fact in mind, we have incorporated in this work special chapters dealing with the sanitary needs of both the Army and Navy, and have emphasised therein such points as are not in strict accordance with the conditions of civil life.

It may be noticed that all foot-notes have been omitted in the following pages. In place of them, we have given at the end of each chapter a Bibliography and References to authors and others quoted in the text. It is not claimed that these bibliographies are in any way complete, but we hope that they may be found of material use to those desirous of referring to matters in their original form.

Throughout the work we have steadily kept in view the importance of freely illustrating the text. To Dr Thresh and to Mr Casella we are indebted for several blocks. To Surgeon-Colonel L. A. Irving, A.M.S., we owe our thanks for the drawings from which Plate I. has been prepared; while to Dr S. Abbott of the Massachusetts State Board of Health we desire to express our acknowledgments for the loan of blocks used in the construction of Plate II. Many of the other illustrations have been drawn for us by Mrs Bruce and by Miss Triscott.

It is not without some diffidence we offer this book to the public, as we are aware of its imperfections; but, at the same time, we are conscious of having spared no labour in endeavouring to bring it thoroughly up to date, in order to render it not only a mere text-book for those preparing for examinations in Hygiene, but also a comprehensive and reliable work of reference and guidance for those engaged in the often difficult but always responsible duty of being the sanitary advisers to local authorities, as well as for those employed in naval and military duties.

WOOLSTON, HANTS,
January 1896.

CONTENTS

CHAPTER I.

WATER.

CHAPTER II.

AIR.

CHAPTER III.

VENTILATION AND HEATING.

CHAPTER IV

FOOD.

CHAPTER V.

BEVERAGES AND CONDIMENTS.

CHAPTER VI.

CLOTHING.

CHAPTER VII.

EXERCISE.

CHAPTER VIII.

SOIL.

CHAPTER IX.

HABITATIONS.

CHAPTER X.

DISPOSAL OF SEWAGE AND REFUSE.

CHAPTER XI.

PARASITES.

CHAPTER XII.

THE INFECTIVE DISEASES.

CHAPTER XIII.

DISINFECTION.

CHAPTER XIV.

CLIMATE.

CHAPTER XV.

METEOROLOGY.

CHAPTER XVI.

VITAL STATISTICS.

CHAPTER XVII.

OFFENSIVE TRADES.

CHAPTER XVIII.

SANITARY LAW.

CHAPTER XIX.

MILITARY HYGIENE.

CHAPTER XX.

MARINE HYGIENE.

APPENDICES.

ERRATA.

Page 78.—In the third and seventh lines of the *Example* given on this page, *for* 1 mgm. of oxygen *read* 0·8 mgm. of oxygen ; in the eighth line of the same example, *for* 0·2 mgm. *read* 0·16 mgm. in two places ; in the tenth line of the same example, *for* 0·08 part *read* 0·064 part.

DIRECTIONS TO BINDER.

Plate	I.	to face page	288.
,,	II.	,,	400.
,,	III.	,,	506.
,,	IV.	,,	508.
,,	V.	,,	510.
,,	VI.	,,	576.
,,	VII.	,,	602.
,,	VIII.	,,	614.
,,	IX.	,,	622.
,,	X.	,,	636.

THE THEORY AND PRACTICE OF HYGIENE.

CHAPTER I.

WATER.

THE supply of wholesome water in sufficient quantity is a fundamental sanitary necessity. Without it injury to health inevitably arises, either simply from deficiency of quantity, or more frequently from the presence of impurities. In all sanitary investigations, the question of the water-supply is one of the first points of inquiry, and of late years much evidence has been obtained of the frequency with which diseases are introduced by the agency of water. There are many industries that cannot be carried on without the use of tolerably pure and soft water, and it has also been found to be the most effectual and economic agent in the removal from our habitations of waste slops and sewage; but paramount to all these is the value of the sanitary results growing out of the maintenance of health and the inducement to cleanliness of person and habitation by the supply of an abundance of water delivered constantly to the householder.

PROPERTIES OF WATER.

Water, long believed to be an element or simple substance, is now known to be a chemical compound, consisting of two volumes of hydrogen and one volume of oxygen, and is formed whenever hydrogen gas or a combustible substance containing hydrogen is burnt in oxygen or atmospheric air. At the ordinary temperature of the air it is a clear, transparent, tasteless, and odourless liquid; it appears colourless when seen in small quantities, but that it has a pale blue colour is apparent when a white object is viewed through a column about two feet in depth.

At the temperature of 0° C. (32° F.) water becomes solid or freezes; during the act of freezing it expands nearly $\frac{1}{11}$th of its volume, a fact which explains the reason why, during frosts, frozen pipes split or burst, and why damp soils and rocks tend to crack during frost. This disintegrating action of water upon rocks and soils is due to the expansive force exerted by water when it solidifies, and the ice formed is practically incompressible—hence the hardest rocks are split and broken up. This solid water or ice has a specific gravity of 0·9168 when compared with water at the same temperature, consequently ice always floats on the surface of the water, and, since the density of water is greatest at 4° C. (39°·2 F.), it follows that, when part of it is cooled below that point, the colder portion remains at the surface, and when it reaches the freezing point, is then converted into ice, while the water just below remains a few degrees warmer, being protected by this crust of ice from the cooling currents of air.

The density of water in the liquid state is about 770 times more than atmospheric air, this density being greatest at a temperature of 4° C. (39°·2 F.). The density of water is always taken as the standard of comparison in reference to which the densities of other solid and liquid substances are expressed. In this country the density of water at the temperature of 15°·5 C. (60° F.) is taken as unity, but on the Continent the temperature of its maximum density, namely 4° C. (39°·2 F.), is more usually adopted.

The following table gives the weights of certain volumes of water in terms both of the metric system and of the system of weights and measures used in this country :—

Grains.	Cubic centimetres at 4° Cent. as grammes.	Cubic inches at 60° F.	Pounds.	Gallons at 60° F.	Cubic feet at 60° F.
1					
15·432	1	0·061		0·0002201	0·0000353
252·456	16·386	1			
7000	454·345	27·727	1	0·1	0·016046
70000	4543·458	277·276	10	1	0·16046
436495	28315	1728	62·355	6·2355	1

Water possesses a certain amount of elasticity and compressibility. Thus by increasing the pressure by the weight of 200 atmospheres its volume is said to be reduced $\frac{1}{12}$. This compressibility of water increases as the temperature rises. Water has a high capacity for heat, and its specific heat is taken as the standard of unity in reference to which the capacities of other substances for heat are expressed; on the other hand, it is a very bad conductor of heat. Water evaporates at all temperatures when in contact with atmospheric air or other gas, and the vapour given off has a density and tension determined by the temperature.

Under the ordinary atmospheric pressure—760 mm. (29·922 inches)—water boils at the temperature of 100° C. (212° F.) and is converted into more than 1600 times its own volume of gas (steam). If the pressure be reduced to nearly that of a vacuum the boiling point is lowered to nearly 0° C. (32° F.), but if the pressure be increased, then the temperature of the boiling point is raised, as shown by the following table :—

Pressure in atmospheres.	Temperature Centigrade.	Pressure in atmospheres.	Temperature Centigrade.	Pressure in atmospheres.	Temperature Centigrade.
1	100°	7	166°·5	18	209°·4
2	121°·4	8	172°·1	20	214°·7
3	135°·1	10	181°·6	25	226°·3
4	145°·4	12	190°·0	30	236°·2
5	153°·1	14	197°·2	35	244°·8
6	160°·2	16	203°·6	40	252°·5

The boiling point of water under the ordinary pressure is slightly influenced by the nature of the vessel in which it is heated and by the state of its surface. Thus in glass and porcelain vessels with very smooth surfaces water boils at a temperature 1 or 2 degrees higher than in metallic vessels with a rough surface.

Water has a remarkable power of dissolving substances, and is the most universal known solvent. It dissolves or retains all the known gases, and there are only a few solid substances that do not gradually yield to the solvent action of water, assisted as this is by the gases present in all natural waters. The solubility of different substances is, however, very unequal. Generally, the solubility of any particular body is increased in proportion as the temperature is raised, but there are exceptions to this rule; for example, water at 0° C. dissolves nearly twice as much lime as water at 100° C. In the case of gases, the amount which water can dissolve is largely dependent upon the pressure; and under ordinary pressure it is generally larger in proportion as the temperature is lower.

The aqueous solutions of solid substances and of certain liquids and gases have a higher density than ordinary water. The freezing point of water-solutions is lower than that of water, thus sea-water, which is largely a solution of various salts of magnesium, sodium and potassium, freezes less readily than fresh water. The boiling point of water is raised when it contains solid substances in solution. Liquid and gaseous substances dissolved in water sometimes cause a rise and sometimes a depression of the boiling point.

ON THE QUANTITY AND SUPPLY OF WATER.

In estimating the quantity of water required daily for each person, it is necessary to allow a liberal supply. There should be economy and avoidance of waste; but still, any error in supply had far better be on the side of excess. In England many poor families, either from the difficulty of obtaining water, or of getting rid of it, or from the habits of uncleanliness thus handed down from father to son, use an extremely small amount. It would be quite incorrect to take this amount as the standard for the community at large, or even to fix the smallest quantity which will just suffice for moderate cleanliness. It is almost impossible to give a definition of cleanliness, nor perhaps is it necessary, since there is a general understanding of what is meant.

It must be clearly understood for what purposes water is supplied. It may be required for drinking, cooking, and ablution of persons, clothes, utensils, and houses; for cleansing of closets, sewers, and streets; for the drinking and washing of animals, washing of carriages and stables; for trade purposes; for extinguishing fires; for public fountains or baths, &c.

It follows that the quantities necessary for different communities must vary a good deal, according as men live together in towns or are scattered in rural districts, and according as there may be or may not be systems of drainage or trades and manufactures.

In towns supplied by water companies, the usual mode of reckoning is to divide the total daily supply in gallons by the total population, and to express the amount per head per diem.

Thus in 1893 the total population of the Metropolis and suburbs was reckoned at 5,373,650, and the water supplied daily by all the eight companies was 190,033,379 gallons, representing a daily consumption of 35·36 gallons per head, or 238 gallons per house, for all purposes. The average daily supply delivered from the Thames was 103,466,816 gallons; from the Lee, 52,371,230 gallons; from springs and wells, 34,095,470 gallons; and from ponds at Hampstead and Highgate, for non-domestic purposes, 99,863 gallons.

The following are some of the gross amounts used at the present time for all the above purposes, as judged of in this way:—

	Gallons per head daily.
London (1893)—	
Chelsea Water Works Company,	38·40
East London ,,	35·06
Grand Junction ,,	49·35
Kent ,,	30·30
Lambeth ,,	35·11
New River ,,	32·88
Southwark and Vauxhall ,,	36·58
West Middlesex ,,	32·98
General average for London,	35·36
Liverpool,	27
Manchester,	24
Edinburgh,	36
Glasgow,	52
Dublin,	35
Paris,	53
Berlin, .	22
St Petersburg,	49
Rome,	220

The average supply to 46 English towns in 1888 was 25 gallons per head, of which 20 gallons were for domestic purposes. In Warwick, by careful inspection as regards waste, it has been reduced from 22 to 15 gallons per head daily. The average amount in London for domestic use was 27·12, and in Manchester 15 gallons per head.

By decision of the Secretary of State for War, each officer, man, and woman occupying quarters receives 20 gallons, and each child 10 gallons, daily.

The gross amount thus taken is used for different purposes, which must now be considered.

Amount required for Domestic Purposes (water-closets included).—For drinking purposes the amount varies with age, sex, weight, climate, and occupation; but it may be laid down as a rule that the total daily amount necessary is equal to about half an ounce for each pound weight of the body, or in other words, an adult takes in daily about 70 to 100 ounces (3½ to 5 pints) of water for nutrition. Now of this water about one-fourth to one-third exists in the so-called solid food, that is, in the meat, bread, &c., and the remainder is taken in some form of liquid. There are, however, wide ranges from the average. Women drink rather less than men; children drink, of course, absolutely less, but more in proportion to their bulk than adults.

For the cooking of food a certain amount is required, only part of which is actually consumed with the food. This will generally not be less in the case of adults than three-quarters of a gallon daily. Taking all sexes and all ages together, we may lay down the minimum necessary for drinking and cooking purposes as 1 gallon per head per diem.

Parkes measured the water expended in several cases: the following was the amount used by a man in the middle class, who may be taken as a fair type of a cleanly man belonging to a fairly clean household :—

	Gallons daily per one person.
Cooking,	·75
Fluids as drink (water, tea, coffee),	·33
Ablution, including a daily sponge-bath, which took 2½ to 3 gals.,	5
Share of utensil and house-washing,	3
Share of clothes (laundry) washing, estimated,	3
	12

These results are tolerably accordant with actual experiments, if we remember that with a large household there is economy of water in washing utensils and clothes, and that the number of wives and children in a regiment is not great. In poor families, who draw water from wells, the amount has been found to vary from 2 to 4 gallons per head, but then there was certainly not perfect cleanliness.

Bateman states that, in a group of cottages with 82 inmates, the daily average amount was 7½ gallons per head, and in another group 5 gallons per head. Letheby found in the poor houses in the city of London the amount to be 5 gallons. In experiments in model lodging-houses, Muir states that 7 gallons daily were used. Easton, in his own house in London, found he used about 12 gallons per head, of which about 5 were for closets, leaving 7 for other uses; but probably the laundry washing was not included. In the convict prison at Portsmouth, where there are water-closets, and each prisoner has a general bath once a week, the amount is 11 gallons.

In several of the instances just referred to, it may be questioned whether the amount of cleanliness was equal to what would be expected in the higher ranks. In most instances quoted, no general baths were used; but it is now becoming so common in England to have bath-rooms that they are often put even in eight-roomed houses. A general bath for an adult requires, with the smallest adult bath (*i.e.*, only 4 feet long and 1 foot 9 inches wide), 38 gallons, and many baths will contain 50 to 60 gallons. A good shower-bath will deliver 3 to 6 gallons. General baths used only once a week will add 5 or 6 gallons per head to the daily consumption.

We may safely estimate that for personal and domestic use, without baths, 12 gallons per head daily should be given as a usual minimum supply; and with baths and perfect cleanliness, 16 gallons should be allowed. This makes no allowance for water-closets or for unavoidable waste. If from want of supply the amount of water must be limited, 4 gallons daily per head for adults is probably the least amount which ought to be used, and in this case there could not be daily washing of the whole body, and there must be insufficient change of under-clothing.

If public baths are used, the amount must be greatly increased. The largest baths the world has seen, those of Ancient Rome, demanded a supply of water so great as, according to Leslie's calculations, to raise the daily average per head to at least 300 gallons.

Amount required for Water-Closets.—The old arrangements with cisterns allow any quantity of water to be poured down, and many engineers consider that the chief waste of water is owing to water-closets. In some districts, by attention to this point, the consumption has bee greatly reduced. Small cisterns, termed water-waste preventers, are put up in towns with constant water-supply, which give only a certain limited amount each time the closet is used. The usual size now in use holds about 2 gallons; but even 2 gallons are insufficient to keep the pan and soil-pipe perfectly clean. A committee appointed by the Sanitary Institute to report on the quantity of water required to flush water-closets, after making a large number of experiments, recommended that the minimum quantity of flushing water should be fixed at 3 gallons, and that the maximum quantity should not be less than 3½ gallons. Considering also that some persons will use the closet twice daily and sometimes oftener, and that occasionally more water must be used for thoroughly flushing the pan and soil-pipe, 6 gallons a day per head should probably be allowed for closets. In this particular instance a false economy in the use of water is most undesirable. Water latrines require less; the amount is not precisely known; the experiments of the Royal Engineers at Dublin give an average of 5 gallons per head, but it is considered that this might be reduced.

In fixing the above quantities, viz., 12 gallons per head for all domestic purposes, except general baths and closets, 4 gallons additional for general baths, and 6 for water-closets, endeavours have been made to base them upon facts, and they are probably not much in error. It is, however, necessary to make some allowance for unavoidable waste within the premises, and for extra supply to closets, and it will be a moderate estimate to allow 3 gallons daily per head for this purpose. This will make 25 gallons.

There is another reason for believing that an amount of about 25 gallons per head should pass from every house daily into sewers, if sewers are used. It is that in most cases this quantity seems necessary to keep the sewers perfectly clear, though in some cases, no doubt, with a well-arranged and constructed sewerage, a less amount may suffice. But the complete cleansing of sewers is a matter of such fundamental importance, that it is necessary to take the safest course. Hitherto much water has run merely to waste.

Amount required for Animals.—The Queen's Regulations fix the maximum daily supply for each horse in the army at 20 gallons. This amount includes that necessary for the washing of both horses and carriages, and seems ample. Of course the amount that horses drink varies as much as in the case of men, and depends on food, weather, and exertion; but if a horse is allowed free access to water at all times, and this should be the case, he will drink on an average 6 to 10 gallons, and at times more. In the month of October, with cool weather, a horse 16 hands high, doing 8 miles a day carriage work, and fed on corn and hay, was found to drink 7½ gallons. Another carriage horse drank nearly the same amount. In a stable of cavalry horses doing very little work, and at a cool time of the year, the amount per horse was found to be 6⅓ gallons. Taking a horse as weighing 1000 ℔ avoir., this is just an ounce of water per pound weight of horse. The amount used for washing was 3 gallons daily. In hot or dirty weather the quantity for both purposes would be larger. For washing a horse requires at least 1½ gallons, and twice this amount if he is washed twice a day. There is a saving, however, if grooms wash several horses in the same water. It is difficult to say how much is used for carriage washing. On the whole, including carriage washing, &c., 20 gallons per horse is not an excessive amount. A cow or an ox, on dry food, will drink 6 or 8 gallons; a sheep or pig, ½ to 1 gallon.

In the Abyssinian expedition, the following was the calculation for the daily expenditure of water per head on ship-board :—

Elephants,	25 gallons.
Camels,	10 ,,
Oxen (large draught),	6 ,,
Oxen (small pack animals),	5 ,,
Horses,	6 ,,
Mules and ponies,	5 ,,

For 20 elephants and 100 men, 50,000 gallons were put on board for a voyage of 60 days. For camels on board ship 8 gallons, and on land 15 gallons are required per day (Wolseley). F. Smith found, from experiments in India, that a horse in the month of February consumed on an average 8½ gallons daily ; this accords with Parkes's experiments at home ; of course in hot weather the amount would be greater.

Amounts required for Municipal and Trade Purposes.—For municipal purposes water is taken for washing and watering streets, for fountains, for extinguishing fires, &c. The amount for these and for trade purposes will vary greatly. Rankine, who gives an average allowance of 10 gallons per head for domestic purposes, proposes 10 more for trade and town use in non-manufacturing towns, and another 10 gallons in manufacturing towns. One ton of water (224 gallons or 35·9 cubic feet) is sufficient to lay the dust over a surface of 600 square yards of gravel or macadamised road, or 400 square yards of granite paved streets. The average number of days in which watering is required in England is 120.

If, now, the total daily amount for all purposes be stated per head of population, it will be as follows :—

	Gallons.
Domestic supply (without baths or closets).	12
Add for general baths,	4
Water-closets,	6
Unavoidable waste,	3
Total house supply,	25
Town and trade purposes, animals in non-manufacturing towns,	5
Add for exceptional manufacturing towns,	5
	35

In India and hot countries generally, the amounts now laid down would have to be altered. Much more must be allowed for bathing and for washing generally, while a fresh demand would arise for water to cool mats, punkahs, or air-passages by evaporation. In Calcutta the supply for a population of 433,219 is 37 gallons of filtered, and 5·8 unfiltered water, in all 42·8 gallons per head per day. In Madras, in 1887, the consumption was about 18 gallons, and in 1888 about 16 gallons daily per head, the supply being somewhat restricted.

Amount required for Hospitals.—In hospitals a much larger quantity must be provided, as there is so much more washing and bathing. From 40 to 50 gallons per head are often used. There are no good experiments as to the items of the consumption, but the following is probably near the truth :—

	Gallons daily.
For drinking and cooking, washing kitchen and utensils,	2 to 4
For personal washing and general baths,	18 ,, 20
For laundry washing,	5 ,, 6
Washing hospital, utensils, &c.,	3 ,, 6
Water-closets,	10 ,, 15
	38 to 51

It would be very desirable to have more precise data; possibly the amount for closets is put too high, but not greatly so when all cases are taken into account.

At Netley the amount per head per diem is put approximatively at 70 gallons. At Haslar the quantity is the same. At the Cambridge Hospital, Aldershot, the average is 90; Herbert Hospital, Woolwich, 89. These amounts include that used by the hospital attendants and medical staff. In some of the Metropolitan hospitals there is singular diversity in the quantities: University College Hospital, 58 gallons per head; St Thomas's, no less than 106; St Bartholomew's, 57 gallons; whereas at Guy's, where special care is taken to check unnecessary waste, only 35 gallons are used, including what is taken by the resident medical staff.

There is no doubt that a considerable quantity of water is wasted, and economy might be effected without any detriment to sanitary requirements. In some places it has been found that when the water-supply was 30 gallons, the actual amount used in the houses was not more than 20 gallons, and in some cases even less. By introducing proper waste-detectors economy of water might be accomplished, while the full amount for hygienic requirements might still be given to the consumer.

SOURCES OF WATER-SUPPLY.

The constant evaporation which takes place from the surface of all masses of water exposed to the atmosphere, the diffusion of water-vapour throughout the atmosphere, and its subsequent condensation there to the liquid or solid state, give rise to the incessant circulation of water which is continually taking place.

Of this condensed atmospheric vapour, falling on the surface of the various continents and islands, part penetrates into the soil until it reaches a less permeable stratum, above which it accumulates; part flows away and becomes the source of the great rivers and lakes, some is absorbed by the soil itself, while the remainder passes off in vapour to be again condensed.

The sources of water-supply are very varied; each class has its own peculiar characteristics, but all are derived from the same source and descend to us in the form of rain, dew, mist, hail and snow.

Rain-Water approaches nearer to absolute purity than any other kind of natural water. When collected in clean vessels it contains only such dissolved substances as it can take up from the atmosphere. As it falls through the air it becomes highly aërated, the amount of contained gas averaging 25 c.c. per litre. The ratio of the oxygen to the nitrogen by volume in this gas is greater than in atmospheric air on account of the greater solubility of oxygen in water. The Rivers Pollution Commissioners in their sixth report (1874) give the following as the gaseous constituents of rain-water:—

	c.c. per litre.
Nitrogen,	13·08
Oxygen,	6·37
Carbon dioxide,	1·28
Total gases,	20·73

In its passage through the air rain-water carries down ammoniacal salts (carbonate, nitrite, and nitrate), and nitrous and nitric acids in small amount. The total quantity of nitrogen in ammoniacal salts, nitrous and nitric acid, is 0·0985 part per 100,000. Frankland puts the average at 0·032.

At Montsouris, mean of seven years, the ammonia amounted to 0·193 per 100,000; mean of all Paris (1881–82), 0·287 per 100,000; the nitric acid (NO_3), mean of six years, to 0·354 per 100,000. This gives a total nitrogen, from ammonia and nitric acid, of 0·239 per 100,000. The amount is greater just after the commencement of rain than when it has continued for a long time. In towns with coal-fires it takes up sulphurous and sulphuric acids, and sometimes hydrogen sulphide. The sulphates in rain increase, according to Angus Smith, as we pass inland, and before large towns are reached; they are, according to this author, "the measure of the sewage in air" when the sulphur derived from the combustion of coal can be excluded, but in this country the exclusion could never be made. Free acids are not found with certainty when combustion and manufactures are not the cause. The acidity taken as sulphuric anhydride (SO_3) was equal to 0·014 part per 100,000 of rain in a country place in Scotland, and 1·513 in Glasgow; in Manchester in 1870 it was 1·202; and in London 0·387. The nitric acid in Glasgow was as much as 0·244 part per 100,000, and in London only 0·0884. Albuminoid ammonia was no less than 0·0326 part per 100,000 in London rain. Rain also carries down many solid substances, as sodium chloride, in sea air; calcium carbonate, sulphate, and phosphate; ferric oxide; carbon.

In the following table are recorded the maximum, minimum, and average proportions of each of the several ingredients determined in seventy-one samples of rain, collected in a special rain-gauge (Rivers Pollution Commission):—

	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Chlorine.	Hardness.
Minimum.	0·62	0·021	0·003	0·005	0	0	0
Maximum,	8·58	0·375	0·121	0·155	0·044	1·65	1·7
Average,	3·42	0·095	0·021	0·049	0·007	0·33	0·5
Rain water from Land's End,	42·80	0·131	0·034	0	0·020	21·80	10·0
Rain water from Hyde Park, London,	2·76	0·385	0·040	0·210	0·008	0·008	1·1

It is thus seen that the composition of rain-water, even in the open country, is liable to very great fluctuations, and that the amount of impurity, both mineral and organic, is occasionally large.

Sometimes microscopic plants of the lowest order (as *Protococcus pluvialis* and others) are present, and in towns the débris arising from street dust.

The uncertainty of the rainfall from year to year, the length of the dry season in many countries, and the large size of the reservoirs which are then required, are disadvantages. On the other hand, its general purity and its great aëration make it both healthy and pleasant. The greatest benefits have resulted in many cases from the use of rain instead of spring or well water, which is often largely impregnated with earthy salts. In all places where the spring or well water is bad, rain-water should be substituted. So also it has been suggested that in outbreaks of cholera anywhere, the rain-water is less likely to become contaminated with sewage matters than wells or springs, into which organic matters often find their way in an unaccountable manner.

Rain-water is very soft, owing to the absence of salts of lime and magnesia;

it is therefore good for washing or cooking purposes, although it is less palatable than other kinds for drinking.

Ice and Snow Water.—In freezing, water becomes purer, losing a large portion of its saline contents. Even calcium carbonate and sulphate are partially got rid of. The air is at the same time expelled. Ice-water may thus be tolerably pure, but heavy and non-aërated. Snow-water contains the salts of rain-water, with the exception of rather less ammonia. The amounts of carbonic acid and air are very small.

An analysis of the ice supplies made by the State Board of Health of Massachusetts showed that, taking an average of all the samples examined, the organic impurities of snow ice, as measured by the ammonias, amounted to 69 per cent. of those of the water; that the organic impurities of all the ice, except the snow ice, amounted to 12 per cent., and that clear ice gave only 6 per cent. of the impurities of the waters. The salt the waters contained was nearly all removed by the act of freezing.

There were 81 per cent. as many bacteria in the snow ice as in the waters; 10 per cent. as many in all other ice, and 2 per cent. as many in the clear ice as in the waters. It is therefore much safer to use for drinking water, and for placing in contact with food, that portion of the ice which is clear.

Upland Surface Water.—This, of the various kinds of water, most nearly approaches rain-water. The dissolved solid matters are larger, their amount and nature depending on the kind of soil over which the water rests, and consequently it is usual to subdivide this class according to the geological character of the ground from which the upland surface water is obtained. These waters do not contain any considerable amount of dissolved matters, except they are derived from calcareous strata; the organic substances present are chiefly of vegetable and not of animal origin. There is also an absence of ammonia, nitrates and nitrites beyond that in which they occur in rain-water. The chlorine is also low and the water soft. These upland surface waters are not only valued because of their safety for drinking, but also on account of their fitness for trade purposes.

Spring and Well Water.—The rain falling on the ground partly evaporates, partly runs off, and partly sinks in. The relative amounts vary with the configuration and density of the ground, and with the circumstances impeding or favouring evaporation, such as temperature, movement of air, &c. In the magnesian limestone districts, about 20 per cent. penetrates; in the New Red Sandstone (Triassic), 25 per cent.; in the chalk, 42; in the loose Tertiary sand, 90 to 96. Evans, from twenty-nine years' observations in the chalk at Hemel-Hempstead, gives the winter average at 60·8 per cent., the summer at 15·5 per cent., and the whole year 37·5 per cent.

Penetrating into the ground, the water absorbs a large proportion of carbonic acid from the air in the interstices of the soil, which is much richer (250 times) in CO_2 than the air above. It then passes more or less deeply into the earth, and dissolves everything it meets with which can be taken up in the time, at the temperature, and by the aid of carbonic acid. In some sandy soils there is a deficiency of CO_2, and then the water is also wanting in this gas, and is not fresh and sparkling.

The chemical changes and decompositions which occur in the soil by the action of CO_2, and which are probably influenced by diffusion, and perhaps by pressure, as well as by temperature, are extremely curious, but cannot be entered upon here. The most common and simple are the solution of calcium carbonate, and the decomposition of calcium and sodium silicate by carbonic acid, or alkaline carbonates. Salts of ammonia, also, when they exist, appear from Dietrich's observations to have a considerable dissolving effect on the silicates.

Spring-water is almost always clear and bright, in consequence of the great degree of filtration which it naturally undergoes in percolating through the strata which it may have traversed between the gathering ground from which it has penetrated and the point at which it issues again from the earth. For the same reason it is generally cool, unless coming from a depth much above 200 feet; and by reason of the gas it contains, it is sparkling and brisk to the taste. The temperature of the water varies, and is chiefly regulated by the depth. The temperature of shallow springs alters with the season; that of deeper springs is often that of the yearly mean. In very deep springs, or in some Artesian wells, the temperature of the water is high.

Wells are of different kinds—shallow wells, deep wells, and Artesian wells.

A well of 50 feet in depth, or less, is generally regarded as a shallow well; one of 100 feet or more, as a deep well. Artesian wells (so called from having been first sunk in the province of Artois in France) are generally of great depth, passing through an upper impermeable stratum, *e.g.*, clay, and penetrating a water-bearing stratum, which crops up elsewhere at some higher point, and below which is another impermeable stratum. Ordinary wells are sometimes supplemented by borings to increase the supply.

Shallow wells may be contaminated with any impurities at or near the surface of the ground, and the water from such wells is always to be regarded with suspicion. Even when the organic matter is only small in amount, it is generally highly nitrogenous, pointing to its probable animal origin, and in some exceptional cases the organic nitrogen found is actually in excess of the carbon. Deep wells are generally good sources of supply. The great efficiency of the filtration which most of these deep-well waters have undergone is attested by their entire freedom from organic matter, and by their almost absolute freedom from every kind of suspended material whether organic or inorganic. Deep-well waters are, as regards organic matter, amongst the purest to be found in nature, and unless extremely hard, they are of the best for drinking purposes.

In shallow wells (10 to 50 feet deep) the soakage water from the ground in loose soils of chalk and sand is often very impure. Thus in a town the well-water often shows evidence of nitrites, nitrates, ammonia, and chlorine far in excess of river-water in the neighbourhood, though the strata are the same. Occasionally, by constant passage of the water, a channel is formed, which may suddenly discharge into the well; and probably some of the cases of sudden poisoning from water have thus arisen.

A well drains an extent of ground about it nearly in the shape of an inverted cone. The area must depend on the soil; but the experiments at Grenelle and Passy show that the radius of the area drained is equal to four times the depth at least, and that it often exceeds this. Dupuit shows that the curve of the subterranean water level rises suddenly near the well, and becomes flatter and flatter as it extends under the ground surface, the distance to which it reaches depending upon the lowering of the level of water in the well. Thus a shallow well heavily pumped may drain an area wider than a deeper well under moderate pumping. The distance to which the influence of pumping extends is very variable, ranging from 15 to 160 times the depression of the water in the well. It is this depression of water in [illegible] of water taken out, that determines the drainage area, rather than the mere depth of the well. Ansted states that the deepest (non-Artesian) well will not drain a cone which is more than half a mile in radius.

A well which yields a moderate quantity of good water may, if the demand on it be increased, draw in water from the surrounding parts to meet the supply, and thus tap sources of impurity which a moderate demand left untouched. A sudden rise in the ground water may also lead to direct communication between a cesspool and a well, by the water tapping the former in its flow.

In some cases a well at a lower level may receive the drainage of surrounding hills flowing down to it from great distances. Good coping stones, so as to protect from surface washings, and good masonry for several feet below the surface of wells in very loose soils, so as to prevent superficial soakage, are necessary in all shallow wells.

River-Water.—Fed from a variety of sources, river-water is even more complex in its constitution than spring-water; it is also more influenced by the season, and by circumstances connected with season, such as the melting of snow or ice, rains and floods, &c. The water taken on opposite sides of the same river has been found to differ slightly in composition.

Leffman and Beam state that by admixture of the waters from widely-separated districts, the character and amount of the dissolved matters are much modified, and give the following as an example. The Schuylkill River rises in the anthracite coal region of Pennsylvania, and receiving much refuse mine water becomes impregnated with iron salts and free mineral acid, which render it quite unsuitable for drinking or manufacturing purposes. In its course of about 100 miles it passes over an extensive limestone district, and receives several large streams highly charged with calcium carbonate. The result is a neutralisation of the acid, and a precipitation of the iron and much of the calcium. The river becomes purer, and at its junction with the Delaware at Philadelphia it contains neither free sulphuric nor hydrochloric acid, only traces of iron, and but a small amount of $CaSO_4$. Thus there is produced a soft water, superior to that of the river near its source, and to the hard waters of the middle Schuylkill region.

The dissolved solids in river-water vary less than in spring-water: they rarely exceed 30 to 40 parts per 100,000. Sometimes the water is almost as pure as rain-water. The amount of dissolved organic substances is generally much greater than in spring-water. This is due to the surface drainage being discharged into the rivers. River-water is generally good and palatable, unless sewage or other impurities are allowed to get into it.

The general result of solution and decomposition is, that the water of springs and rivers often contains a great number of constituents—some in very small, others in great amount. Some waters are so highly charged as to be termed mineral waters, and to be unfit for drinking, except as medicines. The impurities of water are not so much influenced by the depth of the spring as by the strata it passes through. The water of a surface spring, or of the deepest Artesian well, may be pure or impure.

The substances which are contained in spring, river, and well waters are noted more fully under the head of "EXAMINATION OF WATER." There may be suspended matters, mineral, vegetable, or animal; dissolved gases, viz., nitrogen, oxygen, carbon dioxide, and in some cases hydrogen sulphide and carburetted hydrogen; and dissolved solid matters, consisting of lime, magnesia, soda, potash, ammonia, iron, alumina, combined with chlorine, and sulphuric, carbonic, phosphoric, nitric, nitrous, and silicic acids. Less frequently, or in special cases, certain metals, as arsenic, manganese, lead, zin and copper, may be present.

The mode of combination of these substances is as yet uncertain; it ma be that the acids and bases are equally distributed among each other, c some other modes of combination may be in play. The mode of combination may *usually* be assumed to be as follows. Each separate substanc being determined, the chlorine is combined with sodium; if there is a excess it is combined with potassium or calcium; if there is an excess o sodium, it is combined with sulphuric acid, or if still in excess, with carbonic acid. Lime is combined with excess of chlorine, or sulphuric acid, o if there be no sulphuric acid, or an excess of lime, with carbonic acid Magnesia is combined with carbonic acid. So that the most usual combinations are sodium chloride, sodium sulphate, sodium carbonate, calcium carbonate (held in solution by carbonic acid), calcium sulphate, calcium chloride and silicate, and magnesium carbonate; but the results of th analysis may render other combinations necessary.

Distilled Water.—Distilled water is now largely used, and affords a easy way of getting good water. It is the most effectual mode of freeing water from all its impurities. On board ships distillation of sea-water is resorted to in order to render salt water fit for drinking, and although the water thus obtained is pure, yet all the gases having been driven from it by the boiling, it is unpalatable, and by some supposed to be indigestible. It may be aërated by allowing it to trickle slowly down through a long column of wood charcoal, or by filtration through animal charcoal or other porous substance. Distilled water is also employed for the manufacture of aërated waters, and for artificial ice.

Care should be taken that no lead, zinc, or copper finds its way into the distilled water. Many cases of lead poisoning have occurred on board ships, partly from the use of *minium* in the apparatus, and partly from the use of *zinc pipes* containing lead in their composition. If possible, *block tin* should always be used.

Sea-Water.—While the ocean is constantly receiving waters more or less impure, it is at the same time losing pure water in the form of vapour, the mineral salts remaining behind, and imparting to it its saline character.

The composition of sea-water varies considerably in different places and at different depths. Thus in the vicinity of the poles, the proportion of salt is less than at the equator, whilst parts of the Mediterranean are more salt than the great oceans.

The average composition of sea-water is given in the following table (Frankland, E.):—

Parts per 100,000.

Source.	Total Solids.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrites and Nitrates.	Total Combined Nitrogen.	Chlorine.	Hardness.	
								Total.	Fixed.
Hastings, two miles from the shore,	3955	0·291	0·135	0·095	0·013	0·152	2050	698	646

Comparative Value of the Various Sources of Water-Supply.—This depends on many circumstances. Spring-water is both pure and impure in different cases: and the mere fact of its being a spring is not, as sometimes imagined, a test of goodness. Frequently, indeed, river-water is purer than spring-water, especially from the deposit of calcium carbonate; organic matter is, however, generally in greater quantity, as so much more vegetable matter and animal excreta find their way into it. The water of a river may have a very different constitution from that of the springs near its banks. A good example is given by the Ouse at York; the water of this river is derived chiefly from the millstone grit, which feeds the Swale, the Ure, and the Nid, tributaries of the Ouse; the water contains only 13 parts per 100,000 of salts of calcium, magnesium, sodium, and a little iron. The wells in the neighbourhood pass down into the soft red sandstone (Yoredale series) which lies below the millstone grit; the water contains as much as 92·8 parts, and even, in one case, 137 parts per 100,000 of total solids; in addition to the usual salts there is much calcium chloride, and calcium, sodium, and magnesium nitrates. Shallow-well water is always to be viewed with suspicion; it is the natural point to which the drainage of a good deal of surrounding land tends, and heavy rains will often wash many substances into it. Instances are recorded where good and bad water was obtained from different levels in the same well.

The following tables are given by the Rivers Pollution Commissioners:—

1. In respect of wholesomeness, palatability, and general fitness for drinking and cooking:—

Wholesome	1. Spring-water,	very palatable.
	2. Deep-well water,	
	3. Upland surface water,	moderately palatable.
Suspicious	4. Stored rain-water,	
	5. Surface water from cultivated land,	palatable.
Dangerous	6. River-water, to which sewage gains access,	
	7. Shallow-well water,	

2. Classified according to softness with regard to washing, &c.:—

1. Rain-water.
2. Upland surface water.
3. Surface water from cultivated land.
4. Polluted river waters.
5. Spring-water.
6. Deep-well water.
7. Shallow-well water.

3. As regards the influence of geological formation in rendering the water sparkling, colourless, palatable, and wholesome. The following water-bearing strata are the most efficient:—

1. Chalk.
2. Oolite.
3. Greensand.
4. Hastings Sand.
5. New Red and Conglomerate Sandstone.

Classification of Drinking Waters.—The general characters of good water are easily enumerated. Perfect clearness; freedom from odour or taste; coolness; good aëration; and a certain degree of softness, so that cooking operations, and especially of vegetables, can be properly performed, are obvious properties. But when we attempt a more complete description, and assign the amounts of the dissolved matters which it is desirable should not be exceeded, we find considerable difference of opinion, and also a real want of evidence on which to base a satisfactory judgment.

Still a hygienic classification or enumeration of potable waters, based on such facts as are generally admitted, will be useful. A division of waters used for drinking into four classes has been adopted in this work :—

1. Pure and wholesome water.
2. Usable ,,
3. Suspicious ,,
4. Impure ,,

The waters belonging to the first and second class are generally obtained from upland surface supplies or from spring and deep-well waters. Upland surface waters may at times receive surface contamination, and it is desirable that such waters should be carefully filtered through sand before delivery. Spring and deep-well water undergoes almost perfect filtration in passing through the porous strata of the earth's crust and is a very pure supply.

Those of the third and fourth class are usually obtained from rivers and shallow wells, upon both of which a large portion of the population is dependent for their supply. The danger in the case of both these classes of water lies in the facility with which sewage matters can gain access to them. When no better source is procurable, every effort must be made to exclude all avoidable sources of contamination and to filter the water through sand before distribution.

COLLECTION, STORAGE AND DISTRIBUTION OF WATER.

Collection of Water.—In many cases collections of water occur naturally in depressions of the ground surface, or by the commingling of small streams forming rivers. The collection by artificial means consists almost entirely in imitating these natural processes, and in directing to, and finally arresting at some point, the rain or the streamlets formed by the rain. The arrangements necessarily differ in each case. Rain-water is collected from roofs, or occasionally from pavements and flags, or cemented ground; in hilly countries, with deep ravines, a reservoir is sometimes formed by carrying a wall across a valley which is well placed for receiving the tributary waters of the adjacent hills, or on a flatter surface trenches may be arranged, leading finally to an excavated tank.

The collection of the surface water which has not penetrated is usually aimed at, but it was proposed by Bailey-Denton to collect the subsoil water by drainage pipes, and thus to accomplish two objects—to dry the land, and to use the water taken out of it. Below the surface the water is collected by wells—shallow, deep, and Artesian—or by boring.

Rain.—The *amount* of water given by rain can be easily calculated, if two points are known, viz., the amount of rainfall and the area of the receiving surface. The rainfall can only be determined by a rain-gauge (the mode of constructing which is given in the chapter on METEOROLOGY); the area of the receiving surface must be measured.

The following formula is the one generally used :—

$$\frac{\text{Area in square feet} \times 144 \times \text{rainfall in inches}}{1728} = \text{cubic feet :}$$

$$\text{Cubic feet} \times 6{\cdot}23 = \text{gallons.}$$

$$\text{Cubic inches} \times {\cdot}003607 = \text{gallons.}$$

The calculation may be much simplified by multiplying the area of receiving surface in square feet by half the rainfall in inches, the result is in gallons; here the error is only about 4 per cent.

To calculate the receiving surface of the roof of a house, we must not take into account the slope of the roof, but merely ascertain the area of the flat space actually covered by the roof. The joint areas of the ground-floor rooms will be something less than the area of the roof, which also covers the thickness of the walls and the eaves.

In most English towns the amount of roof space for each person cannot be estimated higher than 60 square feet, and in some poor districts is much less. Taking the rainfall in all England at 30 inches, and assuming that all is saved, and that there is no loss from evaporation, the receiving surface for each person would give 935 gallons, or $2\frac{1}{2}$ gallons a day. But as few town houses have any reservoirs, this quantity runs in great part to waste in urban districts. In the country it is an important source of supply, being stored in cisterns or water-butts. If, instead of the roof of a house, the receiving surface be a piece of land, the amount may be calculated in the same way. It must be understood, however, that this is the total amount reaching the ground; all of this will not be available; some will sink into the ground, and some will evaporate; the quantity lost in this way will vary with the soil and the season from the one-half to seven-eighths. (See *Appendix*.)

The proportion borne by the available to the total rainfall varies very much, being affected by rapidity of the rainfall and the compactness or porosity of the soil, the steepness or flatness of the ground, the nature and quantity of the vegetation upon it, the temperature and moisture of the air, the existence of artificial drains, and other circumstances. The following are examples:—

Nature of ground and available proportion of total rainfall:—

Steep surfaces of granite, gneiss, and slate, nearly	1
Moorland and hilly pasture, from	0·8 to 0·6
Flat cultivated country, from	0·5 to 0·4
Chalk,	0

One inch of rain delivers 4·673 gallons on every square yard, or 22,617 gallons (101 tons by weight) on each square acre. Inches of rainfall × $14\frac{1}{2}$ = millions of gallons per square mile.

In estimating the annual yield of water from rainfall, and the yield at any one time, we ought to know the greatest annual rainfall, the least, the average, the period of the year when it falls, and the length of the rainless season. Hawksley states that the average of twenty years, *less* one-third, gives very accurately the amount of rain in the driest year, and the same average, *plus* one-third, gives very nearly the amount in the wettest year. The average of the three driest years in twenty is a safe basis.

It may be assumed that on the average $\frac{6}{10}$ths of the rainfall is available for storage. It must also be remembered that the amount of rainfall differs very greatly even in places near together.

Springs and Rivers.—It will often be a matter of great importance to determine the yield of springs and small rivers, as a body of men may have to be placed for some time in a particular spot, and no engineering opinion, perhaps, can be obtained.

A spring is measured most easily by receiving the water into a vessel of known capacity, and timing the rate of filling. The spring should be opened up if necessary, and the vessel should be of large size. The vessel may be measured either by filling it first by means of a known (pint or gallon) measure, or by gauging it. If it be round or square, its capacity can be at once known, by measuring it, and using the rules laid down in the chapter for measuring the cubic amount of air in rooms. The capacity of the vessel in cubic feet may be brought into gallons, if desirable, by multiplying by 6·23.

If a tub or cask only be procurable, and if there is no pint or gallon measure at hand, the following rule may be useful:—Find the middle diameter, that is the diameter midway between the bung and the head, and call it M; head diameter H; bung diameter B; length of cask L; then $(H^2 + B^2 + 4M^2) \times L \times 0{\cdot}0004721$ will give the contents in gallons.

When it is required to ascertain the yield of any small water-course with some nicety, it is the practice of engineers to dam up the whole stream, and convey the water by some artificial channel of known dimensions. For this purpose one of the following methods may be employed.

1. A wooden trough of a certain length, in which the depth of water and the time which a float takes to pass from one end to the other is measured.

2. A sluice of known size, in which the difference of level of the water above and below the sluice is measured.

The discharge of water through a sluice may be found by multiplying the breadth of the opening by the height; this gives the area of the sluice. The discharge equals the area multiplied by five times the square root of the head of water in feet. The head of water is the difference of level of the water above and below the dam if the sluice be entirely under the lower level; or the height of the upper level above the centre of the opening, if the sluice be above the lower level.

3. A weir formed by a plank set on edge in which a rectangular notch is cut, usually 1 foot in width; over this the water flows in a thin sheet, and the difference of level is measured by the depth of the water as it flows over the notch. Then by means of a table the amount of water delivered per minute is read off. The weir must be formed of very thin board and be perfectly level; a plumb-line has generally to be used. If the weir is more or less than a foot, multiply the quantity in the table opposite the given depth by the length of the weir in feet, or decimals of a foot. Thus if the weir measure 1 foot, and the depth of water falling over be 2 inches, the delivery is read at once, viz., 13·63 cubic feet, or 84·9 gallons per minute.

Depth falling over, inches.	Discharge per minute.	Depth falling over, inches.	Discharge per minute.
½	1·70 cubic feet.	2½	19·70 cubic feet.
1	4·82 ,, ,,	3	26·62 ,, ,,
1½	8·84 ,, ,,	3½	33·22 ,, ,,
2	13·63 ,, ,,	4	40·71 ,, ,,

This plan of measuring the yield of water-courses is the one now most generally adopted by engineers.

The same object may, however, be attained with sufficient accuracy for the purposes of the medical officer by selecting a portion of the stream where the channel is pretty uniform, for the length of, say, not less than 12 or 15 yards, and in the course of which there are no eddies. Take the breadth and the average depth in three or four places, to obtain the sectional area. Then, dropping in a chip of wood, or other light object, notice how long it takes to float a certain distance over the portion of channel chosen. From this can be got the surface velocity per second, which is greater of course than the bottom or the mean velocity. Take four-fifths of the surface velocity (being nearly the proportion of mean to surface velocity), and multiply by the sectional area. The result will be the yield of the stream per second.

It may sometimes be worth while, if labour be at hand, to remove some of the irregularities of the channel, or even to dig a new one across the neck of a bend in the course of the stream.

The yield of a spring or small river should be determined several times, and at different periods of the day.

Wells.—The yields of wells can only be known by pumping out the water to a certain level and noticing the length of time required for refilling. In cases of copious flow of water a steam-engine is necessary to make any impression; but, in other cases, pumping by hand or horse labour may be sufficient perceptibly to depress the water, and then, if the quantity taken out be measured, and the time taken for refilling the well be noted, an approximate estimate can be formed of the yield.

With respect to wells, if they are situated near a river, and do not produce sufficient water, it has been recommended to lay perforated earthenware pipes parallel to the river, and below its fine-weather level, in trenches not less than 6 feet deep, and filled up above the pipes with fine gravel. The pipes end in the well, and water passing from the river and filtered through the gravel passes into them.

Tube-wells, commonly known as Norton's Abyssinian tube-wells, are used when a temporary supply is required: they are superior to dug wells, which, from imperfect steining or total absence of it, are liable to become foul from surface pollution. They are constructed by driving tubes into the soil, one length being screwed on to another, the first tube being perforated at the bottom for about 2 feet, its lower end being furnished with a steel point (fig. 3).

When the subsoil water is reached, a pump is attached to the tube; the water after pumping a short time is clear; the tube forms a cavity which corresponds to the ordinary well at the end of the pipe, owing to the removal of the soil by pumping. Koch recommends that iron tubes be placed in dug wells, and the surrounding space filled in with clean gravel and sand, the water to be raised by a pump fixed at the surface.

Permanence of Supply.—The importance of the permanence of a supply is obvious. Any available evidence should be obtained, particularly with reference to the amount and period of rain, without which it is impossible to arrive at any safe conclusion.

The country which forms the gathering ground for the springs or rivers should be considered. If there be an extensive background of hills, the springs towards the foot of the hills will probably be permanent. In a flat country the permanency is doubtful, unless there be some evidence from the temperature of the spring that the water comes from some depth. In limestone regions springs are often fed from subterranean reservoirs, caused by the gradual solution of the rocks by the water charged with carbonic acid; and such springs are very permanent. In the chalk districts there are few springs or streams, on account of the porosity of the soil, unless at the point the level be considerably below that of the country generally. The same may be said of the sandstone formations, both old and new; but deep wells in the sandstone often yield largely, as the permeable rocks form a vast reservoir. In the granitic and trap districts small streams are liable to great variations, unless fed from lakes; springs are more permanent when they exist, being perhaps fed from large collections or lochs.

Storage.—The fluctuations of the rainfall, flow of streams and consumption of water in the different seasons of the year, require almost invariably that there shall be artificial storage of the surface waters of the seasons of maximum flow, to provide for drought during the seasons of minimum flow.

The amount required will depend on two circumstances, viz., the quantity used and the ease of replenishing. It is, of course, easy to calculate the space required when these conditions are known, in this way:—the number of gallons required daily for the whole population must be divided by 6·23 to bring into cubic feet, and multiplied by the number of days which the storage must last; the product is the necessary size of the reservoir in cubic feet. Hawskley's formula for storage is as follows:—$D = \frac{1000}{\sqrt{F}}$, where F equals the mean annual rainfall in inches, say $\frac{5}{6}$ of average annual yield; D is the number of days' supply to be stored. Thus, with a rainfall of 25 inches, we have $\frac{1000}{\sqrt{25}} = \frac{1000}{5} = 200$ days' supply.

There are losses incidental to artificial storage that must not be overlooked; for instance, the percolation into the earth and through the embankment, also evaporation from the reservoir and from its saturated borders.

Whatever be the size of the reservoir, it should be kept carefully clean, and no possible source of contamination should be permitted. In the large reservoirs for town supply the water is sometimes rendered impure by floods washing surface refuse into them, or by substances being thrown in. In fact, in some cases, water pure at its source becomes impure in the reservoirs.

As far as possible, all reservoirs, tanks, &c., should be covered in and ventilated; in form they should be deep rather than extended, so as to lessen evaporation and secure coolness. Though they should be periodically and carefully cleaned, it would appear that it is not always wise to disturb water plants which may be growing in them; some plants, as *Protococcus*, *Chara*, and others, give out a very large amount of oxygen, and thus oxidise and render innocuous the organic matter which may be dissolved in the water or volatilised from the surface. Chevers mentions that the water of some tanks which were ordered to be cleared of water plants by Sir Charles Napier deteriorated in quality. Other plants, however, as some species of duckweed (*Lemna* at home, *Pistia* in the tropics), are said to contain an acrid matter which they give off to the water. It would be well to remove some of the plant, place it in pure water in a glass vessel, and try by experiment whether the amount of organic matter in the water is increased, or whether any taste is given to the water. The presence of some of the *Nostoc* family gives rise to an offensive pig-pen odour when decaying. Dead vegetable matter should never find its way into, or at any rate remain in, the reservoir.

Whenever a reservoir is so large that it cannot be covered in, a second smaller covered tank, capable of holding a few days' supply, might be provided and fitted with a filter, through which the water of the larger reservoir might be led as required.

When tanks are large they are made of earth, stone, or masonry; if mortar be used it should, as in the case of the smaller reservoirs, be hydraulic, so that it may not be acted on by the water.

The materials of small reservoirs and cisterns are stone, cement, brick, slate, tiles, lead, zinc, and iron. Of these, slate is the best, but it is rather liable to leakage, and must be set in good cement or in Spence's metal; common mortar must not be used for stone or cement, as lime is taken up and the water becomes hard. Leaden cisterns, as in the case of leaden pipes, often yield lead to water, and should not be used; they are corroded by mud or mortar, even when no lead is dissolved in the water. Iron cisterns and pipes are often rapidly eaten away; they are sometimes protected by being covered inside with Portland cement or with a vitreous glaze or with Crease's patent cement. Barff's process of producing the magnetic oxide on the surface of iron has been tried, but seems hardly so successful as it promised. Galvanised iron tanks are also very much used; they must be covered, and in India be protected from the sun. Zinc has been recommended, but water passing through zinc pipes, or kept in zinc pails, or in badly galvanised iron vessels, may produce symptoms of metallic poisoning, and even taste strongly of zinc salts, especially if the water is rich in nitrates. It would certainly be better to abandon lead, zinc, and such like materials for cisterns, as much as possible, unless we are sure that the water contains no substance likely to act upon the metal.

Cisterns should always be well covered, protected as much as possible from both heat and light, and thoroughly ventilated if they are of any size. Care should always be taken that there is no chance of leakage of pipes into them. A common source of contamination is an overflow-pipe passing direct into a sewer, so that the sewer gases pass up, and, being confined by the cover of the cistern, are absorbed by the water; to prevent this, the overflow-pipe is curved so as to retain a little water and form a trap, but the water often evaporates, or the gases force their way through it; no overflow-pipe should therefore open into a sewer, but should end *above* ground over a trapped grating. A cistern supplying a water-closet should not be used to supply cooking and drinking water, as the pipes leading to the closet often conduct closet air to the cistern. Hence, a small cistern (water-waste preventer) should be used for each closet. Cisterns should be periodically and carefully inspected; and in every new building, if they are placed at the top of the house, convenient means of access should be provided. Tanks to hold rain-water require constant inspection.

Distribution.—When houses are removed from sources of water the supply should be by aqueducts and pipes. The distribution by hand is rude and objectionable, for it is impossible to supply the proper quantity, and the risks of contamination are increased. Some of the most extraordinary of the Roman works in both the Eastern and Western Empires were undertaken for the supply of water—works whose ruins excite the astonishment and should rouse the emulation of modern nations.

The plans for the distribution of water should include arrangements for the easy and immediate removal of dirty water. This is an essential point, for in many towns where houses are not properly arranged for small families, there are no means of getting rid of water from the upper rooms, and this inconvenience actually limits the use of water, even when its supply is ample.

The supply of water to houses may be on one of two systems, *intermittent* or *constant*. The difference between the two plans is, that in the first case there is storage in the houses for from one to three days; while in the latter case there is either no storage, or it is only on a very small scale for two purposes, viz., for water-closets and for the supply of kitchen boilers. It should, however, be understood that the constant supply has not always meant in practice an unlimited supply, nor has it been the case that the water in the house-pipes was always in direct communication with the water in the reservoirs. On the contrary, the water to the houses has often been cut off, particularly in places where the supply was limited, and the fittings not good, and where there was great waste.

The terms used to describe the pipes differ a little apparently; the mains and district or sub-mains are the large pipes, which are always full of water, the latter being, of course, the smaller; the service-pipe is another term for a district main. The communication-pipe is that which runs from the service-pipe to the house, and in the house it takes the name of house-pipe.

The great arguments against storage on the premises (except on a limited scale for closets and boilers) are the chances of contamination in cisterns, and the very imperfect means of storage, which is especially the case in houses occupied by the working-classes.

In providing a constant supply, certain precautions are necessary. The fittings must be as perfect as possible. When the fittings are good, there is real economy in the constant system,—as shown in the comparison between Lincoln and Oxford, and by Hawksley's evidence with reference to Norwich. Common taps do not answer, and the best screw taps and fittings must be used.

One important sanitary advantage of the constant system is that, in order to facilitate inspection and detection of waste, no waste-pipe is allowed to open into a sewer, but it is always so placed that any escape of water can be easily seen (the so-called warning-pipe). The great evil of sewer gases being conducted back into houses through overflow-pipes is thus avoided. Careful inspection and good fittings so far lessen the waste of the constant system, that in some cases less water is used than under the intermittent plan.

Deacon has shown that the loss on the constant system is due to causes over which the consumer has generally little or no control, and that it occurs for the most part before the water reaches him. It arises chiefly from leaks in pipes, drawn joints, and so on, and up to lately there were no means of detecting this in a way practically useful. By the introduction of his water-waste meter this is done with the utmost precision and accuracy, so that in Liverpool the expenditure of water has been considerably reduced. Comparing the mean supply of the four years prior to 1874 with that of 1876, when the intermittent system had entirely ceased and a constant service under increased pressure had taken its place, we find that in 1876 the loss by leakage had already been so far moderated that a supply was given for metered trade purposes, increased by 25 per cent., and, without restriction for domestic and all other purposes to a population already increased by 33,000 persons, with 12 per cent. less water than in the previous period. The Lambeth Water Company supply part of their district on the constant system and part on the intermittent. The constant supply is checked by Deacon's waste-water meters and the results have been very satisfactory, the saving in consumption being about 7 gallons per head as compared with the Company's entire district. At Bradford, during 1887 and 1888, the saving was estimated to be 2,000,000 gallons per diem. The sanitary benefits of the constant supply, causing a constant internal pressure in the water-mains always above that of the atmosphere, renders impossible the accession of foul matter to the mains which so commonly occurs—when, during intermissions of supply, the internal pressure falls below that of the atmosphere—scarcely admits of exaggeration. Further improvements in the direction of detecting leakage have been made in Frankfort and other cities in Germany, where the microphone in connection with these water-meters has been used.

If the constant system is used, a good screw stopcock, available to the tenant, should be placed at the point of entrance of the pipe into the house, so that the water may be turned off if pipes burst, or to allow the pipes to be empty, as during frost. Every precaution must be taken that impure water is not drawn into the pipes by a pipe being emptied and sucking up water from a distance.

For the supply of a very large city, it might be desirable to divide the city into sections, and to establish a reservoir for each district, holding three or four days' supply. In this way the waste of one section would not take away the water from another. In some instances, people in one part of a town, supplied on the constant system, have used so much water for gardens that other parts have been altogether deprived of supply. The system of secondary reservoirs would not only lessen this chance, but would make it possible to ascertain that every part of the town was getting its supply. The number of water companies in London has in fact somewhat this effect, but the subdivision is not carried far enough.

There is no doubt that the constant system is the safer, especially for poor houses, as it leaves no loophole for inattention in the cleansing of cisterns. Only, it requires that the constant system should really fulfil the conditions laid down for it, viz., it should deliver sufficient water at all times, and not merely delude us with a phrase.

In both plans the water is conducted from the reservoirs in pipes. The pipes are composed of iron, stoneware, or masonry, for the larger pipes or mains, cast iron being those most generally in use. The length of the pipes is usually about 9 feet, and a hub and spigot joint formed, adapted first to a joint packing of deal wedges and afterward to a packing of lead. This form of joint admits of their free expansion and contraction with varying temperatures of water and earth, and renders them less liable to fracture. For the smaller pipes, galvanised iron, lead, tin, vitreous glazed iron pipes, &c., are used.

The action of water upon iron pipes appears to be energetic at first, but diminishes after a little time. Several processes have been proposed for the preservation of the pipe surface. Barff's method consists in raising the temperature of the metal to about 1200° F.—a white heat—in a suitable chamber, into which is passed superheated steam; the metal is exposed to this action for several hours, and becomes coated with a protective oxide. Angus Smith patented a process for coating iron pipes with a varnish of pitch, derived from coal tar; the pipes are heated in a retort or oven to a temperature of about 310° F. and then immersed in a bath of pitch which is maintained at a temperature of not less than 310° F. The pitch is specially prepared, being distilled from coal tar until the naphtha is entirely removed and the material deodorised; to this about 5 or 6 per cent. of linseed oil is added. The pipes should be free from rust and strictly clean when they are immersed in the pitch bath.

Sheet iron water-pipes lined and coated with hydraulic cement are used in the United States. The sheet iron is formed into pipes about 8 feet long, and riveted. These are then lined with hydraulic cement, and when lined are enclosed in a bed of cement. Iron is the best material for the larger pipes, and it is also necessary (steam-piping) for the smaller pipes under the pressure of the constant service system.

Water should be distributed not only to every house, but to every floor in a house. If this is not done, if labour is scarce in the houses of poor people, the water is used several times; it becomes a question of labour and trouble *versus* cleanliness and health, and the latter too often give way. Means must also be devised for the speedy removal of dirty water from houses for the same reasons. In fact, houses let out in lodgings should be looked upon, not as single houses, but as a collection of dwellings, as they really are.

Action of Water on Lead Pipes.—There are more discrepancies of opinion on this subject than might have been anticipated.

From an analysis of the statements made, the following points appear to be the most certain:—

A. The waters which act *most* on lead are:—

(*a*) The purest and most highly oxygenated; as rain-water, and the soft waters of lakes and upland streams.

(*b*) Those containing organic matter, nitrites and nitrates; as impure waters contaminated with sewage, &c.

(*c*) Those containing chlorides; these salts having the power of dissolving the protecting coat of carbonate that may have been formed.

(*d*) Those containing a free acid; as soft peaty waters derived from upland surfaces.

Besides the portion dissolved, a film or crust is often formed, especially at the line of contact of water and air; this crust consists usually of two parts of lead carbonate and one part of hydrated oxide. The mud of several rivers, even the Thames, will corrode lead, probably from the organic matter it contains, but it does not necessarily follow that any lead has been dissolved in the water. Bits of mortar will also corrode lead.

B. The waters which act *least* on lead are:—

(*a*) Those that are rich in earthy salts—that is, hard waters, such as are derived from deep wells, &c. Carbonates, phosphates, and sulphates, all have a protecting influence, especially carbonates, and most especially carbonate of lime. According to Lissauer, the presence of 5·8 parts per 100,000 of $CaCO_3$ renders a water safe. But when sulphates are in excess, they increase the solvent action of the water.

(*b*) The presence of free carbonic acid exercises a protective influence, a basic carbonate being formed, very sparingly soluble, which is deposited on the pipe. But if the CO_2 is in excess, or if the water is charged with it under pressure, this coating is dissolved, and the solvent action increased.

(*c*) The presence of silica, according to Crookes, Odling, and Tidy, to the extent of half a grain per gallon, has a protective influence, an insoluble lead silicate being formed. But although most waters that act markedly on lead contain very little silica, the degree of their activity does not appear proportional to the scarcity of silica present, and some such waters (*e.g.*, Hindhead) contain a considerable amount.

(*d*) It has been said that perfectly pure water containing no gases has no action on lead; this, however, is not strictly correct, as pure distilled water has been known at Netley to take up lead from a leaden pipe.

The deposit which frequently coats the lead consists of carbonate, phosphate, and sulphate of lead, calcium and magnesium, if the water have contained these salts.

C. There are certain conditions that have a great influence on the solvent action of the water upon lead pipes, irrespective of the composition of the water itself:—

(*a*) New lead pipes always give up more lead than old ones.

(*b*) The length of time the water has been in contact with the lead: the water must not only pass through, but remain in, the pipes for some time: the amount dissolved increases during the first twenty-four hours, after this some is deposited, and after six days less lead is found in the water.

(*c*) Temperature: hot-water pipes yield more lead than cold-water pipes.

(*d*) Pressure: increased pressure (up to 140 lbs. on the square inch) increases the solvent action.

Within the last few years numerous extensive outbreaks of lead poisoning have been traced to the water supplied as a public service in towns in the north of England, as Sheffield, Huddersfield, Chesterfield, Bacup, &c. These supplies have all been drawn from upland surface-waters, and the outbreaks have occurred either during, or shortly following, periods of drought. The one circumstance common to all the cases appears to have been the presence of a free acid in the water. Sinclair White of Sheffield considers this to be the cause of the solvent action of such waters upon lead. He found that the dissolving power was proportional to the acidity of the water; that filtration through charcoal of an active acid water removed both its activity and acidity; and that neutralisation by limestone, lime, or bicarbonate of soda, had the same effect. He believes the acid to be derived from decaying peat, *i.e.*, humic acid. Others believe it to be either sulphuric acid or a derivative of this.

Power and Houston have demonstrated that the lead dissolving properties of a water are always associated with corresponding variations in the amount of its acidity. This acidity, in the case of moorland waters certainly, is dependent upon bacterial activity in moist peat soil. Two species of microbes found in peat have well-defined powers of producing acidity and of making waters plumbo-solvent.

D. The lead itself is more easily acted upon if other metals, as iron, zinc, or tin, are in juxtaposition; galvanic action is produced. Bending lead pipes against the grain, and thus exposing the structure of the metal, also increases the risk of solution. Zinc pipes, into the composition of which lead often enters, yield lead in large quantities to water, and this has been especially the case with the distilled water on board ships.

Amount of Dissolved Lead which will produce Symptoms of Poisoning.— Angus Smith refers to cases of lead paralysis in which as little as $\frac{1}{100}$th of a grain per gallon was in the water: he states that $\frac{1}{40}$th of a grain per gallon may affect some persons, while $\frac{1}{10}$th of a grain may be required for others. Adams also speaks of $\frac{1}{100}$th of a grain causing poisoning.

Calvert found that water which had been decidedly injurious in Manchester contained from $\frac{1}{10}$th to $\frac{3}{10}$ths of a grain per gallon.

In the celebrated case of the poisoning of Louis Philippe's family at Claremont, the amount of lead was $\frac{7}{10}$ths of a grain per gallon; this quantity affected 34 per cent. of those who drank the water.

On the whole, it seems probable that any quantity over $\frac{1}{20}$th of a grain per gallon (=0·07 per 100,000) should be considered dangerous, and that some persons may even be affected by less quantities.

The means that have been proposed to prevent injurious effects from lead gaining access to the system through the medium of drinking water are:—(1) to treat the water before it enters the pipes, so as to prevent its being capable of acting on the metal, should it come in contact with it; and (2) to use for distributing the water, pipes which will not allow of the water coming in contact with the lead. Thus, if the free acid present is neutralised by the addition of lime to the water, its solvent action on lead pipes is avoided. This has been found effectual in the case of the Sheffield water which contains a free acid. It is the safest method of dealing with such waters as are known to take up lead readily. The alternative plan is to use pipes that do not yield lead to water, such as cast or wrought iron pipes, and if possible they may be glazed internally. Leaden pipes lined with tin are very liable to fracture of the lining metal when the pipe is bent, and the water being exposed to both metals, galvanic action is set up, when the lead, as being the more oxidisable metal, is dissolved. Block tin pipes are very expensive, and have the further disadvantage of being eaten through, apparently in consequence of the presence of nitrates in the water. Lead, alloyed with 3 per cent. of tin, was formerly believed not to yield lead to water, but later evidence shows this is not the case if free carbonic acid is present in the water. On the whole, good iron pipes appear to be the safest. Filtration through sand, charcoal, or spongy iron will remove lead from water.

Sources of Impurity in Drinking Waters.—The geological formation of a district necessarily influences the composition of the water running through it, though it is impossible to tell with absolute certainty what the constituents of the water may be. Formations vary greatly, and the broad features laid down by geologists do not always suffice for our purpose. In the middle of a sandy district, yielding usually a soft water, a hard selenitic water may be found; and, instead of the pure calcium carbonate water, a chalk well may yield a water hard from calcium sulphate and iron. Still it may be useful to give a short summary of the best-known facts.

Water from springs in Granite and Gneiss is very pure and of most excellent quality for drinking, cooking, and all domestic purposes: the total solid constituents of these waters vary from 1·4 to 9 parts per 100,000; the hardness is usually very trifling; the organic matter is in very small amount. The water is bright, clear, and palatable, and has nearly a uniform temperature throughout the year.

The Silurian rocks, consisting of shales, slate, sandstones, &c., contain more soluble matter than is met with in Granite or Gneiss, and consequently yield to water a larger amount of solid material, nearly the whole of which consists of innocuous salts. The proportion of organic matter is small, and the water is generally soft. The water is clear and sparkling, and is well adapted for drinking, cooking, and washing purposes.

Water from springs in the Devonian rocks and old Red Sandstone is generally of most excellent quality. The average amount of total solids present is 18 parts per 100,000. The organic matter is in very small amount. The water is usually soft or of moderate hardness.

Of the Carboniferous rocks, the mountain limestone yields water clear, colourless, and palatable; it is rather hard, and therefore not well suited for washing purposes, but it may be effectually softened by Clark's process. The total solid constituents average about 26 parts per 100,000. The waters from the millstone grit are very similar. The hardness varies considerably; they contain only a trace of organic matter.

Unpolluted waters from the Lias clays are clear, colourless, palatable, and wholesome. They contain only a trace of organic matter, but are rather hard. Some of these waters are found to contain a large proportion of solid matters in solution, nearly the whole of which consist of mineral matters. Water from Hard Oolite is very pure—nearly the entire composition of these rocks consist of carbonate of lime—and although the waters are hard, it is chiefly of a temporary kind. As water-bearing strata, or as a subterranean reservoir for the purification and storage of water, the Oolite rocks are equal, if not superior, to the chalk.

Water from the Cretaceous rocks, such as the Hastings Sand and the Lower Greensands, is pure and wholesome. The hardness varies within wide limits, but it is usually a very hard water, but admits of softening. Water from the Chalk is very sparkling and clear, and is highly charged with carbonic acid. The total solid matter averages about 30 parts per 100,000, and consists of mineral salts which are not unwholesome; organic matter is usually in small amount. The water is sparkling, colourless, palatable, and wholesome. Any excess of hardness is of the temporary kind, and can be easily removed by Clark's process.

Springs in the Drift and Gravel yield water of very variable quality, owing to the varying character and generally small thickness of the beds through which it percolates. It usually holds in solution a large proportion of organic constituents, although it sometimes contains only a small amount of organic matter. Water from Magnesium Limestone differs from the Chalk waters in containing a large amount of permanent hardness. The salts present are chiefly sulphate and carbonate of calcium and magnesium. The water is organically very pure, but it is too permanently hard to be a wholesome drinking water.

Water from shallow wells in Alluvium and Gravel soils are generally impure, with calcium carbonate and sulphate, magnesium sulphate, sodium chloride and carbonate, iron, silica, and often much organic matter. Occasionally the organic matter oxidises rapidly into nitrites, and if the amount of sodium chloride is large, it might be supposed that the water had been contaminated with sewage. The amount of solids per 100,000 varies from 30 to 170 parts or even more.

Wells sunk in Gravel on the London Clay yield a bright and palatable water, but are generally polluted, their chief sources of supply being from sewers and cesspools. The water is unfit for drinking and washing purposes. All surface and subsoil waters are very variable in composition, often very impure, and always to be regarded with suspicion. Heaths and moors, on primitive rocks, or on hard millstone grit, may supply a pure water, which may, however, be sometimes slightly coloured with vegetable matter. Cultivated lands, with rich manured soils, give a water containing both organic matter and salts in large quantity. Some soils contain potassium, sodium, and magnesium nitrates, and yield these salts in large quantity to water. In towns and among the habitations of men, the surface water and the shallow-well water often contain large quantities of calcium and sodium nitrites, nitrates, sulphates, phosphates, and chlorides. The nitrates in this case probably arise from ammonia, ammonium nitrite being first formed, which dissolves large quantities of lime. Organic matter generally exists in large amount, and slowly oxidises, forming ammonia and nitric acid. In some cases butyric acid, which unites with lime, is also formed.

Marsh water always contains a large amount of vegetable organic matter; it is not unusual to find of volatile solids from 17 to 57 parts per 100,000, and in some cases even more. Suspended organic matter is also common. The salts are variable. A little calcium and sodium in combination with carbonic and sulphuric acids and chlorine are the most usual. Of course, if the marsh is a salt one, the mineral constituents of sea-water are present in varying proportions.

Water taken from wells sunk in the vicinity of cemeteries contains ammonium and calcium nitrites and nitrates, and sometimes fatty acids, and much organic matter. Lefort found a well of water at St Didier, more than 330 feet from a cemetery, to be largely contaminated with ammoniacal salts and an organic matter which was left on evaporation. The water was clear at first, but had a vapid taste, and speedily became putrid. The water from old graveyards (disused) may show less organic matter, but it will contain large quantities of nitrates, chlorides, &c.

The water derived from deep Artesian wells is usually of excellent quality and contains only a very minute quantity of organic matter. In some cases, however, the water is so highly charged with saline matter as to be undrinkable; the water of the Artesian well at Grenelle contains sufficient sodium and potassium carbonates to make it alkaline; there is also present in it a considerable amount of free ammonia. When not very hard, these waters are of good quality, clear and colourless, and, owing to the depth of the well, are usually of a uniform temperature throughout the year. The water is not well aërated, and therefore not so palatable as spring water. Some Artesian well waters are warm, these are generally used for medicinal purposes. Others, again, contain iron or are aperient, these are unfitted for ordinary drinking purposes. The Artesian wells in London are alkaline from the presence of bicarbonate of sodium, and hence are very soft.

Water from wells near the sea frequently contains so much saline matter as to taste quite brackish, although the organic matter may not be very large. In some samples from Shoeburyness (analysed at Netley) the total solids ranged from 148 to 312 parts per 100,000, the chlorides being from 31 to 93: mean of six samples—236 total solids and 50 of chlorides. In one sample, however, the albuminoid ammonia was only 0·007 per 100,000, and in five the oxygen required for organic matter was under 0·075 per 100,000. Samples from wells at Gibraltar yield in some cases large quantities of solids; in one instance as much as 338 parts of total solids and 244 of chlorides in 100,000. At Landguard Fort, water from a boring 150 feet deep yielded more than 700 parts of solids and 540 parts of chlorides.

Rain-water may be contaminated by washing the air it falls through, but more by matters on the surface on which it falls, such as decaying leaves, bird droppings, soot, or other matter on the roofs of houses; it also takes lead from lead coatings and pipes, and zinc from zinc roofs. If stored in underground tanks it may also receive soakings from the soil through leakage.

Impurities added during Transit from Source to Reservoir.—Open conduits are liable to be contaminated by surface washings carrying in finely divided clay, sand, chalk, and animal matters from cultivated land; and the leaves and branches of trees add their contingent of vegetable matters. These impurities may occur in most cases, but in addition the refuse of houses, trades, and factories is often poured into rivers, and all sorts of matters are thus added.

These impurities are broadly divided by the Rivers Pollution Commissioners into "sewage" and "manufacturing": under the former term all solid and liquid excreta, house and waste water, and in fact all impurities coming from dwellings, are included; under the latter term is placed all manufacturing refuse, such as from dye and bleach works, tanneries, papermaking, woollen, silk, and metal works, &c.

The very numerous animal and vegetable substances derived from habitations are usually classed under the vague but convenient term of "organic matter," as the separation of the individual substances is impossible. The organic matter is usually nitrogenous, and Frankland has proposed to express its amount in terms of its nitrogen (organic nitrogen), but this view is not yet generally received on account of the difficulty of estimating the very small quantity of nitrogen. The nitrogenous organic matter undergoes gradual transformation, and forms ammonia, and nitrous and nitric acids. On keeping the water the nitrites disappear, and in some cases the nitrates also gradually diminish, both actions resulting from the presence of *bacteria*.

Many of the "organic matters" in water are not actually dissolved, but are so finely suspended that they pass through filtering paper. There is no doubt that among this "suspended organic matter" many minute plants and animals (including *bacteria* and their spores) are always included. It is probably owing to the variation in the quantity of suspended organic matter (living and dead) that water from the same source sometimes gives different results on analysis, even though the water be taken at the same time.

During its flow in open conduits, purification goes on, by means of subsidence, by the action of the ordinary water bacteria on pathogenic micro-organisms, should these be present in the water, by exposure to direct sunlight, and by the presence of water plants. It must be remembered that the natural habitat of pathogenic bacteria is the interior of the human body: when they pass from this into rivers, they are in an unnatural medium, in which they can only maintain their existence and power of multiplication for a limited period and tend rapidly to disappear under the conditions found in ordinary river-water.

Impurities of Storage.—The chance of substances getting into the water of wells and tanks, and even of cisterns in houses, is very great. Surface washings and soakage contaminate wells and tanks, and leakages from pipes, passage of foul air through pipes, or direct absorption of air by an uncovered surface of water, introduce impurities into cisterns. It is singular in how many ways cisterns and tank waters get foul, and what care is necessary not only to place the cistern under safe conditions at first, but to examine it from time to time to detect contamination of the water. In India, especially, the tank water is often contaminated by clothes washed near, or actually in, the tank; by the passage even of excrement directly into it, as well as by surface washings, so that in fact in some cases the village tank is one of the chief causes of the sickness of the people. There is, perhaps, no point on which the attention of the sanitary officer should be more constantly fixed than that of the storage of water, either on the large or small scale.

Impurities of Distribution.—If water is distributed by hand, *i.e.*, by water-carts, barrels, or skins, there is necessarily a great chance of its being fouled. In India, where the water is generally carried by water carriers (Bhisties), inspection of the carts or skins should be systematically made, and whenever it be possible, pipes should be substituted for the rude method of hand conveyance. But even pipes may contaminate water; metals (lead, zinc, and iron) may be partly dissolved; wood rots, and if the pipes are occasionally empty, impure air may be drawn into them, and be afterwards absorbed by the water. Buchanan in his Report on an Outbreak of Fever at Caius College, Cambridge, showed that this was due to foul trap-water sucked in from the closets. In towns supplied on the constant system, when the pipes are becoming empty the flow of water from a tap has drawn dirty water or air through a pipe at some distance, and in this way even the water of the mains has been fouled.

Coal gas passing into the ground from leaking of gas pipes sometimes finds its way into wells, or even into water pipes. In Berlin, in 1864, out of 940 public wells, 39 were contaminated by admixture with coal gas. A good instance is related by Harvey, where the main pipes were often empty and gas penetrated into them. Having regard to the cases in which gases from the soil (from leaking gas pipes, sewers, &c.) find their way into water pipes, it would seem important not to lay down water pipes near any other, or, what is better, have all pipes in subways where they can be inspected.

EFFECTS OF AN INSUFFICIENT OR IMPURE SUPPLY OF WATER.

Insufficient Supply.—The consequences either of a short supply of water for domestic purposes, or of difficulty in removing water which has been used, are very similar. The want of water leads to impurities of all kinds: the person and clothes are not washed, or are washed repeatedly in the same water; cooking water is used scantily, or more than once; habitations become dirty, streets are not cleaned, sewers become clogged; and in these various ways a want of water produces uncleanliness of the very air itself.

The result of such a state of things is a general lowered state of health among the population; it has been thought also that some skin diseases—scabies, and the epiphytic affections especially—and ophthalmia in some cases, are thus propagated. It also appears likely that the remarkable cessation of spotted typhus among the civilised and cleanly nations is in part owing, not merely to better ventilation, but to more frequent and thorough washing of clothes.

The deficiency of water leading to insufficient cleansing of sewers has a great effect on the spread of enteric fever and of choleraic diarrhœa; and cases have been known in which outbreaks of the latter disease have been arrested by a heavy fall of rain.

Little is known with certainty of the effects produced on men by deficiency in the supply of water. Under ordinary circumstances, the sensation of thirst, the most delicate and imperative of all our feelings, never permits any great deficiency for a long time, and the water-removing organs eliminate with wonderful rapidity any excess that may be taken, so as to keep the amount in the body within certain limits. But when circumstances prevent the supply of water, it is well known that the wish to drink becomes so great, that men will run any danger, or undergo any pain, in order to satisfy it. The exact bodily condition thus produced is not precisely known, but from experiments on animals and men, it would appear that a lessened amount of water in the body diminishes the elimination of the pulmonary carbonic acid, the intestinal excreta, and all the important urinary constituents.

The more obvious effects produced on men who are deprived for some time of water is, besides the feeling of the most painful thirst, a great lowering of muscular strength and mental vigour. After a time exertion becomes almost impossible, and it is wonderful to see what an extraordinary change is produced in an amazingly short time if water can be then procured. The supply of water becomes, then, a matter of the most urgent necessity when men are undergoing great muscular efforts, and it is very important that the supply should be by small quantities of water being frequently taken, and not by a large amount at any one time. The restriction of water by trainers is based on a misapprehension: a little water, and often, should be the rule.

Effects of Impure Water.—In many cases, very little careful inquiry has been made into the state of health of those using the water, and that most fallacious of all evidence, a general impression, without a careful collection of facts, has often been the only ground on which the opinion has been come to. As well observed by Simon, in one of his philosophical Reports, we cannot expect to find the effect of impure water always sudden and violent; its results are indeed often gradual, and may elude ordinary observation, yet be not the less real and appreciable by a close inquiry In fact, it is only when striking and violent effects are produced that public attention is arrested; the minor and more insidious, but not less certain, evils are borne with the indifference and apathy of custom. In some cases it is by no means improbable that the use of the impure water, which is supposed to be innocuous, has been really restricted, or that experience has shown the necessity of purification in some way. This much seems to be certain, that as precise investigations proceed, and, indeed, in proportion to the care of the inquiry and the accuracy of the examination, a continually increasing class of cases is found to be connected with the use of impure water, and it seems only reasonable to infer that a still more rigid inquiry will further prove the frequency and importance of this mode of origin of some diseases.

Recent observations show that epidemics are usually spread by drinking water infected by specific germs or spores, and this has been proved by the discovery of the actual bacteria, associated with particular diseases, in the water, and further, that these forms are capable of producing in healthy persons the same specific disease. Cholera and enteric fever are the two diseases generally recognised in which the proof of origin from polluted water is irrefutable.

As regards the presence of these pathogenic micro-organisms in water the important points to determine are their capacity to persist and to multiply in water and the approximate number that are required to be introduced to set up disease in the human body. On these points, as yet, we have no reliable data for arriving at a conclusion. According to the evidence given before the Royal Commission on Metropolitan Water-Supply, it appears to be the general opinion that the presence of saprophytes in water is deleterious to the growth of pathogenic micro-organisms, such as enteric fever bacilli and the comma bacilli of cholera, and the latter is more readily destroyed by saprophytic bacteria than the former. This report states that it is the generally received opinion of experts that the pathogenic organisms and the ordinary river bacteria, to which the decomposition of organic matter is due, are naturally antagonistic: and that these latter undoubtedly exert an influence in diminishing the vitality of the typhoid bacillus, either actually consuming it, or, as is more probable, giving rise to products that interfere with its growth.

Exposure to direct sunlight destroys these bacteria, while even such diffused daylight as is present in this country injuriously affects their vitality: the influence this can exert largely depends on the depth of the water and whether turbid or otherwise.

The influence that the dissolved oxygen in water has upon bacteria is uncertain: it certainly destroys the organic matter present in the water, but probably its action is limited to certain kinds of organic impurity, and indirectly it reduces the number of micro-organisms by limiting the supply of nutriment available for their growth.

The most practical way of stating the facts connected with the production of disease by water will be to enumerate the diseases which have been traced to the use of impure water, and to state the nature of the impurities.

Cholera.—This disease is endemic in India, in the delta of the Ganges. In other parts of the world it only occasionally appears, but no place is safe from its ravages, as it does not seem to be limited in its spread by either climate or geographical position. There is ample evidence to show that water plays a most important part in its diffusion, and to Snow must certainly be attributed the very great merit of discovering this most important fact.

In 1849, in investigating some circumscribed outbreaks of cholera in Horsleydown, Wandsworth, and other places, Snow came to the conclusion that in these instances the disease arose from cholera evacuations finding their way into the drinking water. In 1854 occurred the celebrated instance of the Broad Street pump in London, which was investigated by a committee, whose report contains the most convincing evidence that, in that instance, the poison of cholera found its way into the body through drinking water.

In 1865 occurred the important outbreak at Newcastle-on-Tyne, when all the circumstances pointed very strongly to the influence of the impure Tyne water. In 1865 also was the remarkable and undoubted case of water-poisoning at Theydon Bois, recorded by Radcliffe, and in the following year the violent outbreak in the east of London was shown to be connected with the circulation of impure water by the East London Water Works Company. The Company distributed foul and unfiltered water, excessively polluted with sewage from their uncovered reservoir at Old Ford, and which, in Radcliffe's opinion, was specifically contaminated with the excrement of the first two patients who died in that year of cholera in the east district of London. The district supplied with water from this source was the sole area of intense cholera in London; the disease limiting itself "almost exactly to the area of this particular water-supply, nearly, if not absolutely, filling it, and scarcely at all reaching beyond it."

In further confirmation of the view that water is a fertile agent in spreading the disease, the following instances may be adduced.

The epidemic of cholera in Hamburg in 1892 was a remarkable instance in which this disease may be spread through the agency of water. "Hamburg, Altona, and Wandsbeck are three towns which adjoin each other and really form a single community; they do not differ except in so far as each has a separate and different kind of water-supply. Wandsbeck obtains filtered water from a lake, Hamburg until recently obtained its water in an unfiltered condition from the Elbe just above the town, and Altona obtains filtered water from the Elbe below the town. Whereas Hamburg was visited with a severe epidemic of cholera, Wandsbeck and Altona, if one excepts the cases brought thither from Hamburg, were nearly quite free from the disease. On both sides of the boundary the conditions of soil, buildings, sewerage, population, everything of importance were the same, and yet the cholera in Hamburg went right up to the boundary of Altona and there stopped." In this large population on each side of the boundary nearly all the factors were the same except the water-supply. The population supplied with the unfiltered water from the Elbe suffered severely from cholera, while the population supplied with carefully filtered water from the same source escaped.

Clemow quotes the following instance of the spread of cholera by water, from the Report of the First Conference of Caucasian Physicians:—"One of a number of Persian labourers, fleeing in panic from the infected governments (Baku and others) and passing through this district, died of cholera during the night's halt close to the village of Dashkesaw. His companions, thinking that if the local authorities knew of the cause of their comrade's death, they would not be allowed to enter Persia, decided to throw the corpse into one of the wells which provided the whole population of Dashkesaw with drinking water. On the following day cholera broke out in the village. There were seventeen deaths from cholera on the first day of the epidemic, and the village suffered incomparably more severely from cholera than any other village in the province."

In the cholera epidemic in Warsaw in 1892 the majority of cases occurred in people living on the banks of the river, every one of whom had drunk unboiled water taken directly from the river. When the practice of taking water from the river was put a stop to and boiled water was generally provided, cases of cholera ceased.

The whole history of cholera in 1892 shows that it was by means of water in almost every instance that cholera was spread; the vast rivers which flow through Russia, and upon which the inhabitants largely rely for their drinking water, affording an easy means for the dissemination of the specific poison.

Considering the vast size of many of these rivers, such as the Volga, the Vistula, the Don, and many others, the degree of dilution in which the virus of cholera may be spread seems to be very great; information on this point is, however, extremely hard to obtain.

Clemow gives a good example of the distance to which the cholera poison may be carried by water and yet maintain its activity; he shows that in one case the infection must have been taken 6½ miles and possibly to another village 13 miles lower down the river.

India furnishes many instances of cholera being conveyed by water. In 1867 the appearance of cholera and its rapid spread among the vast crowd of pilgrims after the great bathing day at Hurdwar was a case of water-poisoning on a gigantic scale. In 1879 a similar outbreak occurred, and again in 1892, from whence it spread to Russia. A remarkable case occurred at Yerrauda jail. Out of 1279 prisoners there were 24 cases of cholera in 5 days, with 8 deaths. Of those, 22 cases occurred among 134 prisoners employed as a road-gang, and only 2 among all the others variously employed. It was shown that the road-gang alone drank of water from the Mootla River, a little below the spot where the clothes of two cholera patients from the village had been washed and their bodies burned a few days before. The rest of the prisoners drank the usual water-supply laid on from a lake near Poonah. In the two cases among those otherwise employed direct infection was undoubted in one, as he attended on cholera patients, and, contrary to orders, took his meals in the cholera ward, and drank water that had been standing there; the other man slept near one of the first cases, the patient vomiting in his immediate vicinity.

If we look at the remarkable results which have followed on the supply of pure water to the European troops who are quartered at Fort-William, Calcutta, within the endemic area of cholera, the evidence is even stronger. From 1826 to 1864 the average mortality among them for this disease was 20 per 1000. From 1863 to the present time it has been 1 per 1000. In 1863 Fort-William was for the first time supplied with pure drinking water, and with the result referred to.

Another example of a similar kind is afforded in the case of Madras. Since the introduction of the new water-supply from the Red Hills, cholera has almost ceased to exist there, and the same immunity extends to the other districts using the water, whereas places which do not use it still suffer from the disease (Furnell). Gunter always suffered from cholera up to 1868, since which time it has been practically free, following the greater care for the water-supply (Tyrrell).

Calcutta showed a greatly diminished cholera mortality when the new water-supply was furnished in 1870. The subsequent increase in cholera was due to the scarcity of the new supply necessitating the use of "tank" water.

In evidence of this kind, we must remember that each successive instance adds more and more weight to the instances previously observed, until, from the mere accumulation of cases, the cogency of the argument becomes irresistible.

The evidence derived from such local outbreaks is supported by that drawn from the history of more general attacks, in which districts supplied with impure water by a water company have suffered greatly, while other districts in the same locality, and presenting otherwise the same conditions, were supplied with pure water, and suffered very little. Thus, Sir J. Simon showed that in the district supplied in 1853, part by the Lambeth Company with a pure water, and part by the Southwark Company with an impure water, the population drinking the Lambeth supply furnished 370 cases per 100,000, while those using the Southwark Co.'s water furnished 1300 cases per 100,000; all other circumstances except the water-supply being identical. Schiefferdecker, in Königsberg, has also given evidence to show the different extent to which districts in the same city supplied with pure and impure water suffer.

In Berlin, in 1866, in the houses supplied with good water, the number of houses in which cholera occurred was 36·6 per cent.; in the houses with bad water, 52·3 per cent.

Additional arguments can be drawn from instances in which towns which could not have had water contaminated with sewage have escaped, and instances in which towns which have suffered severely in one epidemic have escaped a later one, the only difference being that, in the interval, the supply of water was improved. Exeter, Hull, Newcastle-on-Tyne, Glasgow, and Moscow are instances of this. Two very good cases are related by Sir H. Acland. The parish of St Clement was supplied in 1832 with filthy water from a sewer-receiving stream. In 1849 and 1854 the water was from a purer source. In the first year, the cholera mortality was great; in the last years, insignificant. In Copenhagen a fresh water-supply was introduced in 1859. Although cholera had prevailed very severely there previously, in 1865 and 1866 there were only a few cases. In Haarlem, in Holland, cholera prevailed in great intensity in 1849. In 1866 it returned, and again prevailed as severely in all parts of the town except one. The part entirely exempted in the second epidemic was inhabited by bleachers, who, between 1849 and 1866, had obtained a fresh source of pure water. In the epidemic in Spain in 1885, Malaga, Seville, and Toledo drew water from pure sources, and had little cholera; on the other hand, Granada, Zaragoza, and Aranjuez derived water from open canals, and suffered severely.

The prevalence of cholera in Russia, with an outdoor temperature below zero of Fahr., has always seemed an extraordinary circumstance, which it appeared only possible to explain by supposing that, in the houses, the foul air and the artificial temperature must have given the poison its necessary conditions of development. But Routh has pointed out that, in the poorer Russian houses, everything is thrown out round the dwellings; then, owing to the cold and the expense of bringing drinking water from a distance, the inhabitants content themselves with taking the snow near their houses and melting it. It is thus easy to conceive that, if cholera evacuations are thus thrown out, they may be again taken into the body. This is all the more likely, as cholera stools have little smell or taste, and when mixed even in large quantity with water, cannot be detected by the senses.

We may therefore conclude that cholera evacuations which obtain access to drinking water contaminate it and render it immediately capable of producing the disease. If it is taken into the mouth and swallowed, the micro-organism may be destroyed by the acid secretions in the healthy stomach during the process of food digestion; but if, on the contrary, this does not take place, and the specific organism reaches the intestines, then the disease which almost invariably follows is cholera. The relative frequency of such immunity, the incubation period, and the severity of the disease produced, are points still uncertain.

Assuming that the comma bacillus described by Koch, and found by him to be present in the drinking-water tanks in Calcutta, is the actual cause of cholera, the objection that this bacillus would probably be destroyed in a short time by the putrefactive organisms present in such water, loses its force when it is considered that, owing to the habits of the people, the infectious matter has every chance of being imbibed by other persons almost immediately after it reaches the water.

There are some who even still deny that cholera is a water-borne disease, though their number is rapidly diminishing. Pettenkofer of Munich adheres to this opinion. He states that the etiology of cholera appears to him as an equation with three unknown quantities—x, y, and z. x is the specific germ disseminated by human intercourse; y something that depends on the place or time, the "local disposition"; and z the individual predisposition met with in all infectious diseases. These conditions are essential for an epidemic of cholera to take place. These views have not borne the test of time. As he has himself stated, "the contagionists have eliminated the y, finding sufficient explanation in Koch's discovery of the x and seeing in the individual tendency or absence of immunity the factor x."

In addition to the production of cholera from drinking water containing the cholera poison, it has been supposed that the use of impure water of any kind *predisposes* to cholera, though it cannot produce the disease. If the water acts in this way, it may be by causing a constant tendency to diarrhœa, or by lowering the resistance of the body, and rendering it more favourable as a nidus for the poison.

Enteric Fever.—It is now generally accepted that the poison of enteric fever exists in the excretal discharges, especially the urine, of those suffering from the disease, and if these gain access to water, it becomes one of the chief agents in the distribution of the disease. The micro-organism associated with enteric fever is a rod-shaped bacillus described by Eberth and Gaffky.

That water may be the means of propagating this disease has long been admitted by those who have made the subject their special study, and is borne out by the researches of Jenner, Budd, Simon, and Hirsch, who consider that few points in the etiology of enteric are so certainly proved as the conveyance of the morbid poison by drinking water or by food contaminated with infected water. Many instances are recorded showing the connection between this disease and an impure water-supply long before the specific organism which is associated with it was recognised. In Millbank Prison enteric fever prevailed constantly until 1854, the water-supply being derived from the polluted Thames. After this it was taken from an Artesian well in Trafalgar Square: only three deaths occurred from 1854 to 1872 and no case at all since 1865.

At Guildford, in 1867, an outbreak occurred almost exclusively amongst the dwellers in a particular area of water-supply. This particular area of 330 houses had been exceptionally supplied on one day in August with water from a new well; the epidemic broke out ten or eleven days afterwards. On examination the water was found to be polluted with organic matter; the well was situated in porous and fissured chalk, dangerously near a sewer, and this was found to be leaking.

An interesting outbreak is that of Lausen in Switzerland, which occurred in 1872. The cases were confined to those who drank water from a certain spring. On the other side of a hill, 300 feet high, was a brook contaminated with enteric excreta: when this Fürler brook was dammed up to water the meadows, it was noticed that the spring at Lausen became turbid and bad tasting. Shortly afterwards 10 persons were attacked in one day, and 57 more in the nine days following. Salt was put into the Fürler brook, and its presence detected in the water at Lausen, clearly showing a direct connection.

A destructive outbreak took place at Caterham and Redhill during 1878. This was traced to contamination of the water-supply by the stools of a workman suffering from mild enteric fever, who was employed in the Company's wells. The disease was confined to those who consumed the water, and ceased after the wells were pumped out and cleansed. The inmates of the Lunatic Asylum and the detachment of troops at Caterham barracks used the water from the asylum well, and did not suffer.

An outbreak of enteric fever at the Hampshire Lunatic Asylum at Fareham in 1886 was traced to the use of water originally pure, which had become polluted by spreading sewage on a portion of the land, also by percolation from the cemetery; the underground flow from the neighbourhood of the cemetery and the sewage works was in the direction of the well.

An epidemic occurred at New Herrington, Durham, in April 1889: 275 cases were reported between 1st April and 7th June, when the epidemic may be said to have ceased. The cause was traced to the pollution of a deep well (330 feet) by the overflow from a tank containing farm sewage, situated three-quarters of a mile above this well. The overflow escaped and disappeared down a fissure in the ground, which entered the well through a crack in the steining 45 feet below the surface. Two tons of salt were thrown down this fissure, and the chlorine entering the well through the "feeder," rose from 4 to a maximum of 24 grains per gallon. Specific contamination, however, of the farm-house sewage could not be made out, no illness resembling enteric fever having been known there for some years.

One of the most remarkable and extensive epidemics of enteric fever was that which prevailed in 1890–91 in the Lower Tees Valley. Enteric fever attacks occasioning the first outburst were most marked during a six-weeks' period, 7th September to 18th October 1890; that occasioning the second outburst during a six-weeks' period, 28th December 1890 to 7th February 1891.

The total number of enteric cases in the ten Registration Districts, forming the area under consideration, in the two six-weeks' periods referred to, were 1463. Of these 1334, or 91 per cent., occurred in three out of the ten districts, namely, those of Darlington, Stockton, and Middlesbrough, all of which were supplied with water taken from the River Tees. The estimated population in the ten Registration Districts receiving their supply of water from the River Tees amounted to 219,435, whereas the estimated population receiving their water from other sources than the Tees reached 284,181. Calculating the attack rates upon these figures, it was found that the rate of attack from enteric fever per 10,000 living during the first six-weeks' epidemic had been 33 amongst persons supplied with the Tees water and 3 amongst persons supplied with other water; whereas in the second six-weeks' epidemic the rates were 28 and 1 respectively. Above the intakes of the water company the Tees receives either directly or indirectly the drainage of twenty villages and hamlets as well as that of the town of Barnard Castle. "Seldom, if ever, has the proof of the relation of the use of a water so befouled to the wholesale occurrence of enteric fever been more obvious and patent" (Thorne Thorne).

Worthing was visited with a severe outbreak of enteric fever in 1893. Between May 3rd and November 30th 1315 attacks are known to have occurred in the borough, with 168 deaths. After the first three weeks the epidemic abated considerably, only to recur in the month of July with an outbreak of remarkable intensity. On investigating into the circumstances which led to the epidemic of this disease, it was shown that it was intimately related in point of time to the admission to the Worthing Service Supply of water from a new source of supply, undertaken in order to obtain an increase of water for the borough; that thereafter the disease became general throughout the areas supplied by this service, and that within the limits of these areas the incidence of fever was almost wholly on houses supplied with this water. It was further shown that not only was this new source of supply open to dangerous contamination, but that also, on bacteriological examination, subcultures presented, morphologically as well as culturally, all the characters of the enteric fever bacillus. In this case the water was contaminated by sewage which flowed through a fissure communicating with the new well; the sewers being jointed with clay and permitting leakage into the soil. It was also noted that there was comparative immunity from enteric fever of persons who habitually consumed water from local wells; and that there was heavy incidence of the disease on those who used the water delivered by the Public Service Supply. Moreover the water was not filtered.

Experiments made in New York show that the enteric bacillus survives in river-water longer during the cold half of the year than the warm. Ordinary bacteria in the water were found to decrease from 10,500 in December to 300 per cubic centimetre in July. Hence water purifies itself most rapidly in warm weather, and enteric outbreaks are usually in the spring or fall.

The spread of the disease through the medium of milk has now been abundantly proved, the poison having gained access to the milk no doubt through water.

Budd was of opinion that in the cases in which the poison is conveyed by water, infection seems to be much more certain and the incubation period materially shortened, but this latter statement is not borne out by the history of more recent epidemics. In the attack at Guildford the incubation period was 11 days (Buchanan).

Quincke, of Berne, published some cases due to drinking contaminated water, where the incubation period was very accurately determined: the shortest was 8 days, and the longest between 16 and 18 days. From 10 to 15 days is the usual period in enteric fever however propagated.

There has been some difference of opinion as to whether sewage *per se* will produce enteric fever, or must the evacuations from an enteric fever patient pass into the water. This is part of the larger question of the origin and propagation of specific poisons. Those who believe in the evolution of species have perhaps good grounds for considering that any sewage, receiving fæcal matters, may give rise to this specific form of fever; but as yet the weight of evidence is against such taking place.

Diarrhœa.—There is ample evidence to prove that diarrhœa may result from drinking impure water, and when thus produced may be due to a variety of causes.

Suspended mineral matters, such as clay and marl, found chiefly in the waters of rivers, such as the Mississippi, the Maas, Rio Grande, Kansas, and the Ganges, will at certain times of the year produce diarrhœa, especially in persons unaccustomed to the water. The hill diarrhœa at Dhurmsala is said to be produced by very fine scales of mica suspended in the water.

Suspended matters, animal (fæcal) and vegetable, have produced diarrhœa in many cases; such water always contains dissolved organic matters to which the effect may be partly owing. In cases in which the water is largely contaminated with sewage, its use may produce symptoms resembling cholera. An instance is recorded where seven persons in one house were attacked with violent gastro-intestinal derangement (vomiting, diarrhœa, &c.) produced by water contaminated by sewage which had passed into a cistern (Gibb). In St Petersburg the water of the Neva, which is rich in organic substances, gives diarrhœa to strangers.

Gore has recorded a violent outbreak of diarrhœa at Bulama, on the west coast of Africa, produced by water taken from a well: the water was good, but was milky from suspended matters, consisting of the débris of plants, chlorophyll, minute cellular and branched *algæ*, *monads*, *polygastrica*, &c. When filtered the water was quite harmless.

Wanklyn states that in the Leek Workhouse there has been for years past a general tendency to diarrhœa, which could not be accounted for until the water was examined and shown to be loaded with vegetable matter. The water was almost free from chlorine, containing only 0·5 grain per gallon. He also instances the case of a well on Biddulph Moor, a few miles from Leek, which on analysis yielded 0·5 grain per gallon of chlorine and 0·03 free and 0·14 albuminoid ammonia parts per million. The persons who were in the habit of drinking this water suffered from diarrhœa.

An excess of dissolved nitrogenous organic matter may produce diarrhœa, but it is difficult to estimate its exact influence, on account of the presence of other impurities.

The animal organic matter derived from graveyards appears to be especially hurtful; here also ammonium and calcium nitrites and nitrates may be present.

Water containing much hydrogen sulphide will give rise to diarrhœa, especially if organic matter be also present. In the Mexican War (1861–62) the French troops suffered at Orizaba from a peculiar dyspepsia and diarrhœa, attended with immense disengagement of gas and enormous eructations after meals. The eructed gas had a strong smell of hydrogen sulphide. This was traced to the use of water from sulphurous and alkaline springs; even the best waters of Orizaba contained organic matter and ammonia in some quantity. Medicinal sulphuretted waters are well known to have a purgative action. The absorption of sewer gases by water, as when the overflow-pipe of a cistern opens into the sewers, will cause diarrhœa. Dissolved mineral matters, when in excess, may produce diarrhœa. Sulphates of magnesia and lime are the most usual as producing this effect, as is seen in the case of many purgative medicinal waters.

Calcium nitrate waters also produce diarrhœa. A case is on record, in which a well water was obliged to be disused, in consequence of its impregnation with butyrate of calcium (150 parts per 100,000), which was derived from a trench filled with decomposing animal and vegetable matters.

The effect of calcium and potassium nitrate in causing a tendency to diarrhœa was also observed in Berlin.

Brackish water (whether rendered so by the sea, or derived from loose sands) produces diarrhœa in a large percentage of persons, and at some of the Cape frontier stations water of this character formerly caused much disease of this kind. In a water examined at Netley, which became brackish from sea-water and produced diarrhœa in almost all persons, the amount of chloride of sodium was found to be 361 parts per 100,000.

But, doubtless, a much less quantity than this, especially if chloride of magnesium be present, will act in this way.

Sometimes organic matter in water, by producing nitrates and nitrites, which act on metals (lead), may produce illness of a specific character.

Dysentery.—This disease is decidedly produced by impure water, and the substitution of a pure for an impure supply has been frequently followed by a decrease in the prevalence of dysentery in an affected community. The instances in which outbreaks of dysentery have been traced to the use of water contaminated with fæcal impurities are very numerous. We shall simply notice a few of the most conclusive instances of this nature.

On the west coast of Africa (Cape Coast Castle), an attack of dysentery was traced to the passage of sewage from a cesspool into one of the tanks. This was remedied, and the result was the almost total disappearance of the disease.

That in the East Indies a great deal of dysentery has been produced by impure water, is a matter too familiar almost to be mentioned. Its constant prevalence at Secunderabad, in the Deccan, appears to have been partly owing to the water, which percolated through a large graveyard.

The great effect produced by the impure water of Calcutta in this way has been pointed out by Chevers.

In time of war this cause has often been present; and the great loss by dysentery in the Peninsula, at Ciudad Rodrigo, was partly attributed by Sir J. M'Grigor to the use of water passing through a cemetery where nearly 20,000 bodies had been hastily interred.

At Metz, during the summer of 1870, there was a severe epidemic of dysentery in two regiments, the rest of the troops escaping the disease. Inquiry showed that the former had drunk well-water greatly contaminated with fæcal soakage from latrines placed opposite and close to them. When the wells were closed the disease suddenly ceased. In 1881, the troops occupying the same barrack were supplied with drinking water from the same wells, whereupon cases of dysentery reappeared, and the closing of the wells had once more the desired effect.

In a large number of these instances, the water which gave rise to dysentery was polluted with fæcal and possibly with dysenteric discharges. But the disease has also been ascribed to the use of marsh and brackish water, of water contaminated with decaying animal matters, and of waters containing an excess of mineral salts in solution. It is easy to understand that water may not only serve as a vehicle by means of which the specific cause of dysentery may be introduced into the system, but it may also serve as an irritant, and thus act as a predisposing cause of infection.

Yellow Fever.—As, like dysentery, enteric fever and cholera, the alimentary mucous membrane is primarily affected in yellow fever, there is an *a priori* probability that the cause is swallowed also in this case, and that it may possibly enter with the drinking water. But no good evidence has been yet brought forward.

Dyspepsia.—Symptoms which may be referred to the convenient term dyspepsia, and which consist in some loss of appetite, vague uneasiness or actual pain at the epigastrium, and slight nausea and constipation, with occasional diarrhœa, are caused by water containing a large quantity of calcium sulphate and chloride, and the magnesian salts. Sutherland found the hard water of the red sandstone rocks, which was formerly much used in Liverpool, to have a decided effect in producing constipation, lessening the secretions, and causing visceral obstructions; and in Glasgow, the substitution of soft for hard water lessened the prevalence of dyspeptic complaints (Leech). It is a well-known fact that grooms object to give hard water to their horses, on the ground that it makes the coat staring and rough—a result which has been attributed to some derangement of digestion. The exact amount which will produce these symptoms has not been determined, but water containing more than 11 parts per 100,000 of each substance individually or collectively appears to be injurious to many persons. A much less degree than this will affect some persons. In a well-water at Chatham, which was found to disagree with so many persons that no one would use the water, the main ingredients were 27 parts of calcium carbonate, 16 parts of calcium sulphate, and 18·5 parts of sodium chloride in 100,000. The total solids were 71·4 parts in 100,000. In another case of the same kind, the total solids were 83 parts in 100,000; the calcium carbonate was 31, the calcium sulphate 16, and the sodium chloride 20 parts per 100,000.

Iron, in quantities sufficient to give a slight chalybeate taste, often produces slight dyspepsia, constipation, headache, and general malaise. Custom sometimes partly removes these effects.

Malarial Fevers.—Water from marshes has been long considered to produce fever in those who drink it, and the same belief exists now among the inhabitants of marshy countries, who assert that marsh waters can produce fever. Even Hippocrates in his time noticed that the spleens of those who drank water of this kind became enlarged and hard. It is difficult to state exactly the *rôle* water plays in disseminating the poison of malaria, as those who suffer are otherwise exposed to malarious influences: still there is evidence to show that cases have occurred which can only be accounted for by using water derived from marsh lands and malarious soils.

On making some inquiries of the inhabitants of the highly malarious plains of Troy during the Crimean war, Parkes found the villagers universally stated, that those who drank marsh water had fever at all times of the year, while those who drank pure water only got ague during the late summer and autumnal months.

The same belief is prevalent in India. In the Wynaad district in Madras it is notorious that the water produces fever and affections of the spleen. Instances are known where villages are placed under the same conditions as to marsh air, yet in some of them fevers are prevalent, in others not; the only difference being, that the latter are supplied with pure water, the former with marsh or nullah water full of vegetable débris. In one village there were two sources of supply—a tank fed by surface and marsh water, and a spring; those only who drank the tank water got fever. In a village (Tulliwaree) no one used to escape the fever; a well was dug, the fever disappeared, and, during fourteen years, had not returned. Another village (Tambatz) was also "notoriously unhealthy"; here also a well was dug, and the inhabitants became healthy. Nothing can well be stronger than the positive and negative evidence here given.

Moore also noted his opinion of malarious disease being thus produced; and Commaille has since stated, that in Marseilles paroxysmal fevers, formerly unknown, have made their appearance, since the supply to the city has been taken from the canal of Marseilles. In reference also to this point, Townsend, the Sanitary Commissioner for the Central Provinces in India, states in one of his reports that the natives have a current opinion that the use of river and tank water in the rainy season (when the water always contains much vegetable matter) will almost certainly produce fever (*i.e.*, ague), and he believes that there are many circumstances supporting this view. In this way the prevalence of ague in dry elevated spots is often, he thinks, to be explained. He mentions also that the people who use the water of streams draining forest lands and rice fields "suffer more severely from fever (ague) than the inhabitants of the open plain drawing their water from a soil on which wheat grows." In the former case there is far more vegetable matter in the water. The Upper Godavery tract is said to be the most aguish in the province, yet there is not an acre of marshy ground; the people use the water of the Godavery, which drains more dense forest land than any river in India.

In the belt of marshy land and forest stretching along the base of the Himalayas, and known as the Terai, it has always been the belief that the transmission of malarial fever was caused by drinking water. Whalley states that a party of workmen, sent to repair a bridge over the Chuka, and who were dependent on this stream for their drinking water, suffered severely from fever, only three escaping out of thirty, and many dying. Since then a deep masonry well has been constructed a few hundred yards from the bridge, and the forest guards who are located there, and drink only the well-water, find the station as healthy as any other.

The following instructive case bears on this question. The artillery quartered at Tilbury Fort formerly suffered more or less from ague, whilst the people at the railway station, and the coastguard and their families in the ship lying just outside the fort, never suffer from malarious poisoning. The troops had been supplied with drinking water from two underground tanks which received rain-water from the roof of the barracks, whilst the other persons above mentioned draw their drinking water from a spring near the railway station. In the six months, from January to June 1873, there were amongst the troops 12 admissions for ague out of a strength of 102. From December 1873 to July 1874 they were supplied from the spring near the railway station, on account of the barrack tanks being out of repair. From December 1873 to July 1874 there was only one case out of a strength of 90 men; while from November 1874, when the water from the tanks was brought into use again, until March 1875, there were four cases out of a strength of 53 men.

An analysis of the waters showed that the tanks were exposed to soakage from the surrounding salt marsh; for the so-called rain-water yielded 59 parts per 100,000 of total solids in the one case and 207·5 in the other; the chlorine being respectively 18 and 47 parts per 100,000.

Another case of importance is that recounted by Smart. In the Rocky Mountain district of North America a fever prevails, which is popularly known as the *Mountain fever*; it is of a remittent type, and is amenable to quinine. There is, however, no malarious district in the neighbourhood, and cases of intermittent fever from the plains recover rapidly there; the disease occurs sometimes when the thermometer is at times below zero, and always below the freezing point, but most frequently at times when fever does not occur in the plains, but which coincide with the melting of the snows, viz., May, June, and July. On analysis it was found that all the water in the rivers contained a large excess of organic matter, the purest showing from 0·019 to 0·028 per 100,000 of albuminoid ammonia, whilst the springs showed only 0·010. The amount was much increased after heavy snowfall, and on analysing the snow he was surprised to find it contained a large excess of organic matter, especially that which fell in large heavy flakes (as high sometimes as 0·058 of albuminoid ammonia). Smart concludes that vegetable organic matter is blown up from the plains and precipitated with the snow, and, when the latter melts, carried into the streams. The exclusion of the snow-waters and heavy rainfalls, by erecting storage reservoirs, gave the place a comparatively pure spring-water at all times, and this fever occurred afterwards but slightly.

One very important circumstance is the rapidity of development of the malarious disease and its fatality when introduced in water. It is the same thing as in the case of diarrhœa and dysentery. Either the fever-making cause must be in larger quantity in the water, or, what is equally probable, must be more readily taken up into the circulation and carried to the spleen, than when the cause enters by the lungs.

In opposition, however, to all these statements must be placed a remark of Finke's, that in Hungary and Holland marsh water is daily taken without injury; but in Hungary, Grosz states that, to avoid the injurious effects of the marsh water, it is customary to mix brandy with it. Colin, of the Val de Grâce, who is so well known for his researches on intermittent fever, questions the production of paroxysmal fevers by marsh water. He cites numerous cases in Algiers and Italy, where impure marsh water gave rise to indigestion, diarrhœa, and dysentery, but in no case to intermittent fever, and in all his observations he has never met with an instance of such an origin of ague.

Hirsch considers that the observations, which have been adduced to prove the diffusion of malaria by means of drinking water, do not bear the constructions that the writers put upon them; and he believes that there is no proof of the propagation of the disease by this means.

W North adduces the fact that "the healthiest parts of the city of Rome are supplied by water admitted to be the best in the world, and which rises—to take the Acqua di Trevi or Acqua Vergine as an example—on unenclosed land, in springs which bubble up and cover the surface in a locality so unhealthy, that to pass several nights there in August might involve risk to life, and certainly to health." He thinks that "proof that the malarial affection can be conveyed by water is wanting, though very largely credited by the natives of countries where the disease prevails."

Although it has been alleged that malarial diseases may be introduced on board ship by means of drinking water, the records of the Royal Navy do not support this view. The statistical returns for the last thirty years do not show a diminution in the proportion of cases of malarial fever, although very great improvements have been made during that time in regard to supplies of drinking water and the more extended use of distilled water.

Other Zymotic Diseases.—Scarlet fever appears to be the only other zymotic disease likely to be propagated by water. The evidence for such propagation was formerly very slight, but numerous cases have occurred which have been attributed to water mixed with milk. Later researches go to show that it is the milk which is the medium of infection and not the water. Although there seems no *primâ facie* reason against water being a channel of infection, evidence that it is so is wanting: this disease certainly is not disseminated by water as a rule.

It has been suggested that diphtheria may be disseminated by the agency of drinking water, but the evidence at present is against such being the case. In no single instance has water been identified as the probable cause of diphtheria in the investigations undertaken by the Local Government Board. As a matter of fact, the diphtheria organism finds it very difficult to live in water. It can apparently only maintain existence in very polluted water, but average water is to a large extent destructive to its vitality (Thorne).

Oriental Sore.—Under this term are included those specific forms of sores spoken of as Aleppo, Bagdad, or Delhi boil. Various writers have attributed its spread to the use of impure water. It is certain that the disease can be conveyed by inoculation, and therefore that it depends on an organised virus. The disease is probably conveyed in the course of washing with infected water: this possibly being only one means by which it is disseminated.

Goitre.—The opinion that impure drinking water is the cause of goitre is as old as Hippocrates and Aristotle, and has been held by the majority of physicians. The opinion may be said actually to have been put to the test of experiment, since both in France and Italy the drinking of certain waters has been resorted to, and apparently with success, for the purpose of producing goitre, and thereby gaining exemption from military conscription. And this is supported by the evidence of Bally, Coindet, and by many of the French army surgeons, who have seen goitre produced even in a few days (8 or 10) by the use of certain waters.

Apart from this, the evidence for the causation by water is extremely strong, many cases being recorded where in the same village, and under the same conditions of locality and social life, those who drank a particular water suffered, while those who did not do so escaped. Another author who has written on this subject, and who has accumulated an immense amount of evidence, Saint-Lager, expresses himself very confidently on the point.

In the report of the French Commission (1873) we find the following case:—At Bozel (Tarentaise) there were, in 1848, about 900 goitrous persons, and 109 cretins in a population of 1472, while the village of St Bon, standing 800 metres higher, was quite free from both diseases: a water-pipe having been carried from this village to Bozel, and this water having come into general use, the endemic decreased so remarkably, that in 1864 there were only 39 goitres and 58 cretins, and no fresh cases occurring.

The impurity in the water which causes goitre is not yet precisely known. It is certainly not owing to the want of iodine, as stated by Chatin, and there is little probability of its being caused by a deficiency of chlorides, by fluorine, or by silica. On the other hand, the coincidence of goitre with sedimentous water is very frequent. Since the elaborate geological inquiries of Grange and the analysis of the waters of the Isère, magnesian salts in some form have often been considered to be the cause, to which many add lime salts also; and certainly the evidence that the water of goitrous places is derived from limestone and dolomitic rocks, or from serpentine in the granitic and metamorphic regions, is very strong. The investigations now include the Alps, Pyrenees, Dauphiné, some parts of Russia, Brazil, and districts in Oude in North-West India. A table compiled from M'Clellan's work is very striking:—

Goitre and Cretinism in Kumaon (*Oude*).

Water derived from	Percentage of Population affected.	
	With Goitre.	With Cretinism.
Granite and gneiss,	0·2	0
Mica, slate, and hornblende,	0	0
Clay slate,	0·54	0
Green sandstone,	0	0
Limestone rocks,	33	3·0

There are, however, not wanting analyses of water of goitrous regions which show that magnesia may be absent (in Rheims, according to Maumené; in Auvergne, according to Bertrand; in Lombardy, according to Demortain; and Saint-Lager enumerates other cases), while it has been also denied that there need be any excess of lime. Goitre does not appear to be a prevalent disease in Sunderland or in Bristol, towns which have water-supplies which are hard, calcareous, and rich in magnesium salts.

In the jail at Durham, Johnston states that when the water contained 110 parts per 100,000 (chiefly of lime and magnesium salts) all the prisoners had swellings of the neck; these disappeared when a purer water, containing 26 parts per 100,000, was obtained.

Wilson carried out some inquiries at Bhagsu, Dhurmsala, where goitre prevails extensively. He analysed specimens of the drinking water within a radius of ten miles, and found them exceptionally pure, only three showing traces of lime, and none giving any evidence of magnesia or iron.

Macnamara, basing his opinion on personal observation and inquiry, does not believe that there is any relation between the lime and magnesium hardness in water and goitre. In the Brahmapootra and Chenab valleys, are certain spots on the river bank where goitre is prevalent, while in neighbouring villages similarly situated, where the same water, that of the river, is used, there is none. He further states that in all goitrous localities, it is during and after the rains, when the water, so far as their mineral ingredients are concerned, must be in the state of greatest dilution, that the disease most commonly commences and most rapidly develops.

It seems, therefore, that the question is still undecided, and it is much to be desired that more extended inquiry should be made, with careful analyses, as well as records of local and other conditions, which probably contribute more or less to the production of the disease.

Parasitic Diseases.—Whereas the *Tænia solium* and the *Tænia medio-canellata*, and many entozoa, find their way into the body with the food, the two forms of the *Bothriocephalus latus* (*T. lata*) may pass in with the drinking water. Both embryo and eggs (but principally, or perhaps entirely, the former) exist in river-water. The ciliated embryo moves for several days very actively in water; it may after a time lose its ciliary covering, and then, not being able to move further, perishes; or it may find its way into the body of some animal, and there develop into the *Bothriocephalus latus*. It is mostly indigenous to the sea coast and to the shores of lakes and other inland water.

It is most common in the interior of Russia, Sweden, in part of Poland, and in Switzerland.

Distoma hepaticum (*Fasciola hepatica*).—The eggs are developed in water, and the embryos swim about and live, so that introduction in this way for sheep is probable, and for men is possible.

The *Ascaris lumbricoides* (Round-worm) appears also sometimes to enter the body by the drinking water. At Moulmein, in Burmah, during the wet season, and especially at its commencement, natives and Europeans, both sexes and all ages, were, in former years, so affected by lumbrici that it was almost an epidemic. The only circumstance common to all classes was that the drinking water, drawn chiefly from shallow wells, was greatly contaminated by the substances washed in by the floods of the excessive monsoon which prevails there. Similar facts have also been noticed in England.

Leuckart has no doubt of the passage of the *Ascarides'* eggs into drinking water; and, indeed, they have been actually seen in the water by Mosler.

But it seems yet doubtful (as all experiments have failed in producing from the drinking water the worms in animals) whether the eggs alone will suffice, and it seems possible that they must pass through some other host before developing in the human intestine. This was also the opinion of Cobbold. Mosler attributed in his case much influence to the large amount of vegetable food taken by the persons affected.

The *Dochmius duodenalis* (*Strongylus duodenalis, Anchylostomum seu Sclerostoma duodenale*) would appear from Leuckart's statement to be introduced by impure water. It is especially prevalent in Brazil and in Egypt, where it causes the so-called "Egyptian chlorosis" (Griesinger). During the construction of the St Gothard Tunnel, the workmen were much affected by a severe, and often fatal, form of anæmia, due to the presence of this parasite. The disease is propagated mainly, if not altogether, by drinking water containing the ova or embryos. The Beri-beri of Ceylon is said by Kynsey to be due to the presence of *Anchylostomum duodenale* in the intestinal canal; "to be, in fact, *Anchylostomiasis*." The cause is the presence of the ova of the parasite in drinking water.

Oxyuris vermicularis, very common in children, but occasionally also found in adults, is probably sometimes taken through water.

Filaria Dracunculus (Guinea-worm).—The introduction by water of *Filaria* has long been a favourite opinion. It has been a matter of debate whether it is taken into the stomach as drink, and thence finds its way (like *Trichina*, to the muscles) into the subcutaneous cellular tissue, or whether it penetrates the skin during bathing or wading in streams. The latter opinion seems to be the more probable in the majority of cases. Fedschenko, however, has shown that the embryo enters the body of a *cyclops*, which acts as its host, and that it undergoes development there, and is thus taken in with drinking water. Boiling the water before drinking appears to have a preservative effect.

Filaria sanguinis hominis appears to find its way into the blood of man through water in a curious way. Manson has found that the mosquito is an active agent in the propagation of *Filaria*. The embryos are taken into the mosquito's stomach with the blood of persons infected by the hæmatozoon. Arrived there, the parasite penetrates the walls of the stomach, and works its way to the thoracic tissues of the insect, where further development takes place. Thence they are transferred to the water, whence it is assumed that it again finds entrance into the body of man. It produces *Elephantiasis* and *chyluria*.

Bilharzia hæmatobia.—From the observations of Griesinger, John Harley, and Cobbold, there seems no doubt that the embryos of this entozoon live in water, and the animal may be thus introduced probably by the medium of some other animal. Batho doubts, however, this introduction by water, since the entozoon occurred in persons using rain-water and pure mountain stream water. It causes *endemic hæmaturia* in Egypt, the Cape, and elsewhere.

Leeches.—Small leeches may be present in water, which fix on the pharynx, or in the posterior nares, after drinking. Cleghorn noticed that coughs, nausea, and spitting of blood were thus caused. In a march of the French near Oran, in Algiers, more than 400 men were at one time in hospital from this cause. In some cases the repeated bleedings from the larynx have simulated hæmoptysis and phthisis, and have produced anæmia. A leech, once fixed, seldom falls off spontaneously.

Lead, Arsenic, Copper, Zinc, &c., in Water.—The question of lead poisoning by drinking water has already been considered. It is only necessary to mention the fact of metals passing into the drinking water, either by trade refuse being poured into streams, or by the water dissolving the metal as it flows through pipes or over metallic surfaces. The amount of copper required to produce poisonous symptoms appears to be doubtful.

In 1864 a factory at Basle discharged water containing arsenic into a pond, from which the ground and adjacent wells were contaminated, and severe illness in the persons who drank the well-water was produced.

Water, impregnated with sulphurous acid, gives rise in cattle to a number of serious symptoms, among others to diseases of the bones. The sulphur dioxide evolved from the copper works at Swansea has caused numerous actions on account of the loss of herbage and cattle. Rossignol states that water highly charged with calcium carbonate and sulphate was found to give rise to exostoses in horses; pure water being given, the bones ceased to be diseased.

General Conclusions.—An endemic of diarrhœa, *in a community*, is almost always owing either to impure air, impure water, or bad food. If it affects a number of persons suddenly, it is probably owing to one of the two last causes; and if it extends over many families, almost certainly to water. But as the cause of impurity may be transient, it is not easy to find experimental proof.

Diarrhœa or dysentery, constantly affecting a community, or returning periodically at certain times of the year, is far more likely to be produced by bad water than by any other cause. A very sudden and localised outbreak of either enteric fever or cholera is almost certainly owing to the introduction of the poison by water, and the same fact holds good in cases of malarious fever and especially if the cases are very grave. The introduction of the ova of certain entozoa by means of water is proved in some cases and is probable in others.

Although it is not at present possible to assign to every impurity in water its exact share in the production of disease, or to prove the precise influence on the public health of water which is not extremely impure, it appears certain that the health of a community always improves when an abundant and pure water-supply is given; and, apart from this actual evidence, we are entitled to conclude, from other considerations, that abundant and good water is a primary sanitary necessity.

PURIFICATION OF WATER.

The purification of water may be necessary to remove excessive hardness, suspended matters, dissolved organic matter, or the micro-organisms usually associated with specific diseases.

Distillation.—This is undoubtedly the best plan, for if properly carried out all danger is removed. Unless, however, the water is taken from a clean source it may produce illness even if distilled. An outbreak of diarrhœa on board H.M. ships in the harbour of Valetta was attributed to impurities in the water distilled from the not over-clean water of the Grand Harbour. The distilled water was also complained of as "going bad" very quickly in the Soudan campaign; but there the dirty water of the harbour of Suakim was used, and in such a case there may have been an excessive quantity of free ammonia in the water which passed over into the distillate; this shows the necessity of seeking a pure supply to distil the water from. All distilled water should be tested with a few drops of dilute nitric acid and silver nitrate; if no haze appears, then the water may be considered safe: all other waters will give evidence of the presence of chlorine, by the formation of a precipitate, turbidity, or haze according to the amount; and so will distilled water (so-called), if it has been contaminated during the process of distillation, or by being received in vessels not perfectly clean.

Boiling.—This plan is next best to distillation: it gets rid of calcium carbonate, iron in part, and hydrogen sulphide, and lessens, it is said, organic matter. Tyndall's experiments have shown that there are stages in the life of *bacteria* during which they can resist almost any moist heat. But as they soften before propagation a solution can be successfully sterilised by repeated boilings, so as to attack the several crops of *bacteria* in their vulnerable condition. Most *fungus* spores are killed by boiling. On the whole we may take it that water, even only once boiled, is in all likelihood safe, and, if repeatedly boiled at intervals, quite safe.

Chemical Processes.—*Alum* has been used to purify water from suspended matters. It does this very effectually if there be calcium carbonate in the water; calcium sulphate is formed, and this and a bulky aluminum hydrate entangle the floating particles and sink to the bottom. The quantity of crystallised alum to be used should be about 6 grains per gallon.

If a sedimentous water is extremely soft, a little calcium chloride and sodium carbonate should be put in before the alum is added.

Clark's process for the softening of water really combines chemical with mechanical action. This plan has been carried out with great success on a large scale in the form known as the Porter-Clark process. *Lime water* is mixed, by means of rakes or fans, with the water to be purified, and by entering into combination with the CO_2 in the water, the calcic carbonate is rendered insoluble, and thrown down as a precipitate: this acts mechanically in removing a large portion of the organic matter, and, it is said, iron. The water is subsequently clarified either by subsidence or by being forced through a filter of stretched canvas, by which all solid impurities are removed: it does not touch calcium and magnesium sulphate or chloride.

The following equation explains this action:—

$$CaCO_3 + CO_2 + CaH_2O_2 = 2CaCO_3 + H_2O.$$

Sodium carbonate, with boiling throws down lime, and a little lead, if present.

Maignen's process consists in adding to the water a powder, called *anti-calcaire*, containing chiefly lime, sodic carbonate, and alum. The alum precipitates organic matter, whilst the sodic carbonate attacks the lime and magnesia.

Addition of Potassium or Sodium Permanganate.—Pure Condy's fluid readily removes the smell of hydrogen sulphide and the peculiar offensive odour of impure water which has been kept in casks or tanks. If it forms a precipitate of manganic oxide, it also carries down suspended matters; but the formation of this precipitate is very uncertain. The action on the dissolved organic matters will, of course, vary with the nature of the substance; some of the organic matters, both animal and vegetable, will be oxidised; but in the cold it will not act upon the whole of these substances, and some organic matters are not touched.

One objection to the use of the permanganate is that it often communicates a yellow tint to the water, arising from suspended finely divided peroxide of manganese. This is probably of no moment as far as health is concerned, but it is unpleasant. Sometimes the addition of a little alum will carry down this suspended matter; boiling may be used, but often has no effect. Sometimes nothing removes it but filtration.

The indications for the use of permanganate are these. In the case of any foul-smelling or suspected water, add good Condy's fluid, teaspoonful by teaspoonful, to 3 or 4 gallons of the water, stirring constantly. When the least permanent pink tint is perceptible, stop for five minutes; if the tint is gone, add 36 drops, and then, if necessary, 30 more, and then allow to stand for six hours; then add for each gallon 6 grains of a solution of crystallised alum, and if the water is very soft, a little calcium chloride and sodium carbonate, and allow to stand for twelve or eighteen hours.

Filtration.—One of the chief, if not the chief, objects of water filtration for domestic purposes is a removal of disease-producing germs. It is therefore of primary importance to learn the bacterial efficacy of filters, as well as to ascertain what amount of chemical purification the water has undergone by the action of the filtering media. The knowledge which later methods of investigation have afforded concerning the nature of the infective matter, teaches us that water, by the process of filtration, must not only be rendered clear and free from sedimentary deposits, but that, when taken from any doubtful source, it must be freed from the infectious material which may gain access to it. The chemical examination of water affords useful information and is not too hastily to be disregarded or given up for bacteriological tests. It distinctly, in the present instance when dealing with the principles of filtration, indicates the quantity of food material in the water and whether it is present in sufficient amount to support a vigorous growth of bacteria: it also shows whether the organic nitrogen remains the same in the filtering medium, or if it is increased by the organic matter stored in it. While, therefore, we must necessarily rely on bacteriological tests for direct information as regards specific diseases and their dissemination by water, chemical analysis affords us a guide as to the general characters of potable water and whether it is likely to produce disease. One method of investigation assists the other: both taken together afford the best basis from which to draw safe conclusions. It is necessary, therefore, to consider filtration on a large scale as carried out with large water-supplies by public companies, and domestic filtration as applied to relatively small quantities of water in habitations.

Filtration through Sand and Gravel.—On a large scale, water is received into settling reservoirs, where the most bulky substances subside, and is then filtered through gravel and sand, either by descent or ascent, or both.

The New River Company's filter beds are constructed from above downwards of a layer of sand, 30 inches in thickness, followed by 6 inches of gravel placed on a similar thickness of bricks. The water passes through at the rate of 6 inches per hour: half a cubic foot of water (= 3·11 gallons) percolates downwards through each square foot of surface per hour: this is equal to nearly 136,000 gallons per acre per hour.

The action of a sand filter bed is partly mechanical, partly vital: the mechanical action consists in holding back the grosser suspended substances in the water, and this, which was until recently supposed to be the only operation in a filter, is now held to be of secondary importance: the vital action takes place in the deposit from the unpurified water; a gelatinous layer is formed on the surface of the filter, and it is on the activity of the living matter in this surface layer that real filtration takes place. A new filter has no effect in producing bacteriological purification until this deposit, charged with living micro-organisms, is formed on the surface, and it is to these organisms, which rest on the surface and penetrate the sand to a slight distance, that both the nitrification of organic matter and the arrest of other microbes is effected. This surface layer should not be disturbed during the process of filtration until it becomes so thick as to be impermeable to water. Cleansing, by which the superficial layer is removed, should only be carried out when the filter ceases to act.

The thickness of the layer of sand, and the rate the water percolates, are two points requiring careful attention. The former should never be allowed to get below 30 cm. (= 11·8 inches), and the rate of filtration should not exceed 100 mm. (= 3·94 inches) in an hour, in order to obtain the most perfect filtration. If the filter works satisfactorily in every respect, there should be found less than 100 germs capable of development in 1 c.c. of filtered water. The small number of germs remaining in the filtered water are due to the filtering media in process of time being covered with vegetable micro-organisms; these are naturally harmless, and will do no injury. Sand filtration, even under favourable circumstances, cannot give absolute protection against the danger of infection, but it can give such a protection that in practice we may, under existing circumstances, be satisfied with it (Koch).

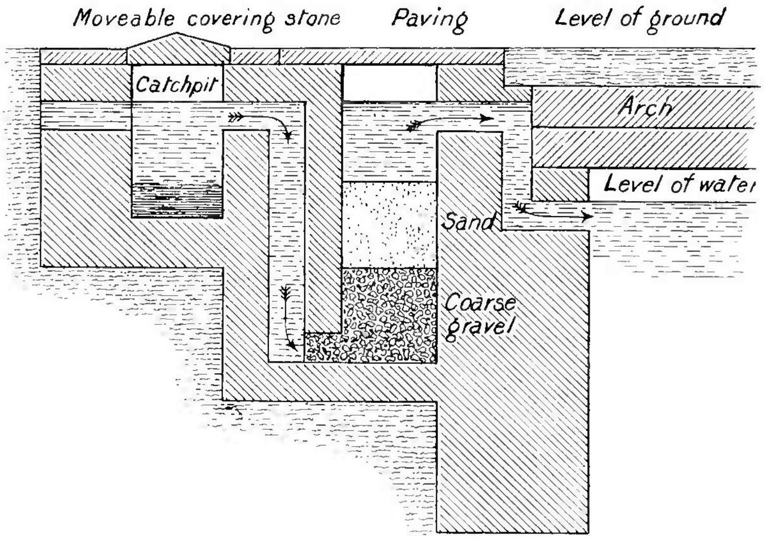


Fig. 1.

Deep filter beds are always preferable to shallow ones: in winter they give a larger body of water which does not freeze readily, and in summer the water is cooler: water keeps better in bulk than in shallow filter beds. Reservoirs to store the filtered water should always be covered, so as to avoid contamination with dust, &c.

Many waters, particularly rain-water, must be filtered through sand before they pass into small cisterns, and the filter should be cleaned every three or four months. Fig. 1 is a single filter recommended for this purpose. A double filter can be made by having a second chamber.

Other substances, such as animal charcoal, spongy iron, magnetic spongy iron or polarite, have been used; these substances are now being gradually replaced by sand filters.

Animal charcoal is far too expensive for use in large filters, and this medium is now almost entirely restricted to small filters used for domestic purposes.

Spongy iron is a substance obtained by roasting hæmatite ore: it is a porous metallic iron, not unlike animal charcoal in appearance, and occupies about twenty cubic feet to the ton. It yields a little iron to water, which, however, can be removed by further filtration through pyrolusite or black oxide of manganese and fine gravel and sand. It acts upon the water itself, decomposing it and setting free hydrogen, the oxygen being given up to the organic matter. Its action on water is both mechanical and chemical, for it arrests suspended matters and also oxidises organic matter in solution. It is said, however, not to sterilise water, and water cannot be stored after filtration without undergoing signs of deterioration. Unless kept covered with water, spongy iron dries rapidly and cakes, when it loses its power of effecting any change, and water ceases to pass through it. This material has been used in the water works at Antwerp, and is said to give satisfaction. It possesses no advantages over sand, while there are certain disadvantages connected with its use, notably its tendency to cake, and the addition of iron salts to the water which have subsequently to be removed. Moreover, it permits the free passage of bacteria.

Polarite, or magnetic spongy carbon, consists of magnetic oxide of iron with some alumina, magnesia, silica, lime, and a trace of carbon. Its action is very similar to that of spongy iron, over which it possesses no special advantages.

All these substances have been abandoned, more or less, in this country as giving less satisfactory results than clean sand. If a fairly pure water-supply be adopted, the best results will be obtained by filtration through clean sand. It is hopeless to attempt to make a polluted water safe for drinking purposes by any process of simple filtration, and any attempt to do so should be deprecated.

Domestic Filters.—When water is supplied by a public company for domestic purposes it should be sufficiently purified, before distribution, so as not to require filtration. Circumstances exist, however, in which domestic filtration is often a necessity. A number of substances have been suggested or used for this purpose. Among the more important of these are, animal and vegetable charcoal, in granules or powder or made into blocks, or fine silica impregnated with charcoal (silicated carbon filters), hæmatite and magnetic iron ores, the so-called magnetic carbide, spongy iron, manganic oxide, flannel, wool, sponges, porous sandstones (natural and artificial), &c.

Animal charcoal was formerly considered to be one of the best filtering materials. Later experiments, however, show that, although it possesses considerable oxidising powers on organic impurities present in water, it does not sterilise it, but, on the contrary, favours the development of micro-organisms in the water. It adds both phosphates and nitrogen to water, which form a nutritive medium for bacteria. Water filtered through animal charcoal rapidly deteriorates as the charcoal yields up impurities to water, so that in many cases the water is more impure after it has passed through the filter than it was originally. While the charcoal attacks and oxidises the putrefactive organic matters in solution, it permits fresh or vital organic matter to pass through unchanged. On the whole, there is perhaps no material more unsuited or unsafe to use as a filtering medium for potable waters than animal charcoal. This cannot be too widely known, as it is still advocated in many standard works as being the best filtering material, notwithstanding the fact that recent methods of investigation have shown it to be the very reverse.

Doulton's *Manganous Carbon* is a mixture of animal charcoal and black oxide of manganese: the manganese dioxide is intended to act as an oxidiser.

Carbalite is used in the Royal Navy. It is said that, while having all the purifying powers of animal charcoal, from the absence of any phosphate or nitrogenous animal matter, it in no way favours the growth of low forms of life. It is used in Crease's filters.

Spencer's *Magnetic Carbide* is prepared by roasting equal parts of red hæmatite ore and sawdust in a retort; the resulting carbide of iron is crushed and mixed with sand: it is said to answer well for filtering purposes.

Spongy iron and *polarite* have also been used in domestic filtration. Beyond a little iron, spongy iron yields nothing to water, and in this respect is preferable to any form of animal charcoal.

Sponge has a considerable effect in mechanically arresting suspended particles; it is apt to get foul, and being itself an organic substance ought not to be used. *Asbestos* is a much better material and can be easily reburnt.

The Chamberland-Pasteur is the best of all domestic filters. Its construction is very simple, for it merely consists of a cylinder of unglazed porcelain made from a well-baked kaolin of a certain degree of porosity and hardness, closed above and terminating below in an open nozzle. This cylinder is inclosed in a metal or glass jacket, a space intervening between the two above and at the sides, while below they are fixed together by a screw tap, with an opening in the centre for the passage of the nozzle. The outer cylinder is closed above except where it joins the water-pipe (fig. 2). The water passes through the porcelain from without inwards and under a pressure of from 1½ to 2½ atmospheres, such as is usually present in the pipes of a water service, at the rate of about three quarts per hour. These filters can be easily cleaned by brushing under a stream of hot water, and afterwards, if deemed desirable, by submitting them to the action of steam, or by heat applied direct from a spirit lamp or Bunsen burner. This filter acts mechanically, and is most efficacious in removing the finest suspended matters, and even micro-organisms are stopped by it. The Berkefeld filter is on the same principle as the Chamberland-Pasteur: it is made of infusorial earth, which is somewhat soft and friable and liable to fracture. This filter, however, possesses distinct sterilising action, inasmuch as it is capable of removing bacteria from samples of water and other impure liquids passed through it. Its action is practically similar to the Chamberland-Pasteur filters, but whether it possesses any superiority over them is doubtful. On the contrary the bougies are brittle and liable to fracture when moist, and further experimental proof is required to show whether or not the frequent cleansing of the filter by brushing will not wear away the bougie too rapidly; a contingency which we know in the case of the Chamberland-Pasteur filter does not exist.

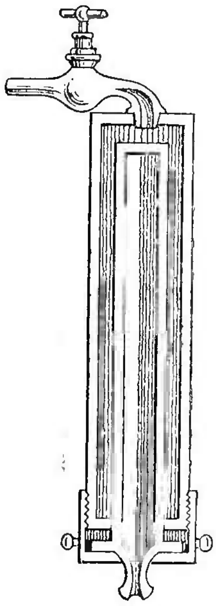


Fig. 2.

Summing up our present knowledge of this subject, we find that *Charcoal filters* are entirely inoperative: recent experiments prove that the bacilli from enteric and cholera cultures pass freely into the filtrate; *Spongy iron* permits the free passage of bacteria, filtration only removing about 40 per cent.; and that none of the more common filtering materials are capable of removing micro-organisms from water. The *Earthenware filters* on the Chamberland-Pasteur and Berkefeld principle give, in nearly every instance, a filtrate practically free from germs. The question, therefore, of the efficient filtration of water is a practical one which closely concerns the daily duties of every sanitary officer. In this connection, it is of the greatest importance that medical officers of health should thoroughly realise that the conversion of a suspicious into a wholesome water depends not upon the mere diminution of organic matter, chemically demonstrable as being present, but upon the removal of the actual sources of danger present in it, that is, micro-organisms. But the evidence is overwhelming that practically few filters, in common use, are long capable of efficiently removing bacteria and other micro-organisms from water. These defects, in this respect, may be and are commonly due to the following causes: (1) Imperfect fittings, particularly of taps and plugs; (2) the employment of a filtering material whose pores are initially too large to exert any specific influence in arresting micro-organisms; (3) structural imperfections in the filtering medium which have been induced during its use or purification by heat, such as cracks or faults in its substance; (4) the gradual growth of bacteria originally present in the water through the substance of the filter, so that they actually appear in the filtrate.

It is the duty, therefore, of every sanitary officer to critically examine every filter coming under his notice in respect of these possible sources of inefficiency. As the rapidity with which any particular filtering medium allows the growth of microbes through it depends upon (*a*) temperature, (*b*) original foulness of the water, (*c*) its quantity, depth, or thickness, (*d*) fineness of its pores, (*e*) pressure or head of water under which filtration proceeds, special attention needs to be directed to seeing that the filters in use do not present any of these conditions. Every medical officer should be in a position to test the efficiency of any filters he may be called upon to examine, by seeing whether they yield a filtrate which is free from micro-organisms. The application of this bacteriological test is the only adequate safeguard against the continued use of foul and dangerous filters.

Search after Water.—Occasionally a medical officer may be in a position in which he has to search for water. Few precise rules can be laid down.

On a plain, the depth at which water will be found will depend on the permeability of the soil and the depth at which hard rock or clay will hold up water. The plain should be well surveyed; and, if any part seems below the general level, a well should be sunk, or trials made with Norton's tube-wells (fig. 3). The part most covered with herbage is likely to have the water nearest the surface. On a dry sandy plain, morning mists or swarms of insects are said sometimes to mark

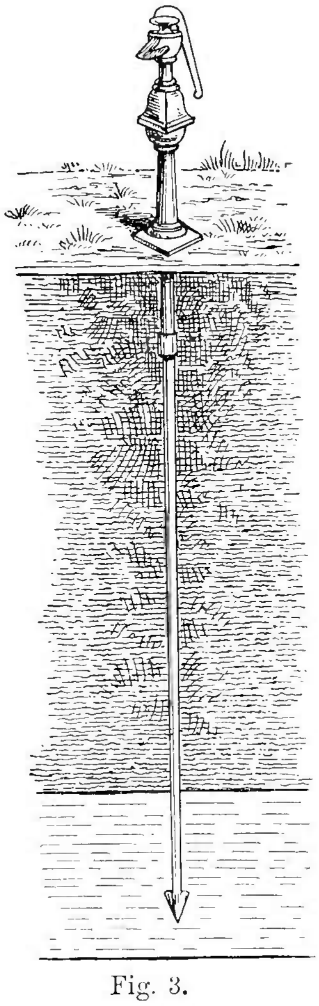


Fig. 3.

water below. Near the sea, water is generally found; even close to the sea it may be fresh, if a large body of fresh water flowing from higher ground holds back the salt water. But usually wells sunk near the sea are brackish; and it is necessary to sink several, passing farther and farther inland, till the point is reached where the fresh water has the predominance.

Among the hills the search for water is easier. The hills store up water, which runs off into plains at their feet. Wells should be sunk at the foot of hills, not on a spur, but, if possible, at the lowest point; and if there are any indications of a water-course, as near there as possible. In the valleys among hills the junction of two long valleys will, especially if there is any narrowing, generally give water. The outlet of the longest valleys should be chosen, and if there is any trace of the junction of two water-courses, the well should be sunk at their union. In a long valley with a contraction, water should be sought for on the mountain side of the contraction. In digging at the side of a valley, the side with the highest hill should be chosen.

Before commencing to dig, the country should be as carefully looked over as time and opportunity permit, and the dip of the strata made out if possible. A little search will sometimes show which is the direction of fall from high grounds or a watershed.

If moist ground only is reached, the insertion of a tube, pierced with holes, deep in the moist ground, will sometimes cause a good deal of water to be collected. The Norton tube-well gave satisfaction in Abyssinia, although it did not succeed so well in Ashantee. It was also used with some success in the Soudan, 1884. This pump will yield about 7 gallons per minute. A common pump will raise the water in it if the depth be not more than 24 or 26 feet; if deeper, a special force pump has to be used.

EXAMINATION OF WATER FOR HYGIENIC PURPOSES.

The analysis of water for hygienic purposes has for its object to ascertain whether the water contains any substances, either suspended or dissolved, which are likely to be hurtful. There are some substances which we know are not likely to do any harm, such as carbonate of sodium, calcium, and magnesium in small quantities. Others are at once viewed with suspicion as indicating an animal origin, and therefore being probably derived from habitations or resorts of men or animals, or from decaying bodies. In other cases, substances in themselves harmless, such as nitrates, nitrites, and ammonia, are suspicious from implying the coexistence of, or the previous contamination of the water by, nitrogenous substances.

In addition to these purely chemical bodies, all waters contain a greater or less number of micro-organisms. The greater number of these are absolutely innocuous, while some others may be the essential causative agents of disease. Unfortunately the chemical conditions of a water sample are not always indicative of the extent and nature of its contained bacteria; for, at times, a water may be found to be chemically free from organic pollution, and yet contain a sufficient number of pathogenic micro-organisms to give rise to distinct disease processes in those consuming it; on the other hand, a water sample may, from chemical evidence, be deemed organically impure, and yet, by virtue of not containing any but non-pathogenic micro-organisms, be incapable of disease production. The difficulties, therefore, in the hygienic examination of a water sample are not inconsiderable, and a judgment will be only correctly arrived at from a collation of all the evidence, rather than from the results of one or two tests. The purely chemical evidence must be considered, as a rule, in conjunction with the bacteriological; for while the former, by informing us of the amount of organic matter present in water, places in our hands evidence of its dangerous or suspicious nature, in that it is either open to sources of infective disease (microbes), or that the presence of organic matter may perhaps render the water a most suitable medium for the growth of pathogenic organisms, should these gain access to it, it is only the bacteriological evidence which can actually say whether these sources of danger are truly absent or not. This statement of the case must not be taken to imply that mere chemical data are valueless as a means of forming a hygienic opinion; on the contrary, they constitute in the majority of cases practically the only facts upon which an opinion can be based, as, in the present state of our knowledge, exact bacteriological examinations of water occupy days or weeks, while a chemical analysis is rapidly performed. As, in the greater number of instances, a definite opinion is wanted without delay, a chemical analysis is still an important procedure, though necessarily incomplete unless supported by a biological investigation.

The examination of water, for hygienic purposes, may be conveniently considered under the general headings of (1) its physical characters, (2) its qualitative chemical examination, (3) its quantitative chemical analysis, (4) the microscopical examination of its suspended matters, and (5) its bacteriological examination. Preliminary to these discussions may be considered the proper precautions to be taken with regard to collection of samples, while as a necessary corollary and conclusion to them will follow a statement as to the interpretation of results.

Collection of Samples.—Great care must be taken that a fair sample of the water is collected in perfectly clean glass vessels (not in earthenware jars)—Winchester quarts, which hold about half a gallon, and can be obtained of most chemists, are most convenient; they should be repeatedly washed out with some of the water to be examined. In taking water from a stream or lake, the bottle ought to be plunged below the surface before it is filled. In drawing from a pipe a portion ought to be allowed to run away first, to get rid of any impurity in the pipe. In judging of a town supply, samples should be obtained direct from the mains, as well as from the houses. The bottle should be stoppered; a cork should be avoided, except in great emergency, but if used it should be quite new, well tied down, and sealed. No luting of any kind (such as linseed meal and the like) should be used.

For a complete sanitary investigation half a gallon is necessary, but with a litre or a couple of pints a pretty good examination can be made if more cannot be obtained. If a detailed mineral analysis is required (which will only be seldom) a gallon ought to be provided. It is always advisable to have a good supply in case of breakage or accident; two Winchester quarts of each sample will generally be found sufficient. The examination ought to be undertaken immediately after collection, if possible. If this cannot be done, then as short a time as may be should be allowed to elapse, for changes in the most important constituents take place with great rapidity. Pending examination, it ought to be kept in a dark cool place.

The fullest information ought always to be furnished with the sample, the following being the most important particulars:—

(*a*) Source of the water, viz., from tanks or cisterns, main or house pipe, spring, river, stream, lake, or well.

(*b*) Position of source, strata so far as they are known.

(*c*) If a well; depth, diameter, strata through which sunk, whether imperviously steined in the upper part, and how far down. Total depth of well and depth of water to be both given. If the well be open, furnished with cover, or with a pump attached.

(*d*) Possibility of impurities reaching the water: distance of well from cesspools, drains, middens, manure heaps, stables, &c.; if drains or sewers discharge into streams or lakes; proximity of cultivated land.

(*e*) If a surface-water or rain-water, nature of collecting surface and conditions of storage.

(*f*) Meteorological conditions, with reference to recent drought or excessive rainfall.

(*g*) A statement of the existence of any disease supposed to be connected with the water-supply, or any other special reason for requiring analysis.

Any further information that can be obtained will always be useful. Each bottle should also be distinctly labelled, so as to correspond with the official letter or invoice.

When it is possible, it is most desirable that the medical officer or analyst should visit the locality itself whence the water is obtained; in this way he may obtain information which might otherwise escape him. If the analysis can be made immediately on the spot, it will be all the more valuable.

Physical Examination.—This will have reference to the following points, and affords, at times, valuable preliminary information as to any given sample.

Colour.—This may be judged of by allowing any sediment to settle, and then pouring off the supernatant water into a tall glass placed upon a piece of white paper. Or a horizontal tube of colourless glass with glass ends may be used. The stratum should be of sufficient thickness, if possible *two* or *three* feet, but a fair idea of the colour may be obtained with 18 inches or even a foot. The Society of Public Analysts recommends 24 inches. If a tube be used, it may either be half full, and the tint compared with the colour of the air in the upper half when directed against a well illuminated white surface; or, better still, it may be filled, and the comparison made with a second tube placed alongside, containing pure distilled water. Perfectly pure water has a bluish tint, but most ordinary waters have either a greyish, greenish, yellow, or brown appearance. The best samples are those coloured bluish or greyish. Green waters owe their colour to vegetable matter, chiefly unicellular *algæ*, and are usually harmless. Yellow or brown waters are most to be feared, as their colour is often due to animal organic matter, chiefly sewage. It is sometimes, however, owing to vegetable matter, such as peat, and under these circumstances it is not generally hurtful. It may also be caused by salts of iron, although in most cases the iron is precipitated as ferric oxide in the sediment.

Clearness.—The presence or absence of turbidity may be judged of in the same way as the colour, only the water should be shaken up, so as to distribute the suspended matter and simulate its condition when drawn. The depth necessary to obscure printed matter may be used as a measure. Occasionally water remains hazy or turbid even after standing for some time; in such a case the suspended matter is in very fine division, such as is sometimes found with sulphate of calcium, minute scales of mica, &c.

Sediment.—The nature of the sediment may be roughly judged of by the eye, as to whether it is mineral or vegetable, or stained with iron or the like. The larger living forms, such as *Anguillulæ*, water-fleas, leeches, &c., may also be detected. But the only satisfactory examination is to be made with the microscope.

Lustre.—The lustre or brilliancy (*éclat*) has been recommended as a good physical indication of the amount of aëration (Gérardin). The different degrees may be noted in any convenient way, such as *nil*, *dull*, *vitreous*, *adamantine*, which is an ascending scale from zero to the maximum brightness.

Taste.—Taste is an uncertain indication. Any badly tasting water should be rejected or purified before use. Suspended animal organic matters often give a peculiar taste, so also vegetable matters in stagnant waters. Some growing plants, as *lemna* and *pistia*, give a bitter taste; but most growing plants have no taste. Dissolved animal matter is frequently quite tasteless. As regards dissolved mineral matters, taste is of little use, and differs much in different persons. On an average—

				Grains per gallon.	Parts per 100,000.
Sodium	chloride	is tasted	when it reaches	75	107
Potassium	,,	,,	,,	20	29
Magnesium	,,	,,	,,	50 to 55	71 to 79
Calcium	sulphate	,,	,,	25 to 30	36 to 43
,,	carbonate	,,	,,	10 to 12	14 to 17
,,	nitrate	,,	,,	15 to 20	21 to 29
Sodium	carbonate	,,	,,	60 to 65	86 to 93
Iron	,,	,,	,,	0·2	0·28

Iron is thus the only substance which can be tasted in very small quantities. A permanently hard water has sometimes a peculiar *fade*, or slightly saline taste, if the total salts amount to 35 or 40 grains per gallon (50 to 57 parts per 100,000), and the calcium sulphate amounts to 6 or 8 grains (8·6 to 11·4 per 100,000). The taste of good drinking water is due entirely to the gases dissolved; water nearly free from carbonic acid hardness, such as distilled water, is not so pleasant as the brisk, well-carbonated waters; it may be called flat, but it is difficult to define the kind of taste or absence of it.

Smell.—The water may be warmed or distilled, when the odour of fæcal matter is often brought out clearly both in the distillate and residue. If the water is put in a stoppered bottle, which it half fills, and is exposed to light, and then opened and smelt after a few days, commencing putrefaction, or the formation of butyric acid, or something similar, can sometimes be detected. Tiemann recommends that the water should be heated to 110° or 120° F. (42° to 49° C.); if hydrogen sulphide be present, add a little copper sulphate, which precipitates it, and permits any putrid smell to be perceived.

The Society of Public Analysts recommends heating the water in a wide-mouthed stoppered bottle to 100° F. (38° C.). This may be done by immersing it in warm water. Any particular smell should be recorded, if distinctly recognised,—with its degree of intensity, such as *nil*, *very slight*, *slight*, *marked*, &c., as the case may be. Sometimes an offensive smell is detected on *boiling*, which is not otherwise perceived.

Although the *physical characters* give only an imperfect idea of the value of a water, they are yet important when no further examination can be made. If a water be colourless, clear, free from suspended matter, of a brilliant (or adamantine) lustre, devoid of smell or taste, except such as is recognised to be the characteristic of good potable water, we shall in the large majority of cases be justified in pronouncing it a good and wholesome water; whilst, according as it deviates from these characters, we shall be proportionately justified in regarding it with suspicion. Suspended matter is probably the most dangerous, and, when in the form of disease-causing micro-organisms, exists without revealing itself by any visible turbidity, or even to any ordinary microscopic examination. Bacteria can only be detected by biological examination: nor must we shut our eyes to the possibility of hurtful dissolved substances, so that when our opinion of a water is based only on its physical characters, the fact ought to be duly recorded.

Qualitative Chemical Examination of Water.—The sample may be either at once treated, or, in the case of some constituents, a portion of it should be concentrated by evaporation.

Water not Concentrated.

Substance sought for.	Reagents to be used, and effects.	Remarks.
Reaction.	*Litmus* and *turmeric* papers; usual red or brown reactions.	Usually neutral. If acid, and acidity disappears on boiling, it is due to carbonic acid. If alkaline, and alkalinity disappears on boiling, to ammonia (rare). If permanently alkaline, to sodium carbonate.
Lime.	*Oxalate of Ammonium.* White precipitate.	Six grains per gallon (9 per 100,000) give turbidity; sixteen grains (23 per 100,000) considerable precipitate.
Chlorine.	*Nitrate of Silver* and *dilute nitric acid.* White precipitate, becoming lead colour.	One grain per gallon (1·4 per 100,000) gives a haze; four grains per gallon (6 per 100,000) give a marked turbidity; ten grains (14 per 100,000) a considerable precipitate.
Sulphuric Acid.	*Chloride of Barium* and *dilute hydrochloric acid.* White precipitate.	One-and-half grain (2 per 100,000) of sulphate give no precipitate until after standing; three grains (4 per 100,000) give an immediate haze, and, after a time, a slight precipitate.
Nitric Acid.	*Brucine* solution and *pure sulphuric acid.* A pink and yellow zone.	The sulphuric acid should be poured gently down to form a layer under the mixed water and brucine solution; half a grain of nitric acid per gallon (=0·7 per 100,000) gives a marked pink and yellow zone; or, as recommended by Nicholson, 2 c.c. of the water may be evaporated to dryness; a drop of pure sulphuric acid and a minute crystal of brucine be dropped in; 0·01 grain per gallon (=0·0143 per 100,000) can be easily detected.
Nitrous Acid.	*Iodide of Potassium* and *starch* in solution and *dilute sulphuric acid.* An immediate blue colour.	Add the solution of iodide of potassium and starch, and then the acid; the blue colour should be immediate; make a comparative experiment with distilled water.
	Solution of *meta-phenylene-diamine* and dilute *sulphuric acid* (Griess's test)—a yellow colour more or less immediate according to amount of nitrous acid.	This is a very delicate test; a yellow colour will appear in the water in half an hour, if there be only one part of nitrous acid in 10,000,000 of water.

Water not Concentrated—continued.

Substance sought for.	Reagents to be used, and effects.	Remarks.
Ammonia.	*Nessler's* solution. A yellow colour or a yellow-brown precipitate.	If in small quantity, several inches in depth of water should be looked down through on a white ground.
Iron.	*Red* and *yellow prussiates of potash* and *dilute HCl.* Blue colour.	The red for ferrous and the yellow for ferric salts.
Hydrogen Sulphide.	A salt of *lead.* Black precipitate.	When the water is heated the smell of hydrogen sulphide may be perceptible.
Oxidisable matter, including organic matter.	*Gold chloride.* Colour varying from rose-pink through violet to olive; a dark violet to black precipitate.	The water, which should be neutral or feebly acid, must be boiled for 20 minutes with the gold chloride. If no nitrous acid be present, the reaction may generally be considered due to organic matter.
Oxidisable matter including organic matter.	Note the darkening of the *silver chloride* in testing for chlorine.	Compare with a precipitate produced in a pure solution of a chloride.
Lead or copper.	*Ammonium sulphide.* Dark colour, not cleared up by hydrochloric acid.	Place some water (100 c.c.) in a white dish, and stir up with a rod dipped in ammonium sulphide; wait till colour produced, then add a drop or two of hydrochloric acid. If the colour disappears, it is due to iron; if not, to lead or copper.
Lead.	Small crystals of *potassium bichromate* give a turbidity.	One-tenth grain per gallon gives an immediate turbidity; one-twentieth grain per gallon after one minute; one-fiftieth grain per gallon after half an hour.
Zinc.	Render water slightly ammoniacal; boil; filter; a few drops of *potassium ferrocyanide* give a haze to white precipitate. *Hydrogen sulphide* gives a white precipitate.	The filtrate must be quite clear before the ferrocyanide is added. This reaction is not available if iron be present or if the water be acid or alkaline.

Water Concentrated to $\frac{1}{50}$th (in a porcelain dish).

Substance sought for.	Reagents to be used, and effects.	Remarks.
Magnesia.	*Oxalate of ammonium* to precipitate lime, then after filtration a few drops of *phosphate of sodium*, of *chloride of ammonium*, and of *liq. ammoniæ.* A crystalline precipitate in 24 hours.	A precipitate forms in 24 hours, and is the triple phosphate either in the shape of prisms or in feathery crystals.

Water Concentrated to $\frac{1}{50}$th (in a porcelain dish)—continued.

Substance sought for.	Reagents to be used, and effects.	Remarks.
Phosphoric Acid.	*Molybdate of ammonium* and *dilute nitric acid.* A well marked yellow colour, and on standing a precipitate.	Add the nitric acid, and stir with a glass rod, then add twice the quantity of molybdate and boil.
Nitric Acid.	*Brucine* test.	If the nitric acid is in small quantity, it may not be detected in the unconcentrated water.
Silicic Acid.	Evaporate to dryness, moisten with *strong hydrochloric acid;* after standing, add boiling distilled water; pour off fluid; dry, ignite; repeat the treatment with hydrochloric acid and water; dry, ignite again, and the residue is silica, or silicate of aluminum.	The residue may be weighed, and thus the silica determined quantitatively. A little clay or oxide of iron will be sometimes mixed with it.
Lead or copper.	As before.	If quantity be very small.
Arsenic.	*Marsh's* or *Reinsch's* tests.	Water should be rendered alkaline with *sodium carbonate* before concentration, then acidulated with *hydrochloric acid.*
Zinc.	Evaporate to dryness; treat residue with *caustic potash* or *ammonia*, filter and test filtrate with *hydrogen sulphide;* a white precipitate falls.	This is necessary if the quantity be small, or if iron be present.

In the preceding qualitative tests, all the reagents may be deemed to be saturated solutions, except the dilute acids, Nessler's reagent, brucine and gold chloride solutions, iodide of potassium and starch solution and the meta-phenylenediamine solution.

The dilute acids are best prepared by adding 1 part of strong acid to 9 of distilled water.

The Nessler's reagent will be more fully explained later on (page 69).

The brucine and gold chloride solutions are made by dissolving 1 gramme of each respectively in 1 litre of distilled water.

The potassic iodide and starch solution is made by boiling 20 grammes of starch intimately mixed with half a litre of distilled water, filtering when cold, and adding 1 gramme of potassium iodide.

The meta-phenylenediamine solution is described on page 73.

Inferences from the Qualitative Tests.—Sometimes no time can be given for quantitative determinations, and the qualitative tests are the only means available by which the questions so constantly put, whether a water is wholesome or not, can be in some degree answered.

If chlorine be present in considerable quantity, it either comes from strata containing chloride of sodium or calcium, from impregnation with sea-water, or from admixture of liquid excreta of men and animals. In the first case the water is often also alkaline, from sodium carbonate; there is an absence, or nearly so, of oxidised organic matters, as indicated by nitric and nitrous acids and ammonia, and of organic matter; there is often much sulphuric acid. These characters are common in deep-well waters. If it be from calcium chloride, there is a large precipitate with ammonium oxalate after boiling. If the chlorine be from impregnation with sea-water, it is often in very large quantity; there is much magnesia, and little evidence of oxidised products from organic matters. If from sewage, the chlorine is marked, and there is coincident evidence of nitric and nitrous acids and ammonia, and sometimes phosphoric acid; and if the contamination be recent, of oxidisable organic matters. A stream fouled by animals or excreta may thus show at different times of the same day different amounts of chlorine, and this, in the absence of rain, will indicate contamination.

Ammonia is almost always present in very small quantity, but if it be in large enough amount to be detected without distillation it is suspicious. If nitrates, &c., be also present, it is likely to be from animal substances, excreta, &c. Nitrates and nitrites indicate previously existing organic matters, probably animal, such as excreta, remains of animals, &c.; but nitrates may also arise from vegetable matter, although this is probably less usual. If nitrites largely exist, it is generally supposed that the contamination is recent. The coincidence of easily oxidised organic matters, of ammonia, and of chlorine in some quantity would be in favour of an animal origin. If a water gives the test of nitric acid, but not nitrous acid, and very little ammonia, either potassium, sodium, or calcium nitrate is present, derived from soil impregnated with animal substances at some anterior date. If nitrites are present at first, and after a few days disappear, this arises from continued oxidation into nitrates; if nitrates disappear, it seems probable this is caused by the action of *bacteria*, or other low forms of life. Sometimes in such a case nitrites may be formed from the nitrates. Phosphoric acid, if in any marked quantity, indicates origin from phosphoric strata (which is uncommon) or sewage impregnation. Wanklyn has ridiculed the idea of phosphoric acid being present in any appreciable quantity in water, if (as is almost always the case) lime be also present. But independent of the fact that the reaction of phosphoric acid is obtained in water, Hehner has clearly shown that phosphoric acid does exist in appreciable quantity as phosphates, especially in polluted waters. Lime in large quantity indicates calcium carbonate if boiling removes the lime; sulphate, chloride, or nitrate if boiling has little effect. Testing for calcium carbonate is important in connection with purification with alum. Sulphuric acid in large quantity, with little lime, indicates sulphate of sodium, and usually much chloride and carbonate of sodium are also present, and on evaporation the water is alkaline. Large evidence of nitric acid, with little evidence of organic matter, indicates old contamination; if the organic matter be large, and especially if there be nitrous acid as well as nitric present, the impregnation is recent. It may also indicate the absence of the nitrifying ferment from the water.

To the above qualitative tests would, of course, be added the physical characters, which would to some considerable extent influence the conclusions to be drawn. When possible, the microscopic appearances ought also to be carefully noted, as the presence of such substances as epithelium, house refuse, &c., will sometimes justify us in condemning a water which may appear chemically only suspicious.

A water containing in appreciable quantity any metal (except iron), other than the alkaline and earthy metals, is to be condemned.

A water containing any gas other than oxygen, nitrogen, or CO_2, is to be considered suspicious, and not to be used without boiling or filtration, or both.

The Quantitative Analysis of Water.—The discrepancies which are sometimes found in the consecutive analyses, or in analyses by two observers of the same water, probably often arise from the difficulty of always separating the suspended matters. Consequently two samples, apparently similar, may in reality contain variable quantities of suspended matters, which affect the determination of the solids, or influence other tests.

To avoid this source of fallacy, if the water be sedimentous, the portion to be examined for solids should be placed in a well-stoppered bottle in a dark place for twenty-four or forty-eight hours, until all sediment has subsided, and the clear water should be then siphoned off. If the sediment is too fine to subside, the water must be filtered through paper (previously well washed with weak hydrochloric acid, and then with distilled water, and then dried), but if possible filtration should be avoided.

Of the solids in water some are mineral, and derived from the mineral constituents of the soil, such as lime, magnesia, and part of the chlorine, and of the sulphuric, carbonic, and silicic acids; others are also inorganic, but are derived from the remains of animals or vegetables, by oxidation or solution, or from the atmosphere, such as ammonia, nitric acid, nitrous acid, some of the chlorine, and of the sulphuric and phosphoric acids. Other constituents, derived from numerous sources, are vegetable or animal matters, which are usually unstable, and are undergoing disintegration and oxidation. They may be nitrogenous or not. The composition of these substances is doubtless extremely various; the determination of the total quantity is difficult; the separation of the different kinds from each other, at present, impossible.

The methods by which the quantity of this organic matter (to use its familiar name) can be expressed have been lately much debated, and even now there is no general agreement; nor, at present, is there any plan by which dissolved vegetable may be distinguished from animal matter, except by reference to the microscopic characters of the sediment, to the source of the water, and the coincident inorganic substances.

The quantitative processes which appear, in a hygienic sense, to be most useful, are the determinations of the total and volatile solids, the chlorine, the nitrogen in ammonium compounds and in organic matter, the nitrogen as nitrates, and nitrites, the oxygen consuming power, the phosphates, the dissolved oxygen and carbonic acid, the total and fixed hardness and the poisonous metals.

The Principles of Volumetric Analysis.—The main principle upon which volumetric quantitative analysis depends is, that in order to convert a compound *a*, existing in solution, into some other *b*, there is required a quantity of reagent *c* proportional to the quantity of *a*. If, therefore, we know *c*, as well as its strength, we can calculate *a*; in other words, a volumetric quantitative analysis is the submission of the substance, to be estimated to certain characteristic reactions, employing for such reactions solutions of known strength; and, from the volume of solution necessary for the production of the reaction, determining the weight of the substance to be estimated, by the application of the known laws of chemical equivalence. The process of adding the reagent from a graduated measure is called *titration*.

For the accurate performance of titration, the following conditions must be fulfilled:—

1. The substance under examination must exist in clear solution in a liquid miscible with the liquid reagent: for this purpose aqueous solutions are the best.
2. The operator must thoroughly understand the relationship between measures of weight and volume.
3. The apparatus employed must be accurately graduated.
4. The titrating reagent must be a solution of known strength, that is, a so-called standard solution.
5. We need a special reagent (indicator) in order to ascertain when sufficient quantity of the standard solution c has been added to effect the required reaction, or the complete transformation of a into b.

To carry out any quantitative analysis, the first essential is the thorough comprehension of the simple relationship between liquids and solids. In the following pages of this work, owing to its uniformity and simplicity in all analytical methods, the metric system of weights and measures will, as far as possible, be employed. Although tables of the various metric weights and measures are given in the *Appendix*, it may not be out of place here to emphasise the fact that a cube of distilled water, at its temperature of greatest density, namely at 4° C. or 39°·2 F., whose side measures 1 decimetre, has exactly the weight of 1 kilogramme, or 1000 grammes, and occupies the volume of 1 litre or 1000 cubic centimetres. In other words, 1 cubic centimetre, as a measure of volume, equals or corresponds to 1 gramme as a measure of weight, and that:—

x	Grammes	of a substance	dissolved in	10	cubic centimetres	of water are		x	parts in	10
x	,,	,,	,,	100	,,		,,	x	,,	100
x	,,		,,	1000	,,	,,	(1 litre)	x	,,	1,000
x	Decigrammes	,,	,,	,,	,,	,,	,,	x	,,	10,000
x	Centigrammes	,,	,,	,,			,,	x	,,	100,000
x	Milligrammes	,,	,,	,,	,,	,,	,,	x	,,	1,000,000
x	,,	,,	,,	100	,,	,,	of water	x	,,	100,000
x	,,	,,	,,	10	,,	,,		x		10,000
x	,,	,,	,,		,,	,,	,,	x	,,	1,000

It is most usual in this country and on the Continent to express the results of a quantitative analysis of water as parts per 100,000, or centigrammes per litre, or milligrammes per 100 cubic centimetres. Some analysts express their results as parts per million, or milligrammes per litre. The statement of a ratio in parts per 100,000 will be adopted in the following analytical processes, while, for the sake of brevity, the term "cubic centimetre" will be written as c.c.

Occasionally, the expression "grains per gallon" is met with in English analysis. This is equivalent to parts per 70,000, as one gallon of water at 39°·2 F. or 4° C. weighs 10 lb., or 70,000 grains. The conversion of parts per 100,000 to grains per gallon is, of course, readily performed by multiplying by seven-tenths, or by 0·7, and from grains per gallon to parts per 100,000 by multiplying by 10 and dividing by 7.

The apparatus specially needed for making an ordinary quantitative analysis of water includes:—

A pair of balances and weights, according to the metric system. In these sets of weights, the larger ones represent grammes, the next in size decigrammes, and the next centigrammes. Small forceps are used for picking up and applying these weights to the pans of the balance. The milligrammes are added by shifting a little piece of bent wire along the cross-beam of the balance, which has on it ten markings, numbered from 1 to 10, on either side of the pivot.

A platinum dish, capable of holding 200 c.c. of water.

One or more shallow *porcelain evaporating dishes*, capable of holding 300 c.c.

A small *porcelain crucible*, with lid, for igniting residues.

A pestle and mortar, for powdering reagents previous to solution.

One or more *retorts*, or boiling flasks.

A Graham's, or Liebig's *condenser*.

Six *Nessler glasses*, each capable of holding 150 c.c.

Glass *stirring-rods*.

Two glass-stoppered bottles, capable of holding 250 c.c.

Glass *funnels* for filtering.

A packet of Swedish *filter papers*.

A dozen *test tubes*, with stand, cleaner, and holder.

A *measuring flask*, to hold at least 1 litre and graduated in c.c.

Glass *burettes*, or graduated tubes, holding 20 c.c., and graduated in c.c. and tenths of a c.c. One of these should be mounted on a wooden stand, and be provided with a stopper at the top, and fitted with a stop-cock at the bottom.

A glass *pipette*, graduated to deliver 10, 20, 50, or 100 c.c.

An iron tripod.

One or more triangles of iron wire, covered with pipe clay.

A pair of small crucible tongs.

A long thermometer, graduated in either Centigrade or Fahrenheit degrees.

The "Standard Solutions" required in a volumetric quantitative analysis are solutions of definite strength, made by dissolving a given weight of a reagent, in grammes, in a definite volume of distilled water in cubic centimetres (or in grains or fluid grains). These solutions are usually made by dissolving either a molecular weight of a reagent in grammes, or some decimal part of such weight in 1000 c.c. (1 litre) of distilled water. The following abbreviations are often used to express the strength of standard solutions:—

N = a normal solution having 1 molecular weight in grammes per litre.
$\frac{N}{2}$ = a semi-normal ,, $\frac{1}{2}$,, ,, ,, ,,
$\frac{N}{10}$ = a deci-normal ,, $\frac{1}{10}$,, ,, ,, ,,
$\frac{N}{20}$ = a viginti-normal ,, $\frac{1}{20}$,, ,, ,, ,,
$\frac{N}{100}$ = a centi-normal ,, $\frac{1}{100}$,, ,, ,, ,,
$\frac{N}{1000}$ = a milli-normal ,, $\frac{1}{1000}$,, ,, ,, ,,

Occasionally, in making standard solutions the equivalent hydrogen weight, or molecular weight of a reagent, cannot be taken, but its particular weight in a particular reaction in a given analysis has to be regarded. For instance, when using a solution of potassic permanganate, as an oxidising agent, having the chemical formula $KMnO_4$, and the molecular weight of 158, and yielding five volumes of oxygen in a particular reaction, its normal solution is made by dissolving one-fifth of its molecular weight, $\frac{158}{5}$, or 31·6 grammes, in a litre of water. In other instances, when the equivalent or combining weights of a substance are not identical with the atomic or molecular weights, the amounts taken are those of their equivalent weights. Thus oxalic acid, $C_2H_2O_4.2H_2O$, with an atomic weight of 126, is a bivalent substance, and its equivalent weight is one-half of its atomic weight; consequently, a normal solution of oxalic acid would be made by dissolving 63 grammes of the crystallised acid in 1 litre of distilled water. Similarly, phosphoric acid, which is a trivalent substance, would require, for the preparation of a normal solution of sodic phosphate, $Na_2HPO_4 12H_2O$, one-third of its molecular weight $\frac{358}{3}$, or 119·3 grammes, being dissolved in 1 litre of distilled water.

In some other cases, standard solutions cannot be prepared directly, because the substance to be dissolved cannot be obtained sufficiently pure to make an accurate solution. Hence we must have recourse to an indirect method. Thus, if it were wanted to make a solution of potash-lye, containing 56 grammes of potassium hydroxide to the litre, we could not make it by simply weighing out 56 grammes of potassium hydroxide and dissolving it in a litre of water, because the alkali can never be procured absolutely pure. But if, say, 65 grammes be dissolved and slowly diluted down until 10 c.c. exactly neutralise 10 c.c. of an oxalic acid solution made by dissolving 63 grammes of $C_2H_2O_4.2H_2O$ in a litre, we then get a solution of the potassium hydroxide of the strength of 56 grammes per litre, because from their molecular weights we know 63 grammes oxalic acid exactly neutralise 56 grammes of potassium hydroxide.

An "indicator" is a substance added to enable us to ascertain by a change of colour, or other equally marked effect, the exact point at which a given reaction is complete. The chief indicators employed are as follows:—

(*a*) *Solution of litmus*, which turns red with acids and blue with alkalies. This solution needs to be made from the best litmus, by boiling in water for eight minutes, then neutralising the alkaline carbonate which it usually contains with HCl, until the wine-red colour remains even on further boiling. The solution is then cooled and an equal volume of strong alcohol added. The stock solution should be kept in a bottle with a delivery pipette inserted through the cork.

(*b*) *Alcoholic solution of phenol-phthalein*, made by dissolving 5 grammes, with the aid of 25 c.c. of spirit of wine, in 500 c.c. of distilled water. This solution is colourless with acids, but becomes red with alkalies.

(*c*) *Starch mucilage*, which turns blue in the presence of free iodine.

(*d*) *Saturated solution of potassium chromate*, which gives a red colour with nitrate of silver, but not until all the halogen present has entirely combined with the silver.

(*e*) *Saturated solution of potassium ferricyanide*, which ceases to give a blue colour when any iron present has been fully raised to the ferric state.

Determination of the Dissolved Solids.—The remark already made about suspended matters must be attended to; if possible, obtain a clear water by subsidence rather than by filtering through paper. The solids are determined by evaporation, and are generally spoken of as the total, fixed, and volatile solids.

Total Solids.—If very good balances are available, 200 c.c. of the water are sufficient, if the balances are inferior, 500 or 1000 c.c. of the water sample must be taken, then evaporate to dryness with a moderate heat, taking care that the water does not boil, else there may be loss from spurting. If the smaller quantity be taken, the whole evaporation may be conducted in one vessel (of platinum, if possible); but if the larger amount must be used the evaporation should be commenced in a large evaporating dish, and the concentrated water and deposit, if any, transferred into a small weighed crucible. The transference demands great care, so that none of the solids shall remain encrusted in the evaporating dish. All the contents of the large dish being transferred, evaporate to complete dryness in air, water, or steam bath, at 212° F. (100° C.). Weigh as soon as the crucible is cold, as the dried mass may be hygroscopic. It may be necessary to replace it in the bath and weigh again after an interval of half an hour. If there is no material difference the drying is completed.

Wanklyn advises a very simple form of steam bath. A common two-gallon tin can is taken, a perforated cork fitted in the mouth, and a funnel passed through the perforation; the crucible is placed in the funnel, a little roll of paper being placed between the funnel and crucible to let the steam pass. Water is boiled in the tin can.

The determination of the total solids is an important point, and should be carefully done. It gives a control over the other quantitative determinations, and if erroneous may make the other conclusions wrong.

Fixed Solids.—Incinerate the dried solids at as low a heat as possible; watch the process, and note if there be much blackening, or if any fumes can be seen, or any smell be perceived as of burnt horn. A piece of filtering paper dipped in solution of potassium iodide and starch, and then dried, or a piece of ozone paper, should be held over the crucible to detect any nitric oxide which may be given off.

Volatile Solids.—The loss on ignition may be stated as "volatile substances." It consists of destructible organic matters, nitrates, nitrites, ammoniacal salts, combined water, combined carbonic acid, and sometimes chlorides. The variableness of the composition of the "volatile substances" has led to the disuse of the process by ignition as too uncertain. Combined with other evidence it gives, however, some useful indications. The incinerated solids may be examined for silica and iron, as hereafter noted.

The combined CO_2 can be partly restored after incineration by adding a few drops of a saturated solution of carbonate of ammonia, then drying and driving off the excess of ammonia.

Example.—1. *Total solids.*—200 c.c. dried as described :—

Weight of dish and residue,	19·27 grammes.
,, of dish alone	19·23
Difference, being grammes of total solids in 200 c.c. of water.	0·04

To bring to centigrammes per litre, or parts per 100,000 :

0·04 × 500 = 20 = centigrammes per litre, or parts per 100,000.

To bring to grains per gallon :

20 × 0·7 = 14·0 grains per gallon.

2. *Fixed solids.*—The above residue is incinerated, and the CO_2 restored to the earthy carbonates if required.

Weight of incinerated residue and dish,	19·26
,, of dish alone,	19·23
Difference, . . . being grammes of fixed solids in 200 c.c. of water.	0·03

0·03 × 500 = 15 parts per 100,000.
15 × 0·7 = 10·5 grains per gallon.

3. *Volatile solids* :—		Parts per 100,000.	Grains per gallon.
Total solids,	=	20·0	14·0
Fixed ,,	=	15·0	10·5
Difference, being volatile solids,		5·0	3·5

The amounts of total solids in ordinary water samples vary from 3 or 4 to 50 or 60 parts per 100,000. Of these not more than 1·5 per 100,000 should be volatile or lost on ignition.

Determination of the Chlorine.—For this purpose two solutions are required.

(1) *A solution of Potassium Monochromate*, made by dissolving 50 grammes of the salt in a litre of distilled water. Nitrate of silver is added until a permanent red precipitate is formed, which is allowed to settle and the clear liquid decanted off.

(2) *A deci-normal standard solution of Silver Nitrate*, made by dissolving 17 grammes of $AgNO_3$ (molecular weight being 170) in a litre of distilled water. This will be equivalent to one-tenth of the atomic weight of chlorine (35·5) or 3·55 grammes of chlorine and 1 c.c. of this solution will equal 3·55 mgms. of chlorine.

The process consists in taking 250 c.c. of the water sample, placing them in a white porcelain dish, and rendering them of a distinct yellow colour by means of two or more drops of the potassium chromate solution. From a burette, run in drop by drop some of the $\frac{N}{10}$ silver nitrate solution, stirring after each addition. The red silver chromate which is at first formed will disappear as long as any chlorine is present. Stop directly the least red tint is permanent. As each c.c. of the silver solution equals 3·55 mgms. of chlorine, the number of c.c. used indicates the mgms. of chlorine in 250 c.c. of the water, that is, parts per 250,000, and that divided by 2·5 or multiplied by 0·4 will give parts of chlorine per 100,000.

Example.—In 250 c.c. of water, rendered yellow with potassium chromate, 1·5 c.c. of silver solution gave a permanent red tint; then—

$$\frac{1{\cdot}5 \times 3{\cdot}55}{2{\cdot}5} = 2{\cdot}13 \text{ parts of chlorine per 100,000.}$$

The purest water, as a rule, contains less than 1·5 parts of chlorine per 100,000. An increase may be due to sea-water, percolation through salt bearing strata, to sewage, or other impurities. Some deep wells often contain large quantities of chlorides; but generally an excessive presence of chlorine is a reason for suspicion unless a satisfactory explanation of its presence is obtainable.

Determination of the Hardness.—Clark's very useful soap test offers a ready mode of determining this in a manner quite sufficient for hygienic and economic purposes. Soap is an alkaline oleate, resulting from the combination of an alkali with one or more of the fatty acids, *i.e.*, oleic, stearic, or palmitic acids. When an alkaline oleate is mixed with pure water, a lather is given almost immediately; but if lime, magnesia, iron, baryta, alumina, or other substances of this kind be present, oleates of these bases are formed, and no lather is given until the earthy bases are thrown down or used up. The hardness of a water depends upon the presence in it of more or less of these earthy bases, and the more they are present the greater will be the expenditure of soap to make a lather. Free carbonic acid has a similar effect. The soap combines in equivalent proportions with these bases, so that if the soap solution be graduated by a solution of known strength of any kind, it will be of equivalent strength for corresponding solutions of other bases. There are, however, one or two points which render the method less certain. One of these is that, in the case of magnesia, there is a tendency to form double salts, so that the determination of magnesia is never so accurate as in the cases of lime or baryta. Carbonic acid appears to unite in equivalent proportions when it is passed through the soap solution; but if it be diffused in water, and then shaken up with the soap solution, two equivalents of the acid unite with one of soap.

A certain amount of the hardness of a water is removed by boiling, hence it is usual to speak of the hardness present before boiling as total hardness, that remaining after boiling as fixed or permanent hardness, and that which has been dissipated by the boiling as the temporary hardness.

The total hardness in most drinking waters is caused by salts of calcium and magnesium with some free carbonic acid. Hence waters from the chalk, oolite, limestone, dolomite, and new red sandstone are apt to furnish the greatest degrees of hardness. Rain-water, being free from these salts, is usually very soft. Many of the salts contributing to the total hardness are held in solution by carbonic acid, which when the water is boiled is dissipated, causing these salts to fall to the bottom or form incrustations on the sides of the containing vessel as insoluble salts. The chief of these are carbonates and sulphates of lime and magnesium with salts of silica, alumina, and iron when these are present.

The permanent hardness, or what still remains in solution, consists mainly of some sulphates, chlorides, and nitrates of calcium and magnesium, with a little iron and alumina.

The amount of hardness is, for convenience, usually expressed either in degrees of the metrical scale (parts per 100,000) or in grains per gallon of calcium carbonate, each grain representing 1 degree of hardness on the scale proposed by Clark. Of course it is understood that the hardness depends on various constituents, but in England is equivalent to so much calcium carbonate. In France, the hardness is also expressed as calcium carbonate, but only on the metrical scale, that is, in parts per 100,000. In Germany, the hardness is always expressed as so much lime, CaO, per 100,000. In cases of comparative analysis, therefore, 1 metrical French or English degree of hardness equals 0·56 German degree, and 1 degree of hardness on Clark's scale equals 0·39 German degree and 0·7 French or English metrical degree.

The Soap solution for the estimation of hardness is best made by thoroughly dissolving by stirring and warming some soft soap in a mixture of 4 parts methylated spirits to 6 of distilled water and then filtering. This solution of soap should be standardised, that is, diluted or strengthened as the case may be, so that 2·2 c.c. of it exactly give a permanent lather when shaken up with 50 c.c. of a solution of nitrate of barium. Barium nitrate, $Ba(NO_3)_2$, has a molecular weight ratio to calcium carbonate, $CaCO_3$, of as 261 is to 100, and if 0·261 gramme of barium nitrate be dissolved in a litre of distilled water, that solution equals 0·1 gramme of calcium carbonate, and 50 c.c. of the same solution equals 5 mgms. of calcium carbonate. Now, if the soap solution be so made that 2·2 c.c. of it give a lather with 50 c.c. of the above barium nitrate solution, after deducting 0·2 c.c. for the amount of soap solution necessary to give a lather with 50 c.c. of distilled water, we get 2 c.c. of the soap solution to equal 50 c.c. of a barium nitrate solution, which again is equivalent to 5 mgms. of calcium carbonate, hence each c.c. of the soap solution equals 2·5 mgms. of calcium carbonate. Say, for instance, 35 c.c. of soap solution of unknown strength have been made, and, on being standardised with 50 c.c. of the barium nitrate solution, it is found that 1 c.c. gives a lather in place of 2·2 c.c. being so required. Then as $1 : 2{\cdot}2 :: 30 : x = 66$; that is, 30 c.c. of it must be diluted up to 66 c.c. to give a soap solution, of which 1 c.c. shall exactly equal 2·5 mgms. of calcium carbonate. Of course, if the soap solution be found too weak it must be proportionately fortified with more soap until 2·2 c.c. exactly give a lather with 50 c.c. of the 0·261 barium nitrate solution.

In some analytical statements the term "measure" is used to avoid the repetition of the expression "tenth of a cubic centimetre." If so employed, one measure of soap solution may be taken, therefore, as precipitating 0·25 of a milligramme of calcium carbonate.

Total Hardness.—Take 50 c.c. of the sample and place in a stoppered shaking bottle. From a burette run in sufficient of the soap solution until, on being briskly shaken, the contents of the bottle give only a faint dull sound with the formation of a quarter inch of fine uniform lather. This lather should show an unbroken surface after standing five minutes.

Example.—Suppose the addition of 2·4 c.c. of the soap solution have produced the necessary sound and lather. Deducting 0·2 c.c. as being necessary for the production of a lather in 50 c.c. of the purest water, we get 2·2 c.c. of the soap solution required by 50 c.c. of the water sample or 4·4 necessary for 100 c.c. Each of these c.c. equals 2·5 mgms. of calcium carbonate: hence 4·4 × 2·5 = 11 mgms. of calcium carbonate in 100 c.c. of the water, representing a total hardness of 11 parts per 100,000, that is 11 degrees of hardness on the metrical scale. Expressed as grains of calcium carbonate per gallon, or degrees of hardness on Clark's scale, we get 11 × 0·7 = 7·7 grains per gallon of $CaCO_3$.

When the total hardness exceeds 4 c.c. of the soap solution, an over-estimation may be made as the excess of calcium and magnesium salts interfere with the formation of the characteristic lather. In these cases, it is better to dilute 25 c.c. of the sample with 25 c.c. of distilled water, proceed as explained, when the net amount of soap solution used will indicate the hardness in parts per 100,000.

The Permanent or Fixed Hardness.—Take 100 c.c. of the water and 100 c.c. of distilled water; boil in a flask briskly for half an hour, allow it to cool down to 60° F. (15°·5 C.) in the vessel, which should be corked, and then make up the bulk to exactly 100 c.c. with distilled water; determine the hardness in 50 c.c. If distilled water is not procurable, then boil 200 c.c. down to 100; take half the remainder (= 100 of unboiled water) and determine the hardness.

By boiling, all carbonic acid is driven off; all calcium carbonate, except a small quantity, is thrown down; the calcium sulphate and chloride are not affected if the evaporation is not carried too far; the magnesium carbonate at first thrown down is redissolved as the water cools.

Example.—Say 50 c.c. of the water thus treated required 1·6 c.c. of soap solution. Deducting 0·2 c.c. for lather, we get 1·4 c.c., and 1·4 × 2·5 × 2 = 7 mgms. of calcium carbonate present in 100 c.c. of the water, and these 7 mgms. $CaCO_3$ represent the permanent hardness of 100 c.c. (100,000 mgms.) of the water sample, or, in other words, 7 parts per 100,000 of permanent hardness, or 4·9 grains per gallon.

Removable Hardness.—The difference between the total and permanent hardness is the temporary or removable hardness, which in the example would be 11 − 7 = 4 degrees of the metrical scale, and 7·7 − 4·9 = 2·8 degrees of Clark's scale.

The total hardness of a water should not exceed 30 parts per 100,000, otherwise it is unsuitable for domestic purposes. What are called hard waters vary from 20 to 30 degrees on the metrical scale; a soft water from 8 to 15; while a very soft water may contain up to 6 or 8.

The amount of permanent hardness is very important, as it chiefly represents the most objectionable earthy salts—viz., calcium sulphate and chloride, and the magnesian salts. The greater the permanent hardness, the more objectionable is the water. The permanent hardness of a good water should not, if possible, be greater than about 5 degrees of the metrical scale, equal to 3 degrees or 4 degrees of Clark's scale.

Determination of Organic Matter in a Water Sample.—It has already been explained how organic matter is constantly gaining access to water by many channels, and that following in the wake of this organic pollution of drinking waters come widespread evil consequences in the form of various kinds of disease. By organic pollution is meant the fouling of water by both animal and vegetable material, together with the products of their decomposition; and although the relative significance of, and danger from, animal contamination is usually greater than that from vegetable impurities, still the recognition of either or both forms of organic matter constitutes an important procedure in the analysis of water for health purposes. Unfortunately there is no single analytical process which, by itself, can give us any closely proximate estimation of this organic matter. Recognising the fact that all organic matter, whether of animal or vegetable origin, exhibits a natural tendency to resolve itself, under suitable conditions of temperature and moisture, into simple parts, such as carbonic acid, ammonia, and oxidised salts of nitrogen, such as nitrites and nitrates, the most reliable processes for the determination of organic matter in water are only indirect ones, being practically estimations of either carbonic acid, ammonia, or nitrogen produced by the decomposition of organic matter.

In addition to these, the chemical processes for the determination of organic matter in water include others whose object is essentially to detect the presence of other chemical constituents which, by entering into the composition of organic bodies, gain access to water along with it, that is, chlorides, sulphates, and phosphates. To these may be added estimations of the affinity of the particular sample for oxygen.

Possibly one of the most ingenious processes proposed to determine the organic matter in water, is that devised by Frankland; but, owing to the need of special apparatus and of great technical skill to avoid errors in its conduction, it is quite unsuited for the requirements of the greater number of those engaged in public health work. By this method, a measured volume of water is evaporated to a solid residue, and this, after collection in a hard glass combustion tube, is mixed with oxide of copper, and burnt in a furnace. The oxide of copper parts with its oxygen to the organic matter, which is completely burnt, and the resulting carbonic acid and nitrogen collected, measured, and returned in terms of "organic carbon" and "organic nitrogen."

By this process the purity of water is judged from a consideration of the actual amounts of organic carbon and organic nitrogen present, and their relative proportions to each other. A low quantity of each and a small relative amount of organic nitrogen is deemed favourable to the water. Much carbon and little nitrogen is indicative of vegetable pollution, whereas, on the other hand, the nearer the amount of nitrogen approximates to that of carbon the greater is the indication of the pollution being of animal origin. Speaking of this particular process of Frankland's, the Rivers Pollution Commission held that "a good drinking water should not yield more than 0·2 part of organic carbon or 0·02 of organic nitrogen in 100,000 parts": on this dictum, one might condemn a water containing as much as 0·1 part of the former and 0·03 part of the latter.

More practical than, if not actually superior to, Frankland's is the method proposed by Wanklyn, Chapman and Smith, in which two kinds of ammonia are recognised, namely, the free or saline ammonia and the albuminoid ammonia. The former is held to have its origin mainly in organic pollution, being virtually an early stage in the decomposition of such matter, while the latter, being derived from nitrogenous organic matter as the result of its breaking up by the addition of a solution of strongly alkaline potassium permanganate, is taken as the indication of pollution actually present as organic matter.

Although no better clue to the presence of organic matter can be well imagined than an estimation based upon the nitrogen resulting from its decomposition, still the difficulty exists in the fact that all hurtful organic matter is not necessarily nitrogenous. In the case of water pollution, this objection is largely theoretical, but it nevertheless suggests the fact that, as regards organic matter, much has yet to be learnt of its chemical constitution and detection. It is further obvious that no chemical process can decide whether any organic matter is living or dead, or whether, if living, it is injurious or not. Remembering how small the germs of disease are, it will be seen at once that even considerable numbers of them in a water cannot by themselves materially increase the organic ammonia: but as they are nearly always associated with an organic nutritive medium, the excessive presence of organic pollution, which analysis would necessarily indicate, at once suggests doubt and suspicion as to the purity of the water under examination.

Besides the combustion process, commonly known as Frankland's, and the ammonia determinations of Wanklyn, a new method, that of Kjeldahl, has been introduced for the determination of the total combined nitrogen, except nitrates, in natural waters. Although it cannot be claimed for them that they will estimate the absolute quantity of organic matter present, the Wanklyn and Kjeldahl processes constitute the two best methods of estimating its relative quantities in different waters, and, being readily performed by any medical officer of health, will be now described.

Determination of the Free Ammonia.—For this estimation it is necessary to have the following solutions:—

(1) *Nessler's Reagent.*—This is a saturated solution of mercuric iodide in potassic iodide. It gives a yellowish tinge, with the faintest trace of ammonia, passing, if much ammonia is present, to the formation of a yellow-brown precipitate of the di-mercuric-ammonium iodide. Nessler's solution is made by dissolving 35 grammes of potassic iodide in 100 c.c. of distilled water. Also dissolve 17 grammes of mercuric chloride in 300 c.c. of distilled water. Add the mercury solution to that of the iodide gradually until a precipitate of the red periodide of mercury just begins to be permanent. Then dilute up to a litre with a 20 per cent. solution of caustic soda: add more mercuric chloride, to render the solution "sharp," until a permanent red precipitate again forms: allow this to settle, and then decant off the clear solution.

(2) *A milli-normal Standard Solution of Ammonium Chloride.*—Ammonium chloride, represented by the formula NH_4Cl, bears a ratio to ammonia, as represented by NH_3, of as 53·5 is to 17. Therefore, if 0·0535 gramme of ammonium chloride be dissolved in 1 litre of distilled water, that solution will be a milli-normal one and equal 0·017 gramme of ammonia: and 1 c.c. of this $\frac{N}{1000}$ solution will equal 0·017 mgm. of ammonia.

To perform the process, place 250 c.c. of the water sample in a retort, then attach the retort to the Liebig's condenser, and distil off about 130 c.c.; collect 1 c.c. more of the distillate, and test it with a few drops of Nessler, to see if any ammonia is still coming over; if so, the distillation must be continued longer. Carefully measure the amount of distillate; test a little with Nessler's solution in a test-tube; and, if the colour be not too dark, take 100 c.c. of the distillate and put it into a cylindrical glass vessel, placed upon a piece of white paper. Add to it 1·5 c.c. of Nessler. Pour into another similar cylinder as many c.c. of the standard ammonium chloride solution as may be thought necessary (practice soon shows the amount), and fill up to 100 c.c. with pure distilled water; drop in 1·5 c.c. of Nessler. If the colours correspond after three to five minutes, the process is finished, and the amount of ammonium chloride used is read off. If the colours are not the same, add a little more ammonium chloride so long as no haze shows itself; if it does, then a fresh glass must be taken, and another trial made. When the process is completed, read off the number of c.c. of ammonium chloride used, allow for the portion of distillate not used, multiply by 0·017 to give mgms. of NH_3; by 4 to bring to the litre; and by 0·1 to bring from mgms. to centigrammes; or shortly, multiply by 0·0068: the result is centigrammes of free ammonia per litre, or parts per 100,000.

Example.—From 250 c.c. of water, 140 were distilled: 100 c.c. were taken for the experiment, and 2·3 c.c. of ammonium chloride solution were required to give the proper colour: then, $2·3 \times \frac{140}{100} \times 0·017 \times 0·4 = 0·02189$ per 100,000 of free ammonia.

Should the colour of the distillate, after the addition of Nessler's reagent, prove too dark, a smaller quantity may be used, and made up to 100 c.c. with distilled water. Wanklyn recommends distilling only 50 c.c., Nesslerising it, and then adding one-third to the result, on the ground that (as he says) two-thirds of the ammonia come off in the first 50 c.c. He also states that with smaller sized apparatus 100 c.c. of water gives satisfactory results. The Society of Public Analysts recommend successive portions being distilled over, and Nesslerised until ammonia ceases to appear. Practically we have found at Netley that the whole of the ammonia comes over in the first 130 c.c., or nearly so; but it is necessary to continue the distillation until ammonia has entirely ceased to come over.

When a Liebig's condenser cannot be obtained, a flask may be used instead of a retort, and the distillate conveyed to the receiver by a tube of glass (or block tin) passing through a vessel of cold water, which must be renewed from time to time. The tube may be bent in any convenient way, so as to expose it to the cooling water as much as possible. Every part of the apparatus must be scrupulously clean and well washed with distilled water previous to commencing the experiment. It is well to wash the retort, flask, and glass tubes with dilute sulphuric acid, and then rinse them out clean with distilled water. In distilling, the retort should be thrust well into the flame, and the distillation carried on rapidly. If the water is very soft, the addition of a little pure or recently heated sodium carbonate may be made, but in ordinary circumstances it is not necessary, and is not advisable.

The typical yellow or brownish colour produced, when Nessler's solution is placed in the presence of minute quantities of ammonia, is due to the precipitation of the di-mercuric-ammonium iodide (NHg_2I), that is, ammonium iodide (NH_4I), from which the four atoms of the monad hydrogen have been displaced by two atoms of the dyad mercury: thus, $NH_3 + 2HgI_2 = NHg_2I + 3HI$.

The "free" or "saline ammonia" represents the ammonia combined with carbonic, nitric, or other acids, and also what may be derived from urea, or other easily decomposable substances, if they are present. The limit in pure waters is taken at 0·002 centigramme per litre; in bad waters it often reaches 100 times this and more: in usable waters it should not exceed 0·005.

After the distillation of the free ammonia, the residue of the water in the retort is used for determining the *albuminoid ammonia*, to be now described.

Determination of the Albuminoid Ammonia.—In addition to the Nessler's solution and the standard ammonium chloride solution used in the last process, the following is required:—

An alkaline Permanganate of Potash solution made by dissolving 200 grammes of caustic potash and 8 grammes of potassium permanganate in 1100 c.c. of distilled water, and then rapidly boiling the solution down to 1 litre or 1000 c.c.

To make this determination, add to the residue left in the retort employed in the last process 25 c.c. of the alkaline permanganate solution and 25 c.c. of ammonia-free distilled water. Proceed to distil over as before, and continue to do so until no more ammonia comes over; this it will generally cease to do after some 110 or 120 c.c. have been distilled. This ammonia is the so-called albuminoid, due to the breaking up of any organic matter present in the water under the influence of an oxidising agent in the presence of a caustic alkali. The determination of the ammonia in this case is conducted in precisely similar fashion as for the free ammonia.

Example.—Suppose 120 c.c. were distilled over; 100 c.c. were taken for the experiment; 4·5 c.c of ammonium chloride solution were required to give the proper colour: then $4{\cdot}5 \times \frac{120}{100} \times 0{\cdot}017 \times 0{\cdot}4 = 0{\cdot}03672$ of albuminoid ammonia per 100,000.

In this process, before adding the alkaline permanganate solution to the residue in the retort, it is as well to boil it (the permanganate) for five minutes in order to get rid of any traces of ammonia which may be in it.

The object of this process is to get a measure of the nitrogenous organic matter in water, by breaking it up and converting the nitrogen into ammonia by means of potassium permanganate in presence of an alkali: the ammonia can be distilled off and estimated as above. It is to be understood that this does not deal with *all* the nitrogenous matter, but the results are sufficiently uniform to be useful. As so calculated out, the albuminoid ammonia is approximately one-tenth of the nitrogenous matter in water.

In drinking waters of good quality, the albuminoid ammonia should not exceed 0·01 per 100,000. Much albuminoid ammonia, with a small amount of free ammonia, indicates usually vegetable contamination, particularly so if the chlorides, nitrites, and nitrates are low. Peaty waters commonly yield large quantities of albuminoid ammonia, which is evolved slowly and somewhat persistently; badly polluted waters, on the other hand, generally yield their high proportion of albuminoid ammonia promptly and sharply.

Determination of the Organic Nitrogen.—The application of Kjeldahl's nitrogen process affords a very convenient method for making this determination in natural waters. The process practically consists of concentrating half a litre of the water down to 300 c.c.: the residual water is then operated upon with sulphuric acid, and after all the water has been driven off, the organic residue is broken up with permanganate of potash in the presence of a caustic alkali, from which, on further distillation, the organic nitrogen is determined from the resulting ammonia. The actual process is as follows:—

Place 500 c.c. of the water in a round-bottomed flask, of about 900 c.c. capacity, and boil until 200 c.c. have been distilled off. The free ammonia which is thus expelled may, if desired, be determined by connecting the flask with a condenser, and its equivalent nitrogen expressed as the ammoniacal nitrogen. To the remaining 300 c.c. of water in the flask, after cooling, add 10 c.c. of nitrogen-free sulphuric acid, agitating the whole gently, so that the acid may thoroughly mix with the water. The flask is then placed at an inclination, on wire gauze, on an appropriate support, and the liquid boiled down till the oily residue is colourless or pale yellow in tint. The flask is removed from the flame, and a very little powdered permanganate of potassium added until the green colour of the liquid shows that an excess of the permanganate has been added. Should the liquid become purple and not green, all the water has not been driven off. After cooling, 200 c.c. of ammonia-free distilled water are added, the neck of the flask being washed free from acid by so doing, and then 100 c.c. of the alkaline permanganate solution as used for albuminoid ammonia also added. So soon as these additions have been made, the flask is at once connected with a condenser, well shaken, and the distillation commenced and continued until the whole of the ammonia has come over. This will usually do so when some 200 c.c. have been distilled. The distillate is collected, measured, and Nesslerised in the usual way for ammonia. This ammonia is now expressed in terms of nitrogen, by multiplying by $\frac{N}{NH_3} = \frac{14}{17} = 0{\cdot}8235$, the product being organic nitrogen, exclusive of that nitrogen existing in the form of either nitrites or nitrates. It is not found that, with the extreme dilution of natural waters, the determination of the organic nitrogen by this process is vitiated by the presence of nitrites and nitrates.

In carrying out the operation, the most scrupulous care must be taken in preventing access of ammonia from any source. The acid solutions will absorb ammonia from the air, if allowed to remain uncovered for any length of time. The process should, therefore, be carried out without interruption, in a place free from dust, and if any doubt exist as to the freedom from ammonia of the reagents, a blank analysis with ammonia-free water should be made. Practically, the organic nitrogen by the Kjeldahl process is about twice the nitrogen of the albuminoid ammonia, and in usable drinking waters does not usually exceed 0·016 part per 100,000. Any water, unless peaty, containing more than this may be regarded with suspicion.

Example.—From 500 c.c. of water, after the first distillation, 200 c.c. were distilled, and its ammonia found to be equal to 2 c.c. of the ammonium chloride solution: then, $2 \times 0{\cdot}017 \times 0{\cdot}2 \times 0{\cdot}8235 = 0{\cdot}0056$ of ammoniacal nitrogen per 100,000. The second distillation, after breaking up of the residual water and residue, gave a distillate of 215 c.c.; of this, 20 c.c. were found to require, on Nesslerising, 2·2 c.c. of the ammonium chloride solution: then $2{\cdot}2 \times \frac{215}{20} \times 0{\cdot}017 \times 0{\cdot}2 \times 0{\cdot}8235 = 0{\cdot}05621$ of organic nitrogen per 100,000.

Determination of the Nitrites.—When organic matter putrefies or decomposes it becomes reduced to its absolute elements. Of these, nitrogen is the chief, and this combining with hydrogen forms first ammonia, hence the presence, more or less, of free or saline ammonia in a water when at all polluted with organic matter, such as raw sewage. In the course of time, or as it percolates through the soil, the ammonia in the water acquires oxygen and gradually becomes partially oxidised to nitrous acid, HNO_2, or to nitric acid, HNO_3, which acids, by combining with bases like calcium, sodium, or potassium, form *nitrites* and *nitrates*. The oxidation of organic matter cannot go beyond the formation of nitric acid and nitrates, while the nitrous acid and nitrites mark an intermediate stage of imperfect oxidation.

The determination, therefore, of nitrites and nitrates in a water is important, as indicating either a pollution at some remote period with possibly dangerous matter, or more recently with a partially or completely oxidised sewage.

Waters fouled by vegetable matter yield, as a rule, little nitrite or nitrate, chiefly because not only does vegetable decomposition yield relatively little nitrogen, but also because the natural tendency of all plant life is to remove both nitrites and nitrates from a water.

For the direct determination of nitrites, in terms of nitrous acid (NO_2), two processes are available, namely, Griess's by means of meta-phenylenediamine and dilute sulphuric acid: and Ilosvay's modification of Griess's test by means of sulphanilic acid and naphthylamine. Both are extremely sensitive, and require for their conduction one or more of the following solutions.

(1) *Dilute Sulphuric acid*, consisting of one volume of strong acid to two of distilled water.

(2) *A solution of Meta-phenylenediamine*, made by dissolving 5 grammes of meta-phenylenediamine in a litre of distilled water, rendered acid with sulphuric acid. This should be decolourised, if necessary, by filtering through animal charcoal.

(3) *A milli-normal Standard solution of Potassium Nitrite.*—Owing to the unstable nature of this salt, it is necessary to prepare it specially for making up this solution. By the following chemical equation,

$$\underset{154}{AgNO_2} + \underset{74{\cdot}5}{KCl} = \underset{143{\cdot}5}{AgCl} + \underset{85}{KNO_2},$$

it is seen that 154 parts of pure silver nitrite, in the presence of 74·5 parts of potassium chloride, are decomposed, with the formation of 143·5 parts of silver chloride and 85 parts of potassium nitrite, or 46 of nitrous acid, as represented by NO_2. Hence, if 1·54 grammes of pure silver nitrite be dissolved in hot water, decomposed with a slight excess of potassium chloride, allowed to cool, made up to a litre, we obtain a $\frac{N}{100}$ solution of potassic nitrite equalling 0·46 gramme of nitrous acid as NO_2. If each 100 c.c. of this solution, after standing and subsidence of the silver chloride, be again diluted up to a litre with distilled water, we get a $\frac{N}{1000}$ solution of KNO_2, equalling 0·046 gramme of NO_2, and each c.c. of which equals 0·046 of a milligramme of NO_2.

(4) *A solution of Sulphanilic acid*, made by dissolving 0·5 gramme in 150 c.c. of diluted acetic acid (sp. gr. 1·04).

(5) *A solution of Naphthylamine*, made by dissolving 0·1 gramme in 20 c.c. of distilled water, then filtering and mixing the filtrate with 180 c.c. of dilute acetic acid.

Griess's test is thus performed. One c.c. of the dilute sulphuric acid and 1 c.c. of the meta-phenylenediamine solution are added to 100 c.c. of the water to be examined, which is put in a Nessler glass; an orange colour is produced, eventually deepening to a reddish tint. Another glass is placed alongside, and into it is put as much of a standard solution of potassium nitrite as may be necessary, making up the bulk to 100 c.c. with distilled water; then add 1 c.c. each of the sulphuric acid and the meta-phenylenediamine. The remainder of the process is carried on much in the same way as ordinary Nesslerising for ammonia. Care must be exercised that the water originally taken is not too strong; so if the red colour be too deep, smaller portions diluted up to 100 c.c. must be used, until the faintest tint distinctly recognisable is obtained. The standard potassium nitrite, being of the strength of 1 c.c. = 0·046 milligramme of NO_2, or nitrogen tetroxide, the number of c.c. used gives the milligrammes of NO_2 present in the sample of water.

Example.—A sample of water containing a good deal of nitrous acid is taken, and 25 c.c., made up to 100 c.c. with pure distilled water, put in a Nessler glass. One c.c. of the sulphuric acid and 1 c.c. of the solution of meta-phenylenediamine added: a distinct orange colour is obtained. Into another Nessler glass 2 c.c. of the standard potassium nitrite are put, made up to 100 c.c. with distilled water, and the same shade of tint obtained with the solution as above.

Then, $2 \times 0{\cdot}046 \times 4 = 0{\cdot}368$ mgms. NO_2 in 100 c.c. of water or parts per 100,000. Multiplying this by $\frac{N}{NO_2} = \frac{14}{46} = 0{\cdot}304$ gives the equivalent in terms of nitrogen.

The above is a very accurate method of determining nitrites, but some care is required, for both the water and the colouring solution must be either colourless or decolourised. The chief objections to Griess's test are that the colour reaction only develops after some five minutes, and the solutions are liable to change.

It may be well to mention here that the method of stating the results varies, as in the case of nitric acid, some reckoning as HNO_2, some as N_2O_3, and others as NO_2. The last is the best, as it corresponds to Cl. In the same way NO_3 is to be preferred for the nitric acid, SO_4 for the sulphuric acid, and PO_4 for the phosphoric acid.

Ilosvay's test is performed by placing 100 c.c. of the water sample in a colour comparison or Nessler glass, and then, by means of a pipette or burette, adding 2 c.c. each of the solutions of sulphanilic acid and naphthylamine. If nitrites are present, a pink colour is produced. Into another clean glass 1 c.c. of the standard nitrite solution is placed, made up with nitrite-free water to 100 c.c., and treated with the reagents as above. At the end of five minutes the colour of the two solutions are compared, and the colours equalised by diluting the darker.

Example.—Suppose the 100 c.c. of water sample is darker than the distilled water, containing 1 c.c. of the standard nitrite solution. It is necessary to dilute the water sample down to the tint given by the other: 60 c.c. of the 100 c.c. are taken and made up to 100 with distilled water: on comparison, suppose the colour to be still too deep: 70 c.c. of this diluted water is then taken and compared with the other. Presuming that the colours or tints now coincide, we get $100 \times \frac{60}{100} \times \frac{70}{100} = 42$ of the original 100 c.c. equal to 1 c.c. of the standard potassium nitrite solution, which again equals $0{\cdot}046$ mgm. of NO_2: therefore $\frac{100 \times 0{\cdot}046}{42} = x = 0{\cdot}085$ mgm. NO_2 in 100 c.c., or 0·085 part per 100,000.

Had the glass containing the 1 c.c. of standard solution been the darker, that could have been diluted down in a similar way, and the various fractions calculated as parts of 1 c.c. or equivalents of 1 c.c. in terms of NO_2.

The reactions in this process consist in the conversion of the sulphanilic acid into diazo-benzene sulphonic anhydride, by the nitrites present: this compound is in turn then converted by the naphthylamine into azo-α-amido-naphthalene-parazobenzene sulphonic acid. It is this last named compound which gives the pink colour to the liquid. Thus,

$$\overset{\text{Sulphanilic acid.}}{C_6H_7NSO_3} + \overset{\text{Nitrous acid.}}{HNO_2} = \overset{\text{Diazo-benzene sulphonic acid.}}{C_6H_4N_2SO_3} + 2H_2O$$

$$\overset{\text{Diazo-benzene sulphonic acid.}}{C_6H_4N_2SO_3} + \overset{\text{Naphthylamine.}}{C_{10}H_7NH_3Cl} = \overset{\text{Azo-alpha-amido-naphthalene parazo-benzene sulphonic acid.}}{C_{10}H_6(NH_2)NNC_6H_4HSO_3} + HCl.$$

It may be accepted as a good rule that no water which shows the presence of nitrites is fitted for domestic use.

Determination of the Nitrates.—For this estimation we have two convenient processes, either of which can be readily performed: they are (1) the phenol-sulphuric acid method, and (2) the aluminium process.

Phenol-Sulphuric Acid Method.—This method is simple in its application, and yields good results: for it the following solutions are required:—

(1) *Phenol-sulphuric acid*, made by adding 6 grammes of pure phenol and 3 c.c. of distilled water to 37 c.c. of strong sulphuric acid free from nitrates.

(2) *Standard solution of Potassium Nitrate*, made by dissolving 0·722 gramme of recently fused nitrate of potassium in water, and the solution subsequently made up to a litre. One c.c. of this solution will contain 0·1 milligramme of nitrogen.

The process is thus performed: 10 c.c. of the water under examination and 10 c.c. of the standard potassium nitrate solution are evaporated separately just to dryness in two porcelain or platinum dishes. To each of the residues, 1 c.c. of the phenol-sulphuric acid is added and thoroughly mixed by means of a glass rod. If the water under examination contains a large amount of nitrates, the liquid will quickly turn red; if it contain but a small quantity, this colour will not appear for about ten minutes. After the dishes have stood for from ten to fifteen minutes, their contents are washed out successively with 25 c.c. of distilled water into two clean Nessler glasses, about 20 c.c. of liquor ammonia added (sp. gr. 0·96), and both made up to 100 c.c. with more distilled water.

Any nitrate present in the solutions converts the phenol-sulphuric acid into picric acid, which, by the action of the ammonium, forms ammonium picrate: this gives a yellow colour to the solution, the intensity of which is proportional to the amount present.

The colours of the two solutions are now compared, and the darker one diluted until the tints are adjusted, the calculation being made as explained in the description of Ilosvay's test for nitrites. The comparative volumes of the liquids furnish the necessary data for determining the amount of nitrate, as the following example will show.

Example.—Say 10 c.c. of the water sample and 10 c.c. of the standard nitrate solution have, after treatment and dilution each to 100 c.c., given two shades of yellow, of which that from the standard solution is the darker. This, on being diluted to 200 c.c., is still found to be too dark, but this again, on being further diluted to 900 c.c., gives the required match in colour. As the 10 c.c. of standard solution originally treated equal 1 milligramme of nitrogen, then, 900 : 100 : : 1 : $x = 0·11$ mgm. of nitrogen in 10 c.c. of the water sample, or 1·1 parts of nitrogen from nitrates per 100,000. If expressed as NO_3, this equals 4·3 per 100,000.

In the case of very good waters, it is better to evaporate down 20, 50, or more c.c. of the sample and only 5 c.c. of the standard nitrate of potassium: if the water under examination be very rich in nitrates, 10 c.c. of the sample should be pipetted into a 100 c.c. measuring flask, and made up to the mark with distilled water, then 10 c.c. of this well mixed and diluted liquid (= 1 c.c. of original water) withdrawn, evaporated, and treated as above.

Aluminium Process.—If to a strongly alkaline water some aluminium foil be added, decomposition of the water ensues with the evolution of hydrogen. If nitrites or nitrates be present in the water, these salts are reduced by the hydrogen with the result that, on being boiled, their nitrogen is given off as ammonia.

The reagents required for the determination of the nitrates are (1) some thin aluminium foil, and (2) a solution of sodium hydrate. This is best made by dissolving 100 grammes of solid sodium hydrate in 1 litre of distilled water. When cold, introduce a strip of aluminium foil, previously heated to just short of redness, wrapped round a glass rod. When the aluminium is dissolved, boil the solution briskly in a porcelain basin until about one-third of its volume has evaporated : allow it to cool and make it up to its original volume with ammonia-free distilled water. The solution should be tested to prove the absence of nitrates.

100 c.c. of the water sample with 100 c.c. of the sodium hydrate solution and a strip of the aluminium foil are placed in a retort, corked, and left for six or more hours. At the termination of this time, heat must be applied, after connecting the retort with a condenser, and the ammonia present in the flask contents distilled over in precisely the same way as described for estimating the free and albuminoid ammonias. The ammonia which will come over in the distillate will consist partly of any free ammonia which may be present in the sample, partly of ammonia due to reduction of nitrites, if any be present, and partly of ammonia due to reduction of nitrates, if they be present. After elimination of the two former, the remaining ammonia will represent nitrates, and from it the quantity of nitric acid as nitrates can be readily estimated.

The principle of this process consists in the deoxidation of nitric acid or nitrates, and consequent formation of ammonia by evolution of hydrogen. Thus,

$$4Al + 4NaHO + 4H_2O = 2Al_2Na_2O_4 + 6H_2$$
$$12H_2 + 3KNO_3 = 3KHO + 6H_2O + 3NH_3.$$

Example.—Presume that the whole of the ammonia has come over in 120 c.c. Ten c.c. of this distillate are taken for experiment, and diluted to 100 c.c. : on Nesslerising, 4 c.c. of the ammonium chloride solution are found to give the required colour. Then $4 \times \frac{120}{10} \times 0{\cdot}017 = 0{\cdot}816$ mgm. of ammonia in 100 c.c. of water or parts per 100,000. This 0·816 part of ammonia in 100,000 is the total ammonia yielded by the 100 c.c. of water sample, and includes not only free ammonia (if any), but also ammonia due to nitrites (if any) and nitrates.

Suppose this particular water sample to have already yielded 0·005 of free ammonia and 0·52 of nitrites as NO_2, both in parts per 100,000. The 0·52 of NO_2 is convertible into NH_3 in the ratio of as 46 is to 17, or $\frac{17 \times 0{\cdot}52}{46} = 0{\cdot}192$ of NH_3, and this added to the 0·005 of free $NH_3 = 0{\cdot}197$ of ammonia per 100,000 to be deducted from the total ammonia before we get the NH_3 due solely to the reduction of any nitrates present. This means $0{\cdot}816 - 0{\cdot}197 = 0{\cdot}619$ per 100,000 of NH_3 representing nitrates as NO_3. Converting this NH_3 into terms of NO_3, we get $\frac{62 \times 0{\cdot}619}{17} = 2{\cdot}257$ mgms. of NO_3 in 100 c.c. of the sample or parts per 100,000.

Expressed as nitrogen, this equals 0·509 part per 100,000.

Speaking generally, no water, used for drinking purposes, should contain more than 0·35 part per 100,000 of nitrogen in the form of nitrates: this equals about 1 grain per gallon of N_2O_5 or 1·5 parts of NO_3 per 100,000.

Determination of the Oxygen Consuming Power.—Although, by itself, of little value as a measure of the organic impurity of a water sample, this determination of its affinity for oxygen, when taken in conjunction with other analytical facts, is often a material aid in forming an opinion as to the quality of any particular water. Much of the organic matter present in water is capable of oxidation, but since the ease of oxidation bears no constant ratio to the nature of the organic matter, its estimation affords no very reliable index to the real pollution present. In all the efforts to judge the oxidisable organic matter, advantage is taken of the fact that, in the presence of most organic substances, permanganate of potassium freely parts with its oxygen until all the permanganate has been reduced to hydrated manganese dioxide: thus, $2KMnO_4 = K_2MnO_4 + MnO_2 + O_2$. Unfortunately, different substances reduce different proportions of permanganate, and slight variations in temperature and acidity or alkalinity materially influence the readiness with which the permanganate parts with its oxygen.

To determine the oxidisable organic matter, use is best made of what is known as Tidy's process. This process is based upon the chemical fact that, in the presence of an acid and heat, the following decomposition of permanganate takes place:—$4KMnO_4 + 6H_2SO_4 = 2K_2SO_4 + 4MnSO_4 + 6H_2O + 5O_2$, or in other words, 632 parts of potassium permanganate yield in the presence of sulphuric acid 160 parts of oxygen.

For Tidy's process, the following solutions are necessary :—

1. *Standard Potassium Permanganate Solution.*—Since 632 parts of the salt with an acid yield 160 parts of oxygen, then 0·316 gramme of potassium permanganate, if dissolved in a litre of water, will be equivalent to 0·08 gramme of oxygen. This constitutes the standard solution; 1 c.c. of it used with acid yields 0·08 mgm. of oxygen.

2. *Potassium Iodide Solution.*—A 10 per cent. solution in distilled water.

3. *Sodium Thiosulphate Solution.*—One gramme dissolved in a litre of distilled water.

4. *Starch Solution.*—One gramme of starch, mixed with half a litre of distilled water, boiled for five minutes, and filtered.

5. *Dilute Sulphuric Acid*, consisting of one volume of strong acid to three of distilled water.

In performing this process, Tidy recommended two determinations to be made, namely, one of the oxygen absorbed after fifteen minutes' exposure at a temperature of 80° F., and one after four hours' exposure at the same heat. He considered that during the first quarter of an hour, the more or less putrescent easily-oxidised animal organic matters were oxidised, while the oxidation of the vegetable organic material did not take place till after four hours or so. Practically, as much information as can be gained is obtained at the end of fifteen minutes; therefore, except in special cases, the second observation after four hours is hardly necessary. If required, it is performed exactly in the same manner as the shorter exposure.

Into a stoppered bottle, capable of holding from 300 to 400 c.c., place 250 c.c. of the water sample, and heat in a water bath to 80° F. (26·7 C.); when the required temperature is reached, run in 10 c.c. of the sulphuric acid and 10 c.c. of the permanganate solution. A pink colour will result. Maintain the bottle contents at 80° F., carefully noting whether the pink tint is discharged; if the tint disappear add more permanganate. At the end of fifteen minutes, add to the water three drops of the iodide of potassium solution. Owing to there being a certain amount of oxygen available from the permanganate, as previously explained, this will liberate iodine from the iodide, with the result that the pink-coloured bottle contents will now become yellow: thus, $5O_2 + 20KI + 10H_2O = 20KHO + 10I_2$.

The quantity of iodine set free will, of course, be dependent on the amount of potassium permanganate remaining unreduced in the water. If the iodine set free is absolutely dependent upon the amount of permanganate left unreduced by the organic matter in the water, it is obvious that any estimation of the iodine liberated will be a measure of the unused oxygen, and this, deducted from what was rendered available by the original quantity of permanganate added, will give a measure of the oxidisable organic matter in the 250 c.c. of water.

We proceed to make these estimations in the following manner. To the iodine-tinted water, the thiosulphate solution is gradually added with the object of reducing it: thus, $I_2 + 2Na_2S_2O_3 = 2NaI + Na_2S_4O_6$. In order to know exactly when all the free iodine has been removed from the water, an indicator in the form of 1 c.c. of the starch solution is added; this, so long as any free iodine is present, will give a blue tint. Therefore, continuing the addition of the thiosulphate, we stop the moment all the blue colour has gone, and read off the actual amount of thiosulphate used.

Unfortunately, thiosulphate of soda is a very unstable salt, and its particular value as a reducing agent needs to be judged, at the time of each experiment, by means of a control observation of its power upon an identical quantity of permanganate in distilled water, as was used for the unknown sample. Accordingly, into a similar bottle, 250 c.c. of distilled water are placed, heated to 80° F., 10 c.c. of the sulphuric acid, and exactly the same amount of permanganate as was used for the water sample added, and the whole kept at 80° F. for fifteen minutes. In this bottle, owing to there being no organic matter, practically the whole of the oxygen liberated from the permanganate under the circumstances will be unconsumed, and consequently, on the addition of three drops of potassium iodide, more iodine will be liberated, and more of the thiosulphate will be required to reduce it. The iodide, the starch, and the thiosulphate are added precisely as in the other experiment.

So soon as all the iodine has been removed, as shown by the disappearance of the blue colour, the amount of thiosulphate used is read off; its volume will represent, for the time being, the actual reducing value of the thiosulphate for the precise amount of permanganate used or added in the experiment. And the difference between the amount of thiosulphate solution needed to reduce the x amount of potassium permanganate in this pure distilled water, and that required for the same amount which has been more or less decomposed or reduced by oxidisable organic matter in the water sample, will represent the quantity of oxygen consumed by such oxidisable matter.

Example.—Say 10 c.c. of $KMnO_4$ in the distilled water have used up 40 c.c. of the thiosulphate solution: therefore, 40 c.c. of the thiosulphate may be considered as equivalent to 10 c.c. of $KMnO_4$ or 1 mgm. of oxygen.

Another 10 c.c. of $KMnO_4$, in the unknown sample, have used up, say, 32 c.c. of thiosulphate solution: therefore, an amount of oxygen equivalent to the difference between 40 and 32 c.c. of thiosulphate solution has been taken up by the organic matter. But if 40 c.c. of thiosulphate equal 1 mgm. of oxygen, then 8 c.c., or the difference between 40 and 32, equal 0·2 mgm. of oxygen. This means that 0·2 mgm. of oxygen is taken up by 250 c.c. of the water sample, or parts per 250,000: this multiplied by 0·4 equals 0·08 part of oxygen consumed by the oxidisable organic matter per 100,000.

In performing this process, the permanganate added must be sufficient to create a pink colour, which remains distinctly permanent at the end of the heating. If the four hours test be applied, it may be necessary to make repeated additions of the permanganate solution. The *total* quantity actually used must be carefully noted, and the same amount, of course, employed in the distilled water experiment.

In endeavouring to interpret the results of this oxygen consuming process, it must be borne in mind that besides organic matter, iron salts, nitrites, and sulphuretted hydrogen will reduce permanganate of potassium; and these latter, if present, must be duly allowed for. It is difficult to distinguish between the oxygen consumed by the nitrogenous and the non-nitrogenous matter. Roughly speaking, the four hours experiment gives information as to the total amount of oxidisable organic matter, while the fifteen minutes reaction is valuable as indicating the proportion of putrescent or readily oxidisable, and presumably dangerous material. Peaty waters consume large quantities of oxygen: hence, as in all other attempts to measure the organic matter in a water sample, the results of the oxygen process must be considered in conjunction with the other analytical data and the source of the water.

In a general way, it may be said that waters of great organic purity will not consume more than 0·05 of oxygen per 100,000 in fifteen minutes at 80° F., and that, when the oxygen consumed exceeds 0·1 per 100,000, the sample may be considered of doubtful purity. If, after four hours' exposure, more than 0·3 part of oxygen are consumed per 100,000 of water, the sample must be regarded with suspicion.

Determination of the Phosphates.—For this estimation, we require *a solution of Ammonium Molybdate*, made by dissolving 10 grammes of molybdic anhydride in 41·7 c.c. of liquor ammonia (sp. gr. 0·96), the solution being then slowly poured, with constant stirring, into 125 c.c. of nitric acid (sp. gr. 1·20), and allowed to stand in a warm place for several days until clear.

The process is carried out by evaporating 500 c.c. of the water, slightly acidified with nitric acid, down to 50 c.c. A few drops of a dilute solution of ferric chloride are added, and then strong ammonia in slight excess. A precipitate of all the phosphates is formed; this is filtered off and dissolved on the filter by the smallest possible quantity of hot dilute nitric acid. At this stage the filtrate and washings should not exceed 5 c.c. in volume: if more, they must be evaporated down to this bulk. The liquid should now be heated to nearly boiling, 2 c.c. of the ammonium molybdate solution added, and the liquid kept warm for half an hour. If there is any appreciable precipitate, this must be collected on a small tared filter, washed with distilled water, dried and weighed. The weight of the precipitate multiplied by 0·035 gives the amount of P_2O_5, or multiplied by 0·0467 gives that of PO_4. If the quantity is too small to collect and weigh, it is usually reported, according to circumstances, as "traces," "heavy traces," or "very heavy traces."

Determination of Iron.—This quantitative process as originally elaborated by Thompson was first described by Sutton in his *Volumetric Analysis*. It is very delicate and presents no difficulties in procedure; for it the following solutions are required:—

A Standard Solution of Ferric Sulphate.—Dissolve 0·7 gramme of ferrous sulphate in distilled water acidified with sulphuric acid, and add potassium permanganate solution until a faint pink colour is produced. The solution is then diluted to a litre. One c.c. of this solution contains 0·1 milligramme of iron.

Dilute Nitric Acid.—Dilute 30 c.c. of pure concentrated nitric acid with distilled water to about 100 c.c.

A Solution of Potassium Sulphocyanate.—Five grammes dissolved in 100 c.c. of water.

To make a quantitative estimation of iron, acidify 100 c.c. of the water sample with pure hydrochloric acid and add just sufficient dilute potassium permanganate solution to convert any iron which may be present to the ferric state. Next evaporate this pink-tinted solution nearly to dryness, in order to drive off excess of acid, then dilute to its original volume of 100 c.c. with distilled water. Into each of two Nessler glasses place 5 c.c. of the dilute nitric acid and 15 c.c. of the potassium sulphocyanate solution. To one of these a measured volume of the treated water is added and both glasses filled up to 100 c.c. with distilled water. If any iron be present in the treated water, a blood-red colour will be produced in the glass to which a measured volume was added. Into the other glass some of the standard iron solution is added until the colour agrees. The precise amount of the treated water to be added to the first glass will depend upon the quantity of iron present; but as a rule not more should be used than will require 2 or 3 c.c. of the standard iron solution to match it, otherwise the colour produced will be too deep for accurate comparison.

Example.—Say, after treating 100 c.c. of the water sample in the manner explained, 10 c.c. of it are added to a Nessler glass, containing 5 c.c. of dilute nitric acid and 15 c.c. of the sulphocyanate solution, and made up to 100 c.c. with water. A red tint is produced. The addition of 2 c.c. of the standard iron solution to the other glass is found to give the same colour. Then 10 c.c. of the original water equal 2 c.c. of the standard iron solution or contain 0·2 milligramme of iron: this is equivalent to 2 parts of iron per 100,000, or 1·4 grains per gallon.

Determination of Lead.—As drinking waters very rarely contain copper, the amount of lead present can be conveniently determined by the following method.

A standard solution of Lead Acetate is prepared by dissolving 0·183 gramme of the crystallised salt in a litre of distilled water. One c.c. of this solution contains 0·1 milligramme of metallic lead.

100 c.c. of the water to be examined are placed in a Nessler glass and acidified by the addition of a few drops of acetic acid: to this is now added 0·5 c.c. of a saturated solution of ammonium sulphide. If any lead be present a brownish-black colouration will be produced. Into another similar vessel 100 c.c. of distilled water are placed, together with the same quantities of acetic acid and ammonium sulphide, and sufficient of the standard lead solution added to match the tint in the other glass. From the amount of lead solution used, the quantity of lead in the water under examination is readily calculated. The result should be expressed both in parts per 100,000 and in grains per gallon.

Many waters, especially those that are soft and peaty, and therefore liable to act on lead, possess sufficient colouration to equal 0·5 or even 1 c.c. of the lead solution: if this is the case, a proportionate reduction should be made before calculating out the amount of lead present. By this method 0·05 per 100,000 or $\frac{1}{30}$ grain per gallon may be easily detected.

Copper, Arsenic, and Zinc.—The mere presence of these metals in appreciable quantity is enough to condemn a water, therefore it will seldom be necessary to determine their amount quantitatively.

Silica may be determined from the incinerated residue by treating it with strong nitric or hydrochloric acid, evaporating to dryness, and again treating with acid; distilled water (about 50 c.c.) is then added, and a little heat applied till everything soluble is dissolved; the residue is silica, which may be collected on a small filter, ignited, and weighed. A number of Indian waters contain considerable quantities of silica, either combined or in the suspended matter.

Determination of the Dissolved Oxygen.—This estimation in connection with water analysis has hitherto been much neglected. For hygienic purposes, a method of estimating dissolved oxygen must be simple, speedy, and accurate, and must not require large quantities of water. A further condition is that the water must not be subjected to a diminished oxygen pressure, *i.e.*, must not be operated upon in an atmosphere of inert gas, otherwise there might be, according to the experiments of Roscoe and Lunt, a rapid loss by diffusion.

Several methods for determining the dissolved oxygen in water have been proposed: the more notable being those of Winkler, Dibdin, Thresh and Mohr. The chief objection to them all has been the necessity of special apparatus. As being perhaps the most simple and readily applied, we here describe Thresh's method.

This process is based primarily upon the fact that 16 parts by weight of oxygen will liberate 254 parts of iodine, and as the latter element admits of being accurately estimated, therefore the oxygen is capable of precise determination. We have simply to add to a known volume of the water a definite quantity of sodium nitrite, together with an excess of potassium iodide and acid, avoiding access of air, and then to determine volumetrically the amount of iodine liberated. After deducting the proportion due to the nitrite used, the remainder represents the oxygen which was dissolved in the water and in the volumetric solution used. The solutions required for the process are :—

Solution of Sodium Nitrite and Potassium Iodide, containing 0·5 gramme of the nitrite and 20 grammes of the iodide, in 100 c.c. of distilled water.

Dilute Sulphuric Acid, containing one part of pure acid to three of distilled water.

A clear or fresh Solution of Starch.

Solution of Sodium Thiosulphate, containing 7·75 grammes of thiosulphate of soda, in a litre of distilled water. 1 c.c. of this solution corresponds to 0·25 milligramme of oxygen.

The apparatus used consists of a wide-mouthed bottle A (see fig. 4), of 500 c.c. capacity, closed with a caoutchouc stopper having four perforations. Through one passes the tube B, connected by a rubber tubing at its upper end with the burette C containing the thiosulphate. Through another opening passes the neck of the "separator" D, of known capacity, and provided with a stopper and stopcock. Through a third opening passes the tube E, which can, by means of rubber tubing, be attached to the ordinary gas supply. Through the fourth aperture is the tube for the gas exit, and to the end of this is sufficient tubing to allow the cork G at its end to be placed in the neck of the separator D when the stopper is removed. A small piece of glass tube projects through this cork to allow of the escaping gas to be ignited.

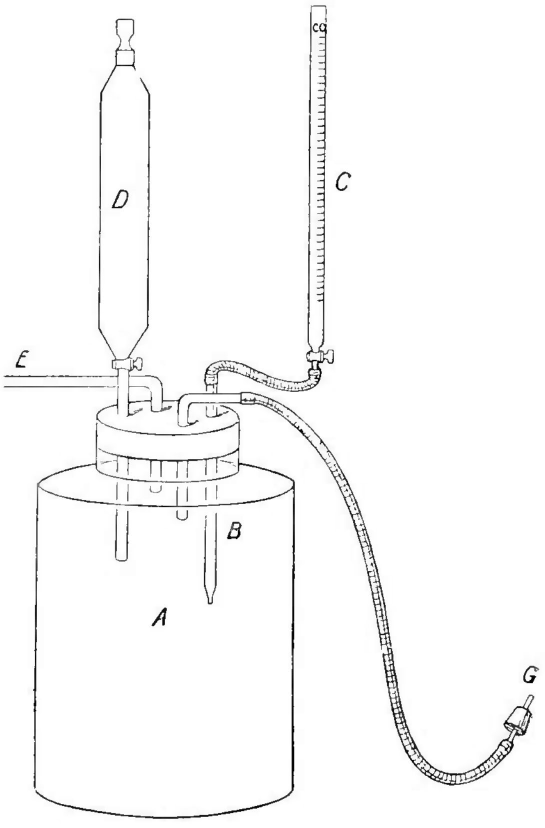


Fig. 4.

The separator D is filled with the water to be examined, and 1 c.c. of the nitrite iodide and 1 c.c. of the acid solution are added, and the stopper instantly fixed in its place, displacing a little of the water, and including no air. By inverting the separator a few times, a uniform admixture of these reagents with the water is secured; then its nozzle is pushed through the bottle cover, and the whole allowed to stand for 15 minutes to enable the reaction to become complete. A rapid current of coal gas is now passed through the bottle A, until all the air is displaced, and the gas burns at G with a bright flame. The flame is now extinguished, the stopper of D removed, and the cork G rapidly inserted in its place. On turning the stopcock of D, the water flows into A. The stopcock is turned off, the cork G removed from D, and the gas relighted at G, being so regulated that only a small flame is produced.

Thiosulphate is now run in from C into the water in A until the yellow colour of the iodine is nearly discharged. A little solution of starch is then poured into D, and about 1 c.c. allowed to flow into the water in A by opening the stopcock. The titration with the thiosulphate is continued until the blue colour is discharged. Frequently, the blue tint returns after a few seconds, due to the oxygen dissolved in the thiosulphate solution; if so, the further addition of a few drops of thiosulphate, however, effects the final discharge. The amount of thiosulphate solution used is now read off and recorded. Call this *e*. This will represent *a*, or the oxygen dissolved in the water examined, *plus b*, or the oxygen in the 1 c.c. of the nitrite-iodide solution and the oxygen in the acid and starch solution added, *plus c*, or the oxygen dissolved in the thiosulphate solution added. To find the value of *a*, it is obvious that *b* and *c* must be ascertained. Once this is known, they do not require redetermination, unless the conditions are changed.

To find the Value of b.—Having completed a determination as above described, then, by means of D, introduce into A, in succession, 5 c.c. each of nitrite-iodide solution, dilute acid, and starch solution. Then titrate with the thiosulphate. One-fifth of the quantity of this used will obviously represent the value of 1 c.c. of each of these solutions as originally used.

To find the Value of c.—This correction is a comparatively small one, and is sufficiently accurately stated if we assume that the thiosulphate solution normally contains as much dissolved oxygen as distilled water at the same temperature. Complete a determination as above described, then remove the stoppered bottle D, and insert a tube similar to that attached to the burette C, and drop in from it 10 to 20 c.c. of oxygen saturated distilled water exactly as the thiosulphate is dropped in. Allow to stand for a few minutes and titrate. One-tenth or one-twentieth of thiosulphate, used according as to whether 10 or 20 c.c. of water were added, gives the correction for each c.c. of volumetric solution used. Call this *d*. Practically, for temperatures between 40° F. and 60° F., the value of *d* may be taken to be 0·031. In *Appendix IX.* is given a table showing the amount of oxygen dissolved by distilled water, per litre, at various temperatures.

The actual calculation of milligrammes of oxygen, dissolved in 1 litre of the water under examination, is conveniently made from the following statement:—

$x = \frac{1000}{4f}(e - b - cd)$: in which f is the capacity of the separator D, *less* 2 c.c. for volume of reagents added: *e* is the number of c.c. of thiosulphate solution used: *b* is, as already explained, the oxygen in the 1 c.c. of nitrite iodide, acid and starch solution added. For strict accuracy, when the water sample contains nitrites, as determined independently by either Griess' or Ilosvay's tests, a deduction of oxygen for them must be made in the proportion of 0·017 milligramme of oxygen per litre for every part of nitrite per 100,000 found, as they may act as oxygen carriers.

Example.—Say 322 c.c. of water were capable of being placed in the separator D, this, *less* 2 c.c. for reagents added, gives 320 c.c. of water operated upon $=f$. After being treated as already explained, presume that 15·2 c.c. of thiosulphate were used $=e$. Say b was found to be 3·1 c.c. and that d is taken as being 0·031: then,

$$x=\frac{1000}{4\times 320}(15{\cdot}2-3{\cdot}1-(15{\cdot}2\times 0{\cdot}031))=9{\cdot}085 \text{ milligrammes } O_2 \text{ per litre.}$$

Presuming further that the water contained 0·02 of nitrites per 100,000, then the dissolved oxygen per million will be $9{\cdot}085-(0{\cdot}02\times 0{\cdot}017)=9{\cdot}08466$.

The presence of nitrates, even in large quantities, does not interfere with the accuracy of this process. Our knowledge at present is small concerning the amount of dissolved oxygen in various waters: but the following table gives some results obtained:—

Source or Kind of Water.	*f.* Amount of Water employed.	*e.* Thiosulphate required.	*e – b – cd.*	*x.* Milligrammes of O_2 per Litre.
Distilled water shaken with air at 60° F.,	232·5	11·90	9·43	10·14
Rain-water,	250·0	11·10	8·65	8·65
Do.	316·0	13·00	10·49	8·30
Shallow-well water,	250·0	10·22	7·80	7·80
Deep-well water,	250·0	9·50	7·11	7·11

Dupré has endeavoured to employ the determination of dissolved oxygen in water as a means of estimating the proportion of oxygen-consuming micro-organisms present. The principle of his method is that pure water, if kept in a closed vessel, will neither gain nor lose oxygen in any length of time; but if organisms capable of causing absorption of oxygen are present, the quantity will decrease. The experiment is carried out by placing a sample of the water in a clean bottle, and vigorously shaking it to saturate with air. A clean 250 c.c. bottle is completely filled with the water, tightly stoppered, and maintained at a temperature of 68° F. (20° C.) for ten days: the oxygen remaining is then determined, and compared with that which was originally dissolved in the water.

The amount of dissolved oxygen in surface waters follows the average temperature of the air. This is proved by graphically plotting the average monthly temperature and the average temperature of saturation of surface waters during that month. The curves follow each other pretty closely, rising steadily from a minimum about January to a maximum about August, and decreasing suddenly in September or October.

Underground waters, as a general rule, are characterised by low dissolved oxygen, the amount bearing no obvious relation to the temperature of the season. In some of the deepest wells only traces of oxygen are found. Usually, as the oxygen is found to be deficient, so is the free CO_2 found to be in excess, but there is no absolute rule for this. What interpretation is to be put upon it is a matter for further experiment. In a water, shown by the presence of free CO_2 and little organic matter to be a ground water, a small amount of dissolved oxygen will be a good rather than a bad sign, as it indicates that the water has come from a depth.

Determination of the Carbonic Acid.—As carbon dioxide is always being absorbed from the atmospheric air, and especially from the ground air, water without carbonic acid does not occur. Carbonic acid may exist in water in three states, namely, as carbonates, bicarbonates, and free acid. The usual German expressions are "combined or fixed" for that existing as simple carbonates, "half-bound" for that necessary to convert the carbonates into bicarbonates, and "free" for that remaining in excess. As practically all the so-called free and half bound CO_2 is expelled from a water on boiling, the sum of these two constitutes what may be called the volatile carbonic acid. The combination of CO_2 is effected chiefly in the form of acid salts of the alkaline earths, especially acid calcium carbonate. If an aqueous solution of this salt is boiled, or even allowed to stand exposed to the air, it is split up into carbonic acid and neutral calcium carbonate. This neutral $CaCO_3$ is almost insoluble in water, and is stable: the so-called acid calcium carbonate (calcium bicarbonate) has a distinctly alkaline reaction.

Thus we have the following scheme:—

$$\text{Total } CO_2 \left\{ \begin{array}{l} \text{Fixed.} \\ \text{Volatile} \left\{ \begin{array}{l} \text{Half-bound.} \\ \text{Free.} \end{array} \right. \end{array} \right.$$

Any attempt to estimate the CO_2 volumetrically is based upon the following facts:—

1. An indicator, like methyl orange, is unaffected by CO_2, hence the earthy bases present as carbonates or bicarbonates can be at once titrated by a standard acid, whether an excess of (free) CO_2 be present or not.

2. Carbonates are alkaline to phenolphthalein; bicarbonates neutral, free CO_2 acid. Hence (*a*) a carbonate titrated with an acid, in dilute solution or under conditions which prevent loss of CO_2, becomes neutral when all the carbonate is converted into bicarbonate: thus, $Na_2CO_3 + HCl = NaHCO_3 + NaCl$. (*b*) Free carbonic acid, in dilute solutions, can be titrated with sodic carbonate, neutrality arriving when the alkali is converted into bicarbonate.

Seyler's experiments have shown that, if a water is neutral or acid to phenolphthalein, and this is generally the case, the half-bound CO_2 is equal to the fixed, and the volatile CO_2 is equal to the sum of the fixed and free. If a water is alkaline to phenolphthalein, it contains no free CO_2, and the volatile CO_2 is less than the fixed by an amount capable of being determined by titration with an acid until neutral to phenolphthalein.

The Free Carbonic Acid may be best titrated, according to Trillich, by taking 100 c.c. of the water, after the addition of phenolphthalein, and dropping in a $\frac{N}{20}$ solution of Na_2CO_3 (2·19 grammes to the litre), until a faint pink colour appears. The consumption of each cubic centimetre of the soda solution represents the presence of 1·1 milligramme of free carbonic acid. The titration must, for any accurate results, be repeated, running in nearly the right amount at once and then finishing drop by drop.

The Fixed Carbonic Acid may be determined, as suggested by Lunge, by taking 100 c.c. of the water, after adding some methyl orange, and dropping in a $\frac{N}{20}$ mineral acid, such, for instance, as sulphuric acid (2·45 grammes to the litre), 1 c.c. of which equals 1·1 milligramme of CO_2. The principle involved in this titration is that, if sulphuric acid is added to a carbonate or bicarbonate, along with an aqueous yellow solution of methyl orange, metallic sulphate and free carbonic acid are formed, and the pale yellow colour remains unchanged until the carbonates are completely decomposed, and a trace of free sulphuric acid is present when a red colour appears. The presence of other salts has no importance. This method determines the combined carbonic acid, a molecule of the acid salt consuming exactly as much acid as a molecule of the neutral salt: thus, $CaCO_3 + H_2SO_4 = CaSO_4 + CO_2 + H_2O$, and $Ca(HCO_3)_2 + H_2SO_4 = CaSO_4 + 2CO_2 + 2H_2O$.

In any case in which both free and fixed CO_2 have to be determined, this may be done upon the same 100 c.c.; titrating first with the alkali, and then adding methyl orange and titrating with the acid. The number of c.c. of soda used is of course subtracted, and the results will be quite accurate, unless the combined CO_2 be very small.

Thus, taking 100 c.c. of a water, neutral or acid to phenolphthalein, and in which the half-bound CO_2 may be taken, from Seyler's experiments, to be equal to the fixed, and the volatile equal to their sum, say 9 c.c. of $\frac{N}{20}$ soda carbonates were used, and 12 c.c. of acid were required, then we have—

Free CO_2 $= 1{\cdot}1 \times 9$ $= 9{\cdot}9$ parts per 100,000.
Fixed CO_2 $= 1{\cdot}1 \times 12$ $= 13{\cdot}2$,, ,, ,,
Volatile CO_2 $= 1{\cdot}1(9 + 12)$ $= 23{\cdot}1$,, ,, ,,
Total CO_2 $= 1{\cdot}1(2 \times 12 + 9)$ $= 36{\cdot}3$,, ,, ,,

In another case, if the water is alkaline to phenolphthalein, 100 c.c. may be titrated with acid until the pink vanishes, and then finished with methyl orange.

If m be the number of c.c. of acid required with methyl orange and p that required with phenolphthalein, then we have—

Fixed CO_2 $= 1{\cdot}1m$ parts per 100,000.
Volatile CO_2 $= 1{\cdot}1(m - 2p)$,, ,, ,,
Total CO_2 $= 1{\cdot}1(2m - 2p)$,, ,, ,,

We have $2p$ here because the same acid corresponds to twice as much CO_2 when phenolphthalein is used as when methyl orange is used. Thus, two simple titrations will in a few minutes give a fairly complete information as to the nature and amount of CO_2 existing in a water sample.

The presence of free carbonic acid is an almost constant characteristic of ground water. The amount varies, but may be as high as 13 parts per 100,000; it appears to be in inverse ratio to the dissolved oxygen. The source of the free CO_2 in ground water is apparently the ground air, increasing with the depth and decreasing with the porosity of the soil. When ground water is exposed to the air it may rapidly lose its free CO_2, and even become alkaline to phenolphthalein. Such waters generally contain magnesic carbonate, and betray their exposure to the air by becoming saturated with dissolved oxygen.

The estimation of free and combined CO_2 is further of interest in regard to the reaction of a water, and also in connection with its action on lead. Waters which contain both free and combined CO_2 are often distinctly *amphioteric:* that is, they turn red litmus paper blue, and blue paper red. These reactions are probably explicable as the result of a competition for the base between the free CO_2 and the red litmus, which is itself a weak acid, having blue salts. If some of the red paper is placed in a solution containing carbonates and free CO_2, it seizes a portion of the base until equilibrium is established. If the blue paper be placed in the solution, the free CO_2 attacks it for part of the base, and liberates red litmus until the same condition of equilibrium is reached. Practically, testing the reaction of a water with litmus paper is much better replaced by an estimation of the free and combined CO_2.

In its connection with the action of water upon lead, the relative amounts of free and combined CO_2 are often important factors. Frequently, waters which act upon lead contain more free than combined carbonic acid, and yet are distinctly alkaline to red litmus paper. In testing the action on lead, it is of importance to conduct the experiments in closed vessels, as well as in open beakers, to prevent the loss of CO_2, as the results will be sometimes found positive in the former and negative in the latter.

Inferences from the Quantitative Tests.—The conclusions to be drawn from the qualitative tests hold good for the quantitative, only greater precision is given. It must, however, be understood that such conclusions are still only approximative, and they are only of a certain value when all the circumstances of the case are taken into consideration. Some chemists have gone so far as to say that they would rather know nothing about the sample, and merely wish it marked with some distinctive mark, such as A or B, or 1 or 2, their confidence being so great in the indications of their analyses that they feel convinced they can give a perfectly trustworthy opinion on the wholesomeness or otherwise from these alone. There is no doubt that a practised chemist may make a fairly good *guess* under such circumstances, but as a rule an opinion so formed is worth very little. It is, of course, desirable that an analyst should come to his inquiry perfectly unbiassed; but before adopting a conclusion as regards a water, the medical officer will always do well to obtain every item of information about it that it is possible to get—otherwise he is sure to fall sooner or later into error. Thus, constituents may be present in a deep-well water and have no particular significance, whilst in a shallow-well water they would be sufficient to condemn it. At present we have little or no means of positively distinguishing vegetable from animal organic matter; yet it is obvious that an amount of the former would be admissible which could not be allowed of the latter.

The analysis should always be as careful and complete as possible, but let the results always be interpreted in the light afforded by a searching examination of the source of the sample. Want of attention to this point is liable to lead to errors fraught with most disastrous consequences.

Subjoined is a critical survey of the more important data, as yielded by a chemical analysis.

1. *Chlorine in Chlorides.*—The purest waters contain small quantities of chlorides, generally less than 1·5 per 100,000. Rain-water generally contains 0·22 to 0·5 per 100,000. An increase in ordinary drinking water may be due to sea-water, salt-bearing strata, or sewage, or other impurities. In the two former cases it is comparatively innocent, but in the last it may be an indication of dangerous contamination, in which case it is usually connected with an increase in the ammonias, the oxidisable matter, and the nitrogen acids. Sewage contamination can never take place without some increase in the chlorides, unless it be through gaseous emanations. Some deep wells contain large quantities of chlorides, but the other details of the analysis will show that this is not due to any recent contamination.

Generally speaking, however, an excess of chlorine is a reason for suspicion, until a satisfactory explanation of its presence is obtained. In most cases, however, a correct judgment can only be formed by comparison with the average character of the waters of the district.

2. *Solids, Total and Volatile.*—The amount of solids varies very greatly with the source of the water. Pure upland surface waters contain very little, sometimes not more than 3 to 4 parts per 100,000. The Loch Katrine water, supplied to Glasgow, yields only 2·4 per 100,000; Thirlmere Lake, supplied to Manchester, almost the same, and the River Vyrnwy, which supplies Liverpool, 3·4 per 100,000.

On the other hand, waters from pure sources other than upland surface show much more than this. On the whole, we may lay it down that the purest upland surface waters seldom contain more than about 7 parts per

100,000, but that considerable latitude may be admitted in waters from deep wells, chalk strata, and the like.

Of the solids not more than about 1·5 per 100,000 ought to be volatile, or capable of being driven off by a red heat. The solids should blacken but very slightly on ignition. A little deviation from this rule is admissible in water from peat land.

3. *Ammonia, Free and Albuminoid.*—Pure waters yield from *nil* to 0·002 per 100,000 of free ammonia, and from *nil* to 0·005 per 100,000 of albuminoid ammonia. Usable water may contain up to 0·005 per 100,000 of free, and 0·01 per 100,000 of albuminoid ammonia. These numbers, however, require qualification, for they may be exceeded in cases where water is thoroughly good for dietetic purposes. Rain-water often contains a large amount of free ammonia, probably derived from soot, and it appears to be harmless.

Deep wells often show a large amount of free ammonia and chlorides without necessarily indicating pollution; but the same amounts in a shallow well would point to probable sewage pollution, or at least to the presence of urine.

The presence of a considerable amount of albuminoid ammonia, with little free ammonia and chlorides, is generally indicative of vegetable organic matter, often peaty. This is the character of the greater part of the water-supply of Ireland. If the chlorine be high, that is, in excess of the average of the district, it may be inferred that the material which yields the ammonia is in great part of animal origin.

The real significance of the albuminoid ammonia has been much discussed, but the results obtained are sufficiently uniform to give us a convenient measure of purity, provided we are careful not to draw the line too close. All the nitrogen of the organic matter is certainly not obtained by this method, but this is immaterial so long as the proportion is fairly maintained. The results correspond to a certain extent with the *organic nitrogen* of Frankland, and the process is much more feasible for medical officers generally.

Practically, 0·615 part of albuminoid ammonia per 100,000 equals 1 part of Frankland's organic nitrogen per 100,000; and double the nitrogen from the albuminoid ammonia equals the organic nitrogen as determined by Kjeldahl's process.

4. *Nitric and Nitrous Acids in Nitrates and Nitrites.*—The significance of these is very important. Nitric acid is the ultimate stage of oxidation of nitrogenous organic matter, and when present in water it is almost always the result of previous pollution, either of the water itself or of the strata through which it flows. It gives us no information, however, as to the exact time when the pollution took place. In some samples from deep wells it is evident that the pollution must have been very ancient. It has been distinctly shown by Schloesing and Muntz and by R. Warington that nitrification is a fermentative process, excited and carried on through the agency of a minute organism, just as ordinary fermentation is carried on through the medium of *torula*. Nitrous acid indicates the presence of organic matter undergoing change: it is either a stage in the direct oxidation of such matter, progressive or arrested, or a retrogression from nitric acid in consequence of the latter having yielded up a part of its oxygen. In this way nitrous acid might retrograde still further and become converted again into ammonia, or be dissipated as nitrogen. Nitrous acid is a much more important substance than nitric, as indicating present danger, and a very small amount of it is sufficient to remove a water into the suspicious class. It is rare to find any of the higher forms of life in a water rich in nitrites, although *bacteria* may be found. Pure water ought

to be quite free from nitrites, and ought to show only traces at most of nitrates.

Few drinking waters, however, come up to this standard: a more practical statement of a permissible limit would be that in cases where the strata may be excluded as the source from which a water derives such salts, the nitrogen in nitrates and nitrites should not exceed 0·1 per 100,000. In other cases, the nitrogen from nitrates alone should not be in excess of 0·35 per 100,000, or the total combined nitrogen (including that in the free and albuminoid ammonias) should in no case exceed 0·4 per 100,000, or one-third of a grain per gallon. On these points it is extremely difficult to lay down any hard and fast rules, as every individual sample of water needs to be judged upon its own analytical facts. The merest traces of nitrites is always suspicious, and in most cases should condemn the water; while the marked presence of nitrates ought to be ground for careful inquiry. In some soils, especially sands and gravels, and in ferruginous soils, the process of nitrification goes on extremely rapidly, and the existence of organic impurity may escape notice if the examination for nitrates be omitted.

5. *Oxygen absorbed.*—This ought not to exceed 0·1 per 100,000 within fifteen minutes for organic matter alone, that is, after deducting any that may be absorbed by nitrous acid if present. This latter, however, should not be present in a water of the first class. Opinions differ as to the significance of the oxygen-consuming power of a water. Attempts have been made to fix limits for the various types of water, and also to gauge the character and condition of the organic matter by observing the rate at which the oxidation takes place, but no positive conclusion can be given. In general, it may be said that a sample which has a high oxygen-consuming power will be more likely to be unwholesome than one which is low in this respect; but the interferences are so numerous, and the susceptibility to oxidation of different organic matters, even if of the same kind, is so different, that the method is, at best, only of accessory value. It is, however, the only one that is practicable for many medical officers, or gives us any measure of the oxidisable organic matter in water, and is, in the present state of our knowledge, indispensable, imperfect though its indication may be. It is certainly an aid to our judgment of the condition of a drinking water, being to Frankland's carbon process something the same as the albuminoid ammonia method is to his nitrogen one. Frankland has fully acknowledged this relation in his latest work, and has proposed a series of factors by which to multiply the oxygen absorbed, so as to express the result in terms of organic carbon. These factors are based on the observed relations between the two processes in a very large number of experiments, and are formed by dividing the average carbon by the average oxygen. The factors differ for different kinds of water in the following proportions:—

River water,	$\frac{C}{O}$	=	2·38
Deep-well water,	,,	=	5·80
Shallow-well water,	,,	=	2·28
Upland surface water,	,,	=	1·80

so that 1 centigramme of oxygen absorbed indicates a probable amount of only 1·8 of organic carbon in an upland surface water, but as much as 5·8 in a deep-well water. A mean of many comparative analyses indicates that 3·35 parts of oxygen absorbed per 100,000 is the equivalent of 1 part per 100,000 of organic carbon by Frankland's process.

No process gives us thoroughly trustworthy information, but for the army or navy medical officer, or any one not provided with a well-appointed laboratory, the permanganate process, combined with the albuminoid ammonia process, gives as much information as is likely to be obtained at present, and sufficient for hygienic purposes. It must be remembered that the permanganate does not act upon fatty substances, starch, urea, hippuric acid, creatin, sugar, or gelatin.

6. *Hardness.*—The fixed hardness should not exceed 3° of the metrical scale. The total hardness may vary more, but if possible should not exceed 7° to 8°·5 (metrical).

7. *Phosphates.*—The presence of these in any marked quantity will generally corroborate inferences as regards sewage contamination drawn from the other indications.

Sulphates.—An excess of sulphates will in many cases also indicate contamination, though they may, like chlorine, come from innocuous sources.

8. *Metals.*—Pure water should contain no *heavy metal*, although a trace of iron may be found sometimes. In some cases iron seems beneficial, as it helps to oxidise the organic matter. The presence of any other *heavy metal* ought to condemn the water.

9. The presence of *hydrogen sulphide* or *alkaline sulphides* ought to condemn the water.

It is always advisable to get information if possible as to the *usual* composition of a water to be examined, as even slight variations may suggest a clue to the nature or cause of an impurity. The microscopic examination of the sediment ought always to be performed where possible, as it often affords important information when the chemical investigation fails. Thus, the presence of such objects as muscular fibre, wheaten starch cells, spiral vegetable fibres, mucous epithelium, disintegrating masses of paper, &c., are sufficient alone to condemn water (especially if it be from a shallow well), even when the chemical constituents are within limits, as they are undoubted evidences of animal contamination, almost certainly sewage. In such cases the nitric acid is nearly always large in amount.

Subjoined, on pp. 114–117, are analyses of typical waters divided into four classes,—1. Pure and wholesome; 2. Usable; 3. Suspicious; and 4. Impure These are merely suggested as general guides, some latitude being necessary according to circumstances.

Microscopic Examination of Suspended and Sedimentary Matter.—The suspended matters may be either mineral (sand, clay, chalk, fine films of mica, iron peroxide), or dead animal or vegetable matters, or living creatures (plants and animals).

To determine the nature of the suspended matters pour some of the water into a long glass as already described, and observe its appearance. Suspended sand or clay give a yellow or yellow-white turbidity; vegetable humus and peat give a darkish, sewage gives a light brown colour; but the colour or turbidity alone is a very insufficient test. Then boil the water, and pour it back into the long glass. Sand, chalk, and heavy particles of the kind will be deposited; finely suspended sewage and vegetable matter is little affected, unless it be a chalk-water, when the deposit of calcium carbonate may carry down the suspended matter.

If the matter is entirely suspended, a drop of the water must be taken at once; but when it can be obtained, a little of the sediment is more satisfactory. To get a sediment, the water should be placed in a conical glass (the space of which ought to be *rounded*, not *pointed*, at the bottom), carefully covered and allowed to stand for a few hours; the upper part of the water is then poured away or siphoned off. The best kind of pipette for taking up the sediment for transfer to the glass slide is a plain straight tube, without bulb and without any narrowing to a point at either end; the diameter may be from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch (1·5 to 3 millimetres). An immense number of dead and living things are often found in water, which it would be impossible to enumerate, but which may be conveniently considered under the following heads :—

(*a*) *Mineral particles* may be easily known; sand appears as large angular particles, often showing distinct conchoidal fracture; clay and marl as round smooth globules unaffected by acids ; carbonate of calcium (chalk) sometimes smooth, but often crystalline, soluble in acids with effervescence. Iron peroxide appears in reddish-brown masses of an amorphous character; it is easily dissolved in hydrochloric acid, and strikes a deep blue with the ferrocyanide of potassium (yellow prussiate).

(*b*) *Vegetable matters:* portions of wood, leaves, bits of the veins, parenchyma, or ducts are easily recognised. When vegetable tissue is more decomposed nothing is seen but a dark, opaque, structureless mass. Any dark formless mass of this kind in water is almost certainly decayed vegetable matter. Bits of textile fabrics, cotton, linen, are not uncommon, and are important as indicating that the water is contaminated with house refuse. So also the cells of the potato, or spiral threads of cabbage and other vegetables used by man, are of value as indications of the same kind. Spiral cells are very indestructible, and are often found in river-water to which sewage gains access. Carbonaceous masses also occur, either portions of soot from coal smoke, or bits of charred wood. Sometimes fragments of paper are met with, probably washed into the water from drains or cesspools.

(*c*) *Animal matters,* consisting of bits of wool, hair, and remains of animals of all kinds, such as wings and legs of insects, spiders and their webs, portions of the skin of water animals, or of fish, &c., are not uncommon. Sewage matters having a darkish-brown or reddish colour, and often in globular masses, and thus distinguishable from the flatter and more spread-out vegetable matter, are sometimes seen. Epithelium (from the skin of man) and hairs of animals are not unfrequent. The identification of these matters is of moment, as indicating the particular source of the contamination. Anything which can be unequivocally traced to the habitations of man must always cause the water to be regarded with suspicion, as, if one substance from a house can find its way in, others may do so too.

(*d*) *Bacteria or Schizomycetes.*—These organisms or their spores are almost invariably present in water, sometimes in very great numbers. The consideration of their significance and the methods for their detection by cultivation will be discussed in the section upon the BACTERIOLOGICAL EXAMINATION OF WATER. High powers (and preferably with immersion lenses) are required to see them properly.

(*e*) *Fungi.*—Small and microscopic fungi are constantly present in water. They may be observed as spores, sporangia, or as mycelium. Both *Aspergillus niger* and *sarcina ventriculi* present familiar instances of these forms.

Fungi rapidly develop in any water containing nitrogenous, saccharine, and phosphatic matter; their spores being readily derived from the air. If fungi are present in any great number in a water sample, it is strong presumptive evidence of impurity, and such water should not be used if it can be avoided, or certainly not until after filtration.

The belief still prevails in some quarters that sewage matter in water gives rise, when sugar is added to the medium, to a special fungus, termed

Beggiotoa alba, formed of very small, spherical, transparent cells arranged in grape-like bundles and characterised by the presence of grains of sulphur in their substance. This organism is found in marsh water and in sulphur springs; it grows freely in water containing sewage, and also in the effluents from certain manufactories, especially sugar factories, tanyards, and in water rich in sulphates. It is, therefore, not characteristic of sewage, but merely indicates the presence of a considerable amount of decomposing organic matter in the water.

(*f*) *Algæ*, *Diatoms*, *and Desmids* are found in almost all running streams, and are also seen in many well waters. They cannot be held to indicate any great impurity; and to condemn water on account of their presence would be really to condemn all waters, even rain, in which minute algoid vesicles (*protococci*) are often found.

The forms of the various *confervæ* in water are very numerous, some being coloured green, whilst at other times they are quite colourless, round, isolated, or clustered vesicles. The immature forms may not be easy of identification. The *Diatoms* are always readily recognised and identified. It may be stated generally that organisms of a grass-green, such as the green *algæ*, need not be objected to; but the bluish-green, such as the *Oscillatorians*, *Nostoc*, &c., are less desirable; not that they are probably directly injurious, but as indicating an impure water, and as being apt to give rise to an unpleasant ("pig-pen") odour. *Leptothrix ochræa*, which was at one time thought to be connected with a special disease poison, is really harmless, and is mostly found in waters containing a good deal of iron peroxide; such waters are usually singularly free from noxious organic matter.

(*g*) *Rhizopoda*, especially *amœbæ* and similar forms, may often be detected with high powers. They appear to indicate, like *bacteria*, the existence of putrefying substances, but this is not yet certain. They are not found in first-class waters.

(*h*) *Euglenæ* (of different species, such as *E. viridis*, *E. pyrum*, &c.) are found in many waters, especially of ponds and tanks. Ciliated, free, and rapidly moving *infusoria*, belonging to several kinds of common *protozoa*, such as *kolpoda*, *paramecium*, *coleps*, *stentor*, *kerona*, *stylonychia*, *oxytricha*, &c., are also found.

In many waters the living objects in the above five classes comprise all that are likely to be seen, but in the other cases there are animals of a larger kind.

(*i*) *Hydrozoa*, especially the fresh-water *polyps*, are common in most still waters, and do not indicate anything hurtful.

(*k*) *Worms*, or their eggs and embryos, belonging to the class *Scolecida*, may occur in water, and are of great importance. The eggs and joints of the tapeworm, the embryos of *Bothriocephali*, the eggs of the round and thread worms, and perhaps the worms themselves, the Guinea-worm, and other kinds of *Filaria*; the eggs of *Dochmius duodenalis*, and other *distomata*, and the embryos of *Bilharzia*, have all been recognised in water, though it has not yet been shown that in all cases they can be thus introduced into the human body. That *Filaria sanguinis hominis* may be taken in drinking water is more probable, seeing that its host, the mosquito, is developed in water, the larvæ of the latter being found in great quantity in tanks and cisterns. Worms themselves cannot well be overlooked, but both eggs and the free-moving embryos are sometimes difficult of identification. The greatest care should be used in examining water to detect ova.

The presence of even common *Anguillulæ* in water shows generally an amount of impurity, and such a water must be regarded with great suspicion. Small leeches also are not uncommon in both still and running waters.

The wheel animalcules are common enough, and cannot be regarded as very important, though certainly when they exist there must be a good deal of food for them, and consequently impurity of water.

(*l*) *Entomostraca* such as the water flea, *Daphnia pulex* (fig. 5); *Cyclops quadricornis* (fig. 6); *Sida*, *Moina*, *Polyphemus*, and others are very common in the spring; they occur in so many good waters that they cannot be considered as indicating any dangerous impurity. It is said that they are only found near (within one or two feet) the surface. *Amphipoda* (*Gammarus pulex*) may also be met with, as well as *Isopoda* (*Asellus aquaticus*) and *Tardigrada* (water bears), especially if water that has been stagnant gets washed into tanks, cisterns, or water-butts.

(*m*) There are, of course, many other tolerably large animals often found in water; the larvæ of the water beetle (*Dytiscus*), the water boatman or skipjack (*Notonecta glauca*), and the pupa form of many insects, may be found, but they are chiefly in pond water.

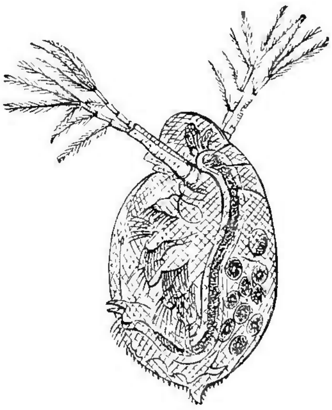


Fig. 5.

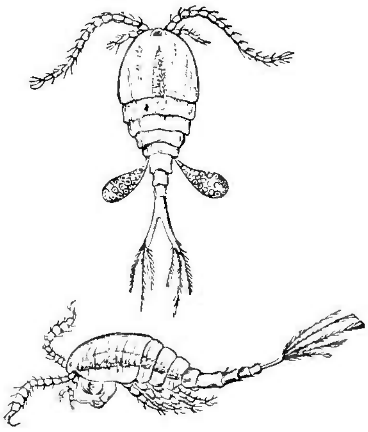


Fig. 6.

So many are the objects in water that the observer will be often very much at a loss, first, to identify them, and secondly, to know what their presence implies. The best way is first to see what objects appear to be mineral, or non-living vegetable substances, and to fix the origin and estimate the quantity as far as it can be done. Then to turn to the living organisms and to look attentively for *bacteria*, *amœbæ*, *fungi*, and *ova*, and small worms and leeches. If none of these exist, and if cultivations show the water to be fairly free from micro-organisms, the water cannot be considered dangerous. Ciliated *infusoria* of various kinds, and *Diatoms*, *Desmids*, and *Algæ*, are chiefly important in connection with microscopic evidence of decaying vegetable matters, and with chemical tests showing much dissolved organic impurity in the water.

BACTERIOLOGICAL EXAMINATION OF WATER.

It is only within recent years that the presence of micro-organisms in water has been recognised, and attempts have been made to study their nature and significance. Miquel in Paris, Koch in Berlin, and Angus Smith in this country, were the earliest investigators in this line of research, but it is to Koch's method of plate cultivations in nutrient gelatin that we are chiefly indebted for the results that have been hitherto attained. By this method a small quantity of water is intimately mixed with fluid gelatin, which is spread in a thin layer upon a glass plate and allowed to solidify; the germs or micro-organisms thus become fixed, and proceed to grow or form "colonies," each germ growing separately in the gelatin wherever it may have lodged, and not interfering with the development of other germs. It is obvious that only such organisms as find this particular nutrient medium favourable to their growth will form colonies on the plates: there may be many other kinds whose presence is not revealed by this method of cultivation: the gelatin process, however, is the one that has been usually employed, and it is at any rate of value in instituting a comparison between the organisms present in different waters, even if it does not show the total amount of microbic life present in any of them. Moulds, yeasts and Schizomycetes or Bacteria are all found to be present in waters, but the significance, both pathological and hygienic, of the two former groups is of far less importance than that of the latter. The two points that require attention are, first, to ascertain the *number* of micro-organisms present; and, secondly, to determine their *nature*, *i.e.*, to differentiate between the several varieties that may be present, and especially to ascertain which are hurtful and which are harmless, when swallowed in drinking water.

As the whole success of any bacteriological observation depends primarily upon the absolute sterilisation of both apparatus and materials, and upon the proper preparation of culture media, it is necessary in the first instance to make some reference to both these points.

Sterilisation of Apparatus, &c.—Small articles of glass and metallic articles can be sterilised by direct ignition in the flame of a Bunsen burner. A red heat is not necessary. If time is no object, both glass and metallic objects may be sterilised by exposure to hot air in a hot-air sterilising oven. Glass vessels should be exposed to a temperature of 150° C. for two or three hours; but it is important to remember that the temperature in these ovens is by no means uniform, and care must be taken to see that the objects are so placed as to be really exposed to the desired temperature.

Dry heat is inapplicable when articles of caoutchouc are to be sterilised: for them and other articles which cannot be exposed without injury to hot air, sterilisation is readily effected by exposure to steam or moist heat by means of a "steam steriliser." By this apparatus, a uniform temperature of 100° C. is obtained, and for the sterilising of glass and other vessels an exposure of from one to two hours is necessary. For culture media, such as potatoes and gelatin, which would suffer by prolonged exposure to so high a temperature, the practice of intermittent sterilisation may be resorted to. This method involves the repeated submission of the substances to a high temperature for a short time only, at intervals of twenty-four hours. For such articles as will stand it, sterilisation may be also effected by simply boiling. In the case of a culture medium, like milk, it may be necessary to effect sterilisation below 75° C., that is, below the temperature of coagulation of albumin; in which case intermittent sterilisation at 60° C. is employed for one or two hours on five to eight days. Gases and some liquids are conveniently sterilised at times by means of filtration. This principle is largely employed in the preservation of culture media in flasks, test-tubes, &c., from aërial micro-organisms by closing their mouths with sterilised cotton-wool stoppers. The sterilisation of liquids by filtration is best secured by passing them through either the Pasteur-Chamberland filter of unglazed porcelain, or the Berkefeld filter of infusorial earth.

The application of chemical agents as a means of sterilisation, except under most unusual circumstances, is not suited to the ordinary routine of bacteriological investigations.

Culture Media.—The more micro-organisms are studied, the more apparent does it become that the greatest diversity prevails in their taste for food, and that media, which are suitable for the growth of some forms, are quite unfitted for the cultivation of others. These facts have caused a considerable variety of materials to be proposed from time to time, as culture media for bacteria: the more important of them are the following:—

Gelatin-peptone is, in many respects, the most important of all the culture media: it may be best prepared in the following manner:—A pound of beef, as free from fat as possible, is finely minced, and infused with one litre of cold water, and allowed to stand for twenty-four hours in a cold place or ice box: the whole mass is then strained through linen, and its original bulk made up with distilled water. To this clear filtrate is now added 100 grammes of gelatin, 10 grammes of dry peptone, and 5 grammes of common salt, after which the whole is placed in a steam steriliser for about an hour, until the complete solution of the gelatin and peptone has taken place. The resulting liquid will be found to have an acid reaction: this must now be carefully neutralised and rendered faintly alkaline with a solution of sodic carbonate. This alkaline liquid is now clarified by mixing with it the white of three eggs, the whole being again placed in the steamer for half an hour. Owing to the coagulation of the albumin this rises to the surface, carrying with it any solid suspended particles. The whole is now strained again through linen until a clear and limpid liquid is obtained. Whilst still liquid, the filtrate is poured into test-tubes which have been previously sterilised and plugged with sterile cotton-wool. The most convenient quantity to take for each tube is 10 c.c. On cooling, this gelatine peptone sets to a straw-coloured transparent jelly. After the tubes are filled, and the cotton-wool stoppers replaced, they are at once steamed for ten to fifteen minutes, which is repeated on the next two days. Gelatin tubes thus prepared should be kept stored in the dark, with their wool stoppers covered by an india-rubber cap to prevent evaporation and concentration.

Glycerin-gelatin-peptone.—By adding from 5 to 8 per cent. of glycerin to ordinary gelatin-peptone, before the jelly is finally sterilised, a most useful culture medium is obtained. Its chief advantage is that it keeps moist much longer than the ordinary gelatin-peptone, whilst most organisms thrive especially well upon it, this being particularly the case with the bacillus of tuberculosis.

Agar-agar.—This is made in a similar way to the ordinary gelatin-peptone, the chief difference being that 20 grammes of agar-agar are used in the place of the 100 grammes of gelatin. When in a fluid condition agar looks transparent and of a rather dark yellow-brown colour, but when it solidifies it loses its complete transparency. Having a much higher melting point (90° C.) than gelatin (22° C.), agar is very useful for cultivations which need to be kept at a high temperature; but owing to the separation of water on solidification, it does not lend itself so satisfactorily to plate cultivations. After sterilising, it is often advantageous to allow the tubes to cool in an oblique position, as in this way a larger surface is obtained, and the liquid which separates out collects at the bottom of the tube. *Glycerin-agar* is made by the addition of from 5 to 8 per cent. of glycerin after the filtration of the jelly.

Potatoes.—The common potato is one of the most convenient culture media, not only because the majority of micro-organisms grow well upon it, but also because its preparation is simple. After having been carefully washed and scrubbed with a nail brush the potato is peeled and cut into slices. These are transferred to sterilised shallow glass dishes, having overlapping glass covers: the dishes and their contained slices of potato are immediately placed in the steam steriliser, and allowed to remain there for an hour or more; if necessary, they may be again sterilised on the following day.

Potato-gelatin.—This was originally devised by Holz: it is prepared in the following manner:—After having been carefully washed and peeled, potatoes are then powdered by means of an ordinary grater. The gratings are pressed through a clean cloth, the resulting juice being collected in a flask, which, on being plugged with cotton-wool, is allowed to stand for twenty-four hours at 10° C. The liquid is next filtered, and the filtrate heated for half an hour in the steam steriliser, and again filtered. To 400 grammes of this now quite clear potato juice are added 40 grammes of gelatin, and the whole sterilised again for an hour, after which it is filtered and poured into test-tubes. When in the test-tubes, it is again sterilised for a quarter of an hour on three successive days. When finished, potato-gelatin is clear, transparent, and slightly brown in colour. In order to neutralise it, it is necessary to add about 1·6 c.c. of deci-normal caustic potash to every 10 grammes.

Beef Broth.—This is merely ordinary bouillon to which an addition of 1 per cent. of peptone has been made. This peptone-broth is made in precisely the same manner as has been already explained for making gelatin-peptone, the only difference being the omission of the gelatin.

Milk often affords a good culture material, and may be prepared by simply placing some in sterile test-tubes, and steaming them in the steriliser at 100° C. for an hour on the first day, and for half an hour on the two following days. This high temperature alters the chemical composition of milk; if this is undesirable, milk may be sterilised by heating it only to 60° C. for two hours on eight successive days. At this lower temperature no coagulation of the albumin takes place, and the milk, being rendered sterile, can be preserved for some length of time.

Although the foregoing do not constitute all the various culture media which have been proposed from time to time for micro-organisms, they practically meet the chief requirements of those making bacteriological examinations of water.

Collection of Samples.—Few bacteriological examinations of water are of value unless promptly made upon samples which have been collected with precautions against contaminations. When possible, the inoculation of the culture medium is best done at the source: if this is not feasible, glass-stoppered bottles, holding about 200 c.c., which have been thoroughly sterilised with their stoppers, must be used for collection. These bottles should be rinsed on the outside with water, dipped below the surface, the stopper withdrawn, and again inserted when the bottle is full. If the samples are to be transported any distance, they should be packed in ice. So soon as received, the examination of the sample should be commenced; while for delivering the measured volume of water a pipette sterilised in the hot air oven should be used.

Culture Manipulations.—For the estimation and isolation of micro-organisms in water, we may employ conveniently either plate or roll cultures.

Plate Cultures.—Having melted the gelatin in a tube by immersion in hot water, its cotton-wool stopper is first singed in a Bunsen flame, and then carefully removed by gently twisting it out; the mouth of the tube is next quickly passed through the flame to destroy any organisms which may be present upon it, and a measured quantity of water transferred from the sample to the test-tube by means of a sterilised graduated pipette. The water and gelatin are intimately mixed together by gently shaking or rolling the tube between the fingers. The mixture is then quickly poured into a sterilised Petri dish to form a plate cultivation; the gelatin becomes solid in from 2 to 10 minutes, according to the temperature. The dish, with its cover, is then placed in an incubator at 18°–22° C., and the medium being spread out in a thin layer over the glass, its appearance can be readily noticed, and growths upon it examined. The actual quantity of the water to be added to each plate culture will necessarily vary with the quality of the sample; speaking generally, 0·5 c.c. is a suitable amount, but as little as 0·1 c.c. or even less may be required in some cases, while in others 1 c.c. may not be too much.

Roll Cultures.—Instead of pouring the nutrient medium, after seeding with the water sample, into a Petri dish, the cotton-wool plug may be replaced, and an india-rubber cap drawn over it. The tube is carefully rotated in a horizontal position in iced or cold water, so as to bring about the solidification of the culture medium in an even layer over the inner surface of the tube. On keeping the tube at 18°–22° C. the colonies develop in the same manner as in the case of an ordinary plate. The method is open to the objection that when liquefying bacteria are present, as will generally be the case, the fluid will run down and inoculate other portions of the layer.

So soon as the colonies have sufficiently developed in either the plate or roll cultures, they must be carefully scrutinised under a low power of the microscope to ascertain what characteristic appearances they present. Each colony, if it has had space to develop freely, is usually a pure culture; so that by removing a portion of any particular one by means of a sterile platinum needle to a test-tube containing some culture medium, the growth may be perpetuated in a state of purity. This "fishing out" of the colonies is comparatively easy when there are only a few on the plate, but somewhat difficult in crowded fields.

Anaërobic Cultures.—Some micro-organisms, like the bacilli of malignant œdema and tetanus, are unable to grow in the presence of free oxygen. To overcome this difficulty, special contrivances have to be employed for their cultivation and study. A very convenient method is the following:—

Take a large tube, charged with about 20 c.c. of gelatin-peptone or other medium, and seed with the infective medium in the usual way. The cotton-wool plug is removed, and immediately replaced by an india-rubber stopper, in which are two perforations fitted with glass tubes, one of these just opens into the test-tube while the other reaches nearly to the bottom. The stopper and tubes have been, of course, previously sterilised. The longer glass tube is connected with a generator of hydrogen gas, and a fairly rapid current of hydrogen is then bubbled through the gelatin, which is kept fluid by immersing the containing tube in a beaker of hot water at 30° C. The hydrogen escapes through the shorter glass tube; when the gas has been passing for fifteen minutes or so, it is stopped, and the two glass tubes rapidly sealed with a blow-pipe. The rubber stopper is next thickly coated with melted paraffin, and the tube, if containing gelatin, is rotated horizontally in cold water until the culture medium congeals as a uniform film over the inside of the tube as in an ordinary roll culture. After incubation, the colonies of those organisms which are capable of growing in the absence of oxygen will appear.

Numerical Determination of Micro-organisms in Water.—The counting of the number of organisms which a given volume of water contains is most readily made by means of gelatin plate cultures. The frequency of liquefying micro-organisms in water renders roll cultures much less serviceable. In all cases, at least, two plate or Petri dish cultures must be set from each water sample. Supposing the water is fairly free from microbes, 1 c.c. may be taken for one plate, and 0·5 c.c. for the other; but, if the water is suspected of containing large numbers of bacteria, then it will be necessary to dilute, say, 1 c.c. of it 10, 20, 100, or even 500 times before seeding the plates. For dilution, sterilised natural water (not distilled water) is best employed. The plates are seeded and incubated in the usual manner,

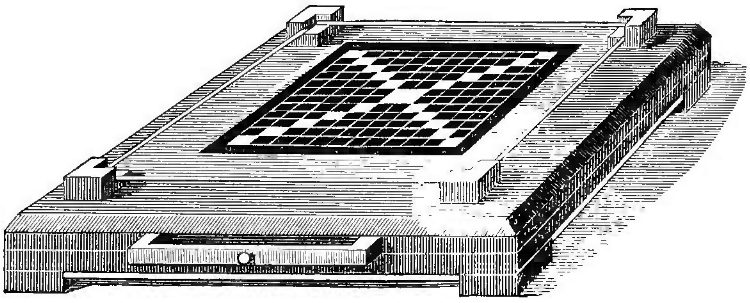


Fig. 7.

while the counting of the resulting colonies is most conveniently made by an apparatus such as Wolffhügel's (fig. 7). This consists of a special glass plate capable of being used upon a stand. The glass plate, ruled by horizontal and vertical lines into centimetre squares, some of which again are subdivided into ninths, is so arranged on a wooden frame that it can cover the nutrient plate without touching it. A lens may be used to assist in discovering minute colonies. If the colonies are very numerous, the number in some small divisions is counted, and then multiplying the average number on these squares or divisions by the total number of squares over which the plate extends, a fairly accurate estimate may be made of their numbers. The number of colonies found is then calculated on 1 c.c. of the original water, and, on the assumption that each colony springs, in the first instance, from a single microbe, the total result is expressed as so many micro-organisms in each c.c. of the water.

The number of micro-organisms found in different water samples varies very much, not only according to their degrees of purity, but also according to season and length of time they have been kept before examination. The following Table, constructed from Frankland's and Miquel's results, shows the varying numbers of micro-organisms found in each c.c. of water from the Thames, Lea, and Seine; the collection of samples having been made at Hampton, Chingford, and Ivry respectively.

	Thames.	Lea.	Seine.
January,	92,000	31,000	52,670
February,	40,000	26,000	43,120
March,	66,000	63,000	34,710
April,	13,000	84,000	38,640
May,	1,900	1,124	12,930
June,	3,500	7,000	28,150
July,	1,070	2.190	14,130
August,	3,000	2,000	6,780
September,	1,740	1,670	20,220
October,	1,130	2,310	22,350
November,	11,700	57,500	37,720
December,	10,600	4,400	78,950

From this Table it will be seen that, as regards micro-organisms, these waters are purer in the summer months: this is probably due to the fact that during dry weather these rivers are mainly composed of spring-water, while at other times they receive considerable washings from cultivated land. All rivers which flow through or near towns and inhabited areas invariably become bacterially impure, but frequently undergo marked purification through sedimentation and dilution as they flow along their course, provided they receive no further considerable intakes of surface and other drainage.

It is exceedingly difficult to obtain precise facts concerning the number of micro-organisms present normally in different wells. The principal source of error is due to the samples having been collected regardless of whether pumping had been going on or not. In a deep well at Netley, which had not been used for twenty-four hours, 109 micro-organisms were found per c.c.; after continuous pumping had been going on for two hours, the numbers had risen to 782, but subsequently, after six hours' continuous pumping, there were only 81 per c.c. It is probable that, in most wells, an enormous increase in the number of microbes in the water follows any disturbance of the sediment or washing and splashing of the sides of the well; so that, if any accurate idea is required of the actual bacterial condition of the water entering or supplying a well, this will only be obtainable after pumping has been going on continuously for some time. As a rule, deep wells possess a high degree of bacterial purity. Frankland's observations upon the deep-well water obtained from the chalk by the Kent Water Company for the supply of London clearly indicate this. He, however, offers the following instructive example of how rapidly the micro-organisms in deep-well water can multiply on standing.

	Number of Micro-organisms obtained from 1 c.c. of water.		
	Date of Collection, April 14, 1886.	April 15, 1886, after standing 1 day at 20° C.	April 17, 1886, after standing 3 days at 20° C.
Kent well sunk into chalk,	7	21	495,000

Spring-water which is properly protected from accidental fouling is commonly very free from micro-organisms. Lake-water is naturally less so. But, even in lakes, the bacterial condition of the water may vary in different parts, being much more impure when taken from near the shore. As to sea-water, our knowledge is small, but the researches of Russell indicate that the distribution of bacteria in the sea is much greater in shallow waters and near the shore than out in the open ocean.

It is difficult to lay down any standard of bacterial purity for drinking water, in terms of permissible numbers, as the power of micro-organisms for good or evil depends not so much upon their actual quantity as upon their quality; that is, whether they are non-pathogenic or pathogenic. For general purposes, a good rule is, to regard no water as being a pure and wholesome one which contains more than 100 micro-organisms in each c.c. when examined at once after collection. The existence of from 100 to 500 microbes per c.c. is suggestive of suspicion, while, as a rule, anything above this latter figure usually points to definite pollution. Care, however, must be taken that the application of these arbitrary standards is only made when bacteriological examinations are made promptly, as any delay soon results in such an enormous increase in the number of micro-organisms in the sample that any opinion based upon their enumeration alone would be highly fallacious. In cases where a delay between the collection and examination of the sample is unavoidable, careful packing in ice is the only practicable remedy. No water sample which has been efficiently filtered should contain any micro-organisms; this point has, however, been dwelt upon elsewhere.

As to the multiplication of micro-organisms in water, on standing, some curious results have been obtained, chiefly by Frankland, Miquel, and Meade Bolton. Summarised, their observations indicate that bacterial multiplication takes place more abundantly in pure, or in waters containing a small number of microbes originally, than in waters which are impure or contain a large initial number. Miquel observes, "that a *rapid but transitory* power of multiplication characterises the bacteria in pure spring-waters, whilst in impure waters, or in waters rich in microbes, the multiplication is *slow and persistent*." He explains this phenomenon by the hypothesis that a particular water acquires an immunity towards further attacks from its contained bacteria. This immunity is due to the generation by the bacteria of soluble and toxic products which inhibit their further growth and multiplication. These toxic products are destroyed on boiling, as a water which will not support further bacterial increase before boiling acquires it after boiling. Pure spring-waters appear to be without these bacterially generated products, hence the rapid and extensive increase of the few micro-organisms which they originally contain.

Vitality and Detection of Pathogenic Bacteria in Water.—Of far greater importance than counting the number of bacteria in a sample of drinking water is the determination of their nature and species. This is always a matter of some difficulty, and involves the expenditure of much time and labour in examining plate cultures, the making of innumerable cover-glass preparations, and the observation of the behaviour and growth of individual species upon different culture media.

The first step is to distinguish those organisms that exist naturally in the water, and are harmless, from those that are known to be pathogenic or disease-producing, none of which (so far as our present knowledge goes) are known to be normal constituents of water.

The indifferent or non-pathogenic organisms that have been found include some hundred species that have been described, besides very many other undetermined varieties, the characters of which are not sufficiently known to warrant their description as distinct species.

The pathogenic bacteria that have hitherto chiefly attracted attention as being found to occur in drinking water are: *Bacillus typhi abdominalis*, Koch's *comma bacillus* of cholera and *bacillus anthracis*. The typhoid bacillus has been found by several observers in connection with epidemics of enteric fever: it has also, on the other hand, escaped the most careful search in some cases where circumstances pointed to the water as the cause of the epidemic. Koch obtained cultivations of the cholera bacillus from tank water at Calcutta, and since then other observers have demonstrated its presence in other waters.

These and other pathogenic bacteria have been introduced experimentally into samples of water of different kinds, and careful investigations carried out, as to whether or no such pathogenic organisms are capable of continuing in an active state or propagating themselves under different circumstances.

Our most recent knowledge upon these points is available from Frankland and Marshall Ward's Third Report to the Royal Society Water Research Committee; their observations having been chiefly made upon the enteric fever bacillus and the *B. coli communis*. Their conclusions may be summarised as follows:—

1. Typhoid bacilli, from ordinary cultures, on being introduced into steam sterilised potable water, in such numbers as not to materially alter the composition of the latter, undergo no multiplication. This result is obtained, whether the water be a surface water like that of the Thames, an upland surface water like that from Loch Katrine, or a deep-well water.

2. Typhoid bacilli which have undergone a prolonged and gradual training in more and more aqueous culture media appear to possess more vitality in potable waters than do bacilli which are at once transferred into water from highly nutritive media. Further, any slight but distinct power of multiplication which these trained bacilli appear to possess in potable water is probably effected at the expense of small quantities of food material introduced along with them at the time of infection, and not at the expense of the organic matter belonging to the water itself.

3. Although no instance of multiplication of the introduced enteric bacilli in sterilised waters was observed, on the other hand the bacilli were found to be possessed of very considerable longevity. This longevity was greatest in the Loch Katrine water (51 days), and least in the deep-well water (20 to 32 days), and intermediate between the two in Thames water. Of these three waters, the Loch Katrine contains the most, the deep-well the least, and the Thames an intermediate amount of organic matter. A summer temperature of 19° C. (66°·2 F.) appears more prejudicial than a winter temperature of 8° C. (46°·4 F.).

4. Enteric bacilli, from ordinary cultures, on being introduced into similar but unsterilised potable waters as above, had the least longevity in Thames water (9 to 13 days), longest in deep-well water (33 to 39 days), and intermediate in the Loch Katrine water (19 to 33 days). This result is of very great practical importance as indicating the greater danger from enteric bacilli gaining access to deep wells than to surface waters. In actual daily life, this danger is increased by the fact that well-water is almost invariably consumed without storage, whilst surface waters are often stored for weeks, and in the case of upland surface waters, the storage not unfrequently extends over many months. The effect of temperature was the same in the case of unsterilised as sterilised waters.

5. The greater bactericidal power of unsterilised water is not apparently due to any remarkable multiplication of the water bacteria, or accentuated "struggle for existence" between the aquatic forms and the specific bacilli, but rather to the elaboration of products by the aquatic bacteria which are prejudicial to the enteric bacilli. This being the case, it may be that unsterile deep-well water does not contain those water bacteria which are particularly fitted for successfully competing with the enteric bacilli, and that such water bacteria are only to be found in the unsterile surface waters.

6. Unsterile Thames water appears to be peculiarly and thoroughly saturated with those bacterial products which are prejudicial to the vitality of the enteric bacillus.

7. The addition of common salt to unsterile Thames water, in the proportion of from 0·1 to 3 per cent., causes an enormous multiplication of the water bacteria present, with a corresponding shortening of life of the enteric bacilli in this water.

8. When the *B. coli communis*, taken from ordinary cultures, is introduced into sterilised waters, it undergoes considerable multiplication; when under similar conditions the enteric fever bacillus does not multiply. The duration of life of the *B. coli communis* in steam sterilised Thames water extended over 75 days: in Loch Katrine water from 14 to 17 days: in very peaty water some 24 days.

9. In unsterile water, the *B. coli communis* persists in the living state for much longer periods than the enteric bacillus. In Thames water, its longevity was upwards of 40 days, and in Loch Katrine water over 20 days.

10. In all waters, except Loch Katrine water, which had been sterilised by filtration through Pasteur-Chamberland or Berkefeld filters, a most remarkably rapid disappearance of both enteric and common colon bacilli is observed.

In connection with the question of the vitality of various pathogenic micro-organisms in water, the following table is not without interest. In it are given the maximum periods at which any observer has been able to detect a particular bacterium after seeding water samples with it. The name of the observer is given in brackets; while the average temperature at which the samples were kept may be taken to be 20° C. (68° F.).

	Unsterilised Ordinary Drinking Water.	Sterilised Ordinary Drinking Water.	Foul Water.	Distilled Water.	Mineral Water.
B. typhi abdominalis,	2 weeks (Uffelmann).	4 months (Pfeiffer).	40 days (Bolton).	6 months (Braem).	11 days (Slater).
Spirillum Choleræ Asiaticæ,	30 days (Koch).	7 months (Wolffhügel).	11 months (Frankland).	20 days (Nicati).	9 hours (Slater).
B. Anthracis (sporiferous),	7 months (Frankland)	7 months (Frankland).	2 months (Frankland).	60 days (Frankland).	5 months (Hochstetter).
B. Tuberculosis,	...	95 days (Straus).	...	115 days (Straus).	...
Staph. pyogenes aureus,	...	20 days (Bolton).	10 months (Bolton).	50 days (Braem).	11 days (Slater).
Strep. pyogenes,	...	15 days (Straus).	...	10 days (Straus).	...
Strep. erysipelatis,	...	5 days (Frankland).	5 days (Frankland).	1 hour (Frankland).	...
M. tetragonus,	...	19 days (Straus).	6 days (Bolton).	19 days (Straus).	...
B. murisepticus,	...	20 days (Straus).	...	19 days (Straus).	...
B. cuniculicida,	...	...	...	2 days (Hochstetter).	1 day (Hochstetter).
B. choleræ gallinarum,	...	30 days (Straus).	...	8 days (Straus).	...
B. of swine plague,	...	17 days (Straus).	...	34 days (Straus).	...
B. mallei,	...	50 days (Straus).	...	57 days (Straus).	...
B. pneumoniæ,	...	7 days (Straus).	...	8 days (Straus).	...
B. Finkler-Prior,	...	2 days (Hochstetter).	2 days (Frankland).	2 days (Slater).	3 hours (Slater).
B. pyocyaneus,	...	73 days (Straus).	18 days (Frankland).	73 days (Straus).	...
B. Tetani,	70 days (Schwarz).	50 days (Schwarz).	50 days (Schwarz).	136 days (Schwarz).	...
Aspergillus flavescens,	...	56 days (Hochstetter).	...	56 days (Hochstetter).	...

Although a vast number of bacteria possessing pathogenic properties have been from time to time detected in natural waters, still, the propagation of the greater number of them is not commonly associated with water. Practically, the only human diseases of the zymotic class which are believed to be commonly propagated by water are enteric fever and Asiatic cholera, and the detection of their specific micro-organisms constitutes the main aim of the bacteriological examinations of drinking waters. In consequence, however, of the enormous preponderance of the common water bacteria, the ordinary process of gelatin plate cultivations will only, in exceptional cases, result in the detection of the pathogenic species; hence, if these latter are to be detected with any ease or certainty, special methods must be adopted in which their growth and multiplication is favoured and stimulated, whilst the proliferation of the other bacteria is either delayed or checked altogether. It is this principle which underlies all the various methods devised for the detection and isolation of the bacteria of enteric fever and cholera. It is not here intended to describe in detail all the various procedures which have, in recent years, been proposed for this purpose, but merely to explain those particular methods which in our hands have given the best results.

Detection of the Enteric Fever Bacillus in Water.—The first difficulty which arises in any attempt to detect the Eberth-Gaffky bacillus in water is the fact that nearly always associated with it are other organisms which so closely resemble it that their differentiation is a matter of extreme difficulty. Prominent among such microbes is the *B. coli communis*, which, while being a normal inhabitant of the human bowel, is frequently found in great numbers in polluted streams, or wells into which drainage has penetrated. Although, hitherto, no method has been devised which will definitely eliminate the *B. coli communis*, and only permit of the growth of the enteric fever bacillus in cultures from water, if it be present therein, the two micro-organisms present sufficiently distinctive characters, when grown upon certain media, as to enable us to differentiate between them. For the practical detection of the enteric fever bacillus in water, the following method, devised by Parietti, is perhaps the best.

This method is based upon the idea that few organisms can flourish in an acid culture medium so well as the Eberth-Gaffky bacillus; but, as the *B. coli communis* is equally capable of growing in an acid medium, it practically only sifts out, as it were, these two particular microbes from among a large number of others, leaving their ultimate differentiation to further culture characteristics.

A series of test-tubes, each containing 10 c.c. of neutral bouillon, receive respectively 3, 5, 6, 7, 8 and 9 drops of the following solution:—carbolic acid, 5 c.c.; pure hydrochloric acid, 4 c.c.; distilled water, 100 c.c. These tubes are incubated for twenty-four hours at 37° C. in order to destroy any organisms which may have gained access during the addition of the solution. To the sterile tubes from 1 to 10 drops of the water under examination are added, well mixed, and incubated at 37° C. for twenty-four hours. They are then examined, and, if any of them appear turbid, plate cultures are set from them, and the resulting colonies carefully examined. If very few enteric bacilli are present, the incubation of the acidified broth must usually be prolonged for forty-eight or even seventy-two hours.

It is sometimes necessary to make a second or even third series of phenolised broth cultures from the first series, owing to the resistance shown to the phenol by certain other organisms, notably, *B. subtilis*, *B. mesentericus vulgatus*, and others. The former species is often very difficult to eliminate.

In attempting to differentiate between the *B. coli communis* and the Eberth-Gaffky bacillus, and apart from microscopic distinctions, attention may be directed to the three following reactions :—

(*a*) Whilst in sterile milk the enteric fever bacillus renders the liquid slightly acid and never coagulates it, the *B. coli communis*, at 37° C., coagulates the milk in from twenty-four to forty-eight hours, and at the same time renders it strongly acid.

(*b*) When inoculated in melted gelatin-peptone, then allowing the latter to solidify, and maintaining at 20° C., the *B. coli communis*, after twenty-four or forty-eight hours, invariably produces gas bubbles, while the enteric fever bacillus does not do so.

(*c*) A further distinction is the so-called *indol-reaction*. To 10 c.c. of ordinary alkaline peptone-broth culture, which has been growing twenty-four hours in the incubator, add 1 c.c. of a solution of sodium or potassium nitrite (0·02 gramme in 100 c.c.), and then a few drops of pure sulphuric acid. If indol is present, a rose to deep red colour is produced, due to the formation of nitroso-indol nitrate. *B. coli communis* yields this reaction, while a growth of the enteric fever bacillus does not.

In place of adding the nitrite and sulphuric acid to the culture, it is often sufficient to add only a drop or two of nitric acid, which is rarely free from nitrite.

To assist the diagnosis of the enteric bacillus in the presence of the *B. coli communis*, "formalin" may be added to sterile neutral broth in the proportion of 1 to 7000. Whereas the colon bacillus will render this formalin-broth turbid in from 8–24 hours, the enteric bacillus refuses to grow and the liquid remains clear. Besides Parietti's method, there are those of Uffelmann, Vincent, Thoinot, Holz, Chantemesse, and Widal. While the first-named uses citric acid, the others employ varying proportions of phenol to hold in abeyance the ordinary bacteria: they, however, all fail to keep back the *B. coli communis*; hence, on subsequent plate cultivation, the colonies obtained may be either those of the colon bacillus or of the enteric fever bacillus, with possibly those of a few other hardy forms, such as *B. subtilis* or *B. mesentericus vulgatus*. Any colonies at all resembling those of the Eberth-Gaffky bacillus must then be further examined, (1) microscopically; (2) on potatoes; (3) in milk; (4) in melted gelatin-peptone for gas bubble test; (5) in broth for indol reaction, before a definite opinion can be given. It must be borne in mind that Eberth's bacillus, when grown in phenolised broth, loses much of its motility; it also tends to occur as a diplo-bacillus, extremely short, almost like cocci; but when transferred to simple broth it regains its proper characters.

Another convenient method for the detection of the enteric bacillus in water is to pass 250 c.c. or more of the sample through a sterile porcelain filter, and then transfer the deposit from the surface of the cylinder by means of a sterile brush into a small quantity of sterile water; the latter, which then contains the bacteria from the original volume of water, should be treated by phenol-broth culture, or one of the other methods of detection.

A scheme showing the chief culture phenomena of the *B. coli communis* and other organisms which closely resemble the enteric bacillus is given on pp. 105–110.

Detection of the Spirillum of Asiatic Cholera in Water.—The same difficulties as are met with in the case of the enteric fever bacillus are prominent in attempts to isolate and detect Koch's comma bacillus of cholera in water samples. It is well known that waters of very diverse origins frequently contain comma-shaped bacteria, which, unless very carefully examined, may be readily confounded with the cholera bacillus. For the identification of cholera commas in water, Koch has suggested the following method:—

Add 1 gramme of peptone and 1 gramme of common salt to 100 c.c. of the water under investigation: well mix and incubate at 37° C. After intervals of 10, 15, and 20 hours, agar plates are set from this peptonised water, coupled with a careful microscopic examination of the mixture. Any colonies which appear on the plates, and which resemble those of the cholera spirillum, are microscopically examined, and, if comma forms are found, are further inoculated into fresh tubes for accurate recognition of their species.

Sanarelli has suggested the following alternative procedure:—To every 100 c.c. of the water under investigation, add 2 grammes of gelatin, 1 gramme of dry peptone, 1 gramme of common salt, and 0·1 gramme of potassium nitrate. The mixture is best made in large flasks, in which, after being incubated for twelve hours at 37° C., a thin pellicle forms on the surface, in which, if spirillar forms are present, they are readily recognised by the microscope. For their subsequent isolation, a small piece of the pellicle is removed, mixed with sterile water, and a gelatin plate cultivation set from the dilution.

For the differentiation of the cholera bacilli from allied forms, Koch recommends the observation of the indol reaction, and of positive pathogenic effects on guinea-pigs. The indol reaction has already been explained in connection with the identification of the enteric fever bacillus. In the case of ordinary cultures of the cholera bacilli, the addition of sulphuric acid, free from nitrous acid, is alone necessary, as the nitrite is already present, having been formed by the reduction of nitrate in the peptone. Care has to be taken that the cultures are pure. Besides the comma bacillus of Koch, another spirillum gives the indol reaction: it is the *Vibrio Metschnikovi.* This has not yet been found in water, and is further distinguishable from Koch's vibrio by its powerfully pathogenic effects upon pigeons and guinea-pigs.

The confirmation of cholera bacilli by animal experiment is best effected by taking a full needle-loop of the surface growth on an agar culture, distributing this in 1 c.c. of sterile broth, and injecting the latter into the peritoneal cavity of a guinea-pig of average size. The injection is quickly followed by a fall in temperature, resulting in death. Though Koch claims that the cholera commas are the only spirilla which will produce these symptoms in minute doses, Sanarelli and other observers have demonstrated that many varieties may exist in water, morphologically distinct from the cholera vibrio, but equally capable of producing a disease in man and animals identical with cholera. The evidence brought forward is so strong that we are compelled to believe that possibly cholera symptoms are produced by more than one variety of vibrio, and that Koch's earlier and more exclusive statement does not meet all requirements of the case.

Details as to the preparation of stains and the manipulative procedures connected with the staining and preparation of specimens of bacteria are given in *Appendix X.* at the end of the volume.

In the following pages is given a scheme showing the culture phenomena of the more important and commoner forms of micro-organisms found in water. Those which are pathogenic to either man or animals are printed in italics.

Culture Phenomena of some of the more important Micro-organisms found in Water.

Species.	Microscopic Appearance.	Gelatin Plates.	Gelatin Tubes.	Agar-agar.	Potatoes.	Milk.
B. Anthracis.	1 to 1·5 μ broad and 3 to 10 μ long, with square cut ends. Often in long threads. Spores formed in presence of oxygen.	Surface colonies appear as masses of convoluted threads. Liquefy.	Quickly liquefy with hair-like ramifications from needle path.	Form a dry grey expansion.	Abundant dry white growth.	...
B. Subtilis.	Resemble anthrax, but narrower and with rounded ends. Have flagella. Forms spores. Very motile.	Surface colonies are liquefied circles of greyish hue. Deep colonies appear as white dots.	Funnel-shaped liquefied channel. Flocculent matter collects at bottom.	White, opaque, wrinkled, and puckered expansion.	Moist white cream like growth.	...
B. Ramosus.	Resembles B. subtilis, 7 μ long and 1·7 μ broad. Has rounded ends. Forms spores and threads. Slightly motile.	Cloudy centres, with root-like extensions from margin. Liquefy.	Surface has a pellicle; whole soon liquefies with grey woolly appearance.	Rapid growth, with characteristic branching.	Dry white uniform expansion.	...
B. Mycoides.	Forms long threads Individual bacilli, 2 μ long and about 1 μ broad. Forms lustrous oval spores Motile.	White cloudy patches, not unlike a mould. Liquefy.	Similar to B. Ramosus.	Mould-like ramifications.	Abundant grey-white shiny growth.	...
B. Vermicularis.	Large bacilli, with rounded ends, similar to B. subtilis. Not motile.	Irregular wrinkled colonies. Liquefy.	Shiny grey surface expansion. Slowly liquefy.	Smooth, slow-growing, shiny, grey growth.	Thick irregular flesh coloured expansion.	...
B. Tetani.	Straight bacilli, with rounded ends. Occurs singly or in long threads. Forms spores. Slightly motile, but the spore-bearing forms are motionless.	Anaërobic. If grown in hydrogen not unlike colonies of B. subtilis.	Anaërobic. A cloudy growth, with radial extensions. Liquefy slowly.	Anaërobic. Grows well if 2 per cent. of grape sugar be added.	...	...
B. Fluorescens tenuis.	Short thick bacilli, 0·8 μ broad and 1·5 μ long. Have rotatory movement.	Shiny denticulated expansions. Colours the gelatin green.	Non-liquefying. Colours gelatin green. Surface expansion is leaf-like.	Similar to growth in gelatin.	Grey-yellow growth, which later on becomes red-brown.	...
B. Fluorescens longus.	Straight and bent rods or wavy threads. Short bacilli are very motile. Threads are motionless.	Surface colonies have mother-of-pearl iridescence. Do not liquefy.	Blue green fluorescent growth.	Greenish yellow expansion.	Moist shining thin expansion.	...
B. Fluorescens non liquefaciens.	Short fine bacilli, with rounded ends. Not motile.	Surface colonies are mother-of-pearl like. Resemble fern leaves.	Fluorescent shimmer along needle's path.	Green coloured surface expansion.	Diffused brownish growth.	...

Culture Phenomena of some of the more important Micro-organisms found in Water—continued.

Species.	Microscopic Appearance.	Gelatin Plates.	Gelatin Tubes.	Agar-agar.	Potatoes.	Milk.
B. Fluorescens liquefaciens.	Short bacillus, with constriction in middle. Occurs in pairs. Is very motile.	Small white dots. On liquefying, the whole gelatin assumes a green fluorescence.	White growth at first, followed by liquefaction and green fluorescence.	...	A brownish growth.	Acidifies milk. Precipitates and peptonises casein.
B. Pyocyaneus.	Small slender bacilli. Very motile. Occur singly or in groups.	Irregular, liquefying, fluorescent colonies.	Funnel-shaped liquid depression. Green fluorescence.	Moist greenish-white expansion: afterwards green fluorescence.	Red-brown growth. If treated with ammonia turns green, with an acid red.	...
B. Aquatilis fluorescens.	Short thin non-motile bacilli, with rounded ends.	Surface colonies are like fern leaves, and resemble mother-of-pearl.	Do not liquefy. Produce a green fluorescence.	Similar to growth on gelatin.	Vigorous and extensive grey growth.	...
B. Murisepticus.	Very small bacilli. Frequently in pairs. Non motile and spore forming.	Do not grow on the surface. Deep colonies, resemble clouds. Liquefy.	Grow very slowly. In deep parts produce a white diffused cloud.	Restricted yellowish-white colonies.	No growth.	...
B. Cuniculicida.	Short broad bacilli, with rounded ends. Often arranged in figure of 8. Not motile. Not spore bearing.	Non - liquefying. Small, round, finely granular colonies.	Delicate white serrated expansion.	White shining growth.	Grows only with difficulty.	...
B. Termo.	Thick rods, 1·4 μ long and 0·8 μ broad. Usually in pairs, sometimes in chains. Motile and flagellated.	Small white colonies, with greyish periphery. Margin often lobulated.	Rapid funnel-shaped liquefaction.	...	...	...
B. Fuscus.	Straight or bent rods, with rounded ends and irregular contour. Non-motile and non-spore bearing.	Surface colonies are raised pin-heads, deep ones small yellow dots.	Projecting button - like growth; later on turns chrome-yellow. Does not liquefy.	Similar to gelatin.	Dark chrome-yellow coarse growth.	...
B. Capsulatus.	Non-motile rod-like forms. Generally in pairs, enclosed in a sort of capsule.	Porcelain white pin-head colonies. Non-liquefying.	Whole growth resembles a nail.	Similar to gelatin, but stringy.	Yellow, moist, stringy growth, with irregular edges.	...
B. Brunneus.	Fine, slender, spore bearing non-motile bacilli.	Thick, dirty white, drop-like colonies. Turn brown later on.	Non - liquefying, shiny, white to grey-brown growth.	As in gelatin.	...	...

B. Cloacæ.	Short plump oval bacilli, with rounded ends. Often in pairs. Very motile.	Bluish expansion, with irregular notched edges. Quickly liquefy.	Iridescent scum on surface, with a heavy flocculent deposit on liquefaction.	Moist, shiny, porcelain-like surface growth.	Raised yellow-white growth.	Coagulates and acidifies.
B. Ubiquitus.	Short plump bacilli, not unlike micrococci. Non-motile.	Surface colonies resemble drops of milk. Turn brown later on. No liquefaction.	Nail-like growth, at first white, but turn to a brownish-grey.	Metallic white to grey growth.	White and shiny growth.	Coagulates and acidifies.
B. Prodigiosus.	Non-motile cells. Often in pairs. 1·7 μ long and 1 μ broad.	Circular depressions, with red centre. Liquefy.	Liquefy as a conical sack, with a red flocculent deposit.	Blood-red, smooth, and shining expansion.	Metallic and bright red growth.	...
B. Rubidus.	Very motile medium sized bacilli, with rounded ends.	Round granular colonies, with smooth rim and reddish centre. Liquefy.	Liquefy with a brownish-red colour.	Similar to gelatin.	Brownish-red growth.	...
B. Aquatilis (*a*).	Slender bacilli, with rounded ends. Hang together in pairs, or form wavy threads. Have a vibratory movement.	Liquefying colonies, with convoluted bands of threads from centre to the periphery.	Slow-growing faint yellow expansion.	Small shining yellow growth.	Grow only with difficulty.	...
B. Aquatilis (*b*).	Short straight bacilli, with pendulum-like movement. No spores.	Raised white dots, like mother-of-pearl.	Non liquefying. White pin-head growth.	White moist expansion.	Smeary grey-white growth. Turns coffee-coloured later.	...
B. Nubilus.	Slender bacilli. 3 μ long and 0·3 μ broad. Possess violent rotatory movement. No spores	Rapidly liquefying cloudy white patches.	Series of horizontal, circular, cloud-like plates along needle track.	Thin, opalescent, blue or violet expansion.	Faintly visible yellow growth.	...
B. Mesentericus. Fuscus.	Very motile short bacilli, with spores. Often in pairs or fours.	Rapidly liquefying round white centres.	Liquid funnel-shaped depressions.	...	Extensive brown to yellow wrinkled growth.	...
B Mesentericus. Vulgatus.	Small fat bacilli, whose ends often stain better than the middle. Very motile and spore bearing.	Circular yellow colonies which quickly liquefy.	Quickly liquefy, with a surface pellicle.	Dirty white growth.	Moist, tough, wrinkled, and stringy growth.	...
B. Typhi abdominalis.	Very motile, short, plump bacilli, about three times as long as broad, with rounded ends. Flagellated, but without spores. No indol reaction in broth-peptone.	Large, spreading, greyish, iridescent colonies, with irregular edges. Have a peculiar woven structure. Do not liquefy.	Grows chiefly on the surface as a delicate greyish-white, iridescent expansion, with irregular edge.	Grey-white moist growth.	Tough but almost invisible grey-white growth.	Acidifies, but does not coagulate.

Culture Phenomena of some of the more important Micro-organisms found in Water—continued.

Species.	Microscopic Appearance.	Gelatin Plates.	Gelatin Tubes.	Agar-agar.	Potatoes.	Milk.
B. Coli communis.	Short bacillus, 0·4 μ broad and 2 or 3 μ long. Very variable, occasionally oval forms not unlike cocci are seen. Slightly motile. Only a few flagella. Does not form spores. Exhibits indol reaction in broth-peptone.	Non liquefying, oval, smooth-rimmed, granular colonies. Have a wavy lineal structure parallel to the periphery.	Grows more in depth than the enteric bacillus, whilst on surface resembles plate colonies.	Dirty white faintly shiny expansions.	Shiny grey growth, but occasionally very like the enteric bacillus.	Acidifies and coagulates.
B. Aquatilis Sulcatus (*a*).	Small rods, not unlike B. typhi abdom. Very motile. No spores.	Serrated colonies, with thin bluish edges and white dense centres. Turn yellow later on.	Non - liquefying. Flat white growth.	Thick white growth, with odour of whey.	Thin cream-coloured growth. Grows best at 10° C.	...
B. Aquatilis Sulcatus (*b*).	Motile small rods, with rounded ends. No spores.	Similar to preceding, only edges are not so serrated.	Do. do.	Grey-white growth	Yellow-brown growth, with smell of urine.	...
B. Lactis Aerogenes.	Non-motile, sporeless, short, plump rods. Often in pairs or in heaps.	Non-liquefying moist porcelain white colonies.	Nail-headed expansion on surface. Free growth along needle path.	...	Cream-like white colonies, impregnated with gas.	...
B. Tholoeideum.	Short rods, with round ends. Very like the preceding.	Surface colonies are like nail heads of an opaque white colour. Deep ones often resemble date stones in shape, and are olive green in colour.	Moist, convex, surface growth, with a white thick band along needle path.	Moist thick expansion.	Lobular and well-defined expansion.	...
B. Tuberculosis.	Slender bacilli, from 1·5 to 3·5 μ long. Non-motile. Spore formation doubtful.	No growth.	No growth.	Dirty white compact and wrinkled surface growth.	Smooth white colonies.	...
Proteus vulgaris.	Slightly bent bacilli, often woven into snake-like threads. No spores, but very motile.	Yellow - brown colonies, with a bristly edge, and innumerable tendril-like coils. Liquefy rapidly.	Rapid liquefaction, with a thick deposit.	Moist thin grey-white expansion.	Dirty smeary growth.	...
Proteus Zenkeri.	Bacilli, 0·4 μ broad and 1·6 μ long. Motile.	Thick grey-white colonies which slowly liquefy.	Thin surface growth.	...	...	...

Proteus Mirabilis.	Motile sporeless bacilli. Often nearly round.	Circular white colonies. In deeper colonies zoogloea masses seen.	Thick moist surface pellicle; quickly liquefies.	...	...	...
Vibrio Aquatilis.	Bent bacilli. Very motile, with one cilium at one pole.	Circular smooth rimmed brown colonies. Liquefy.	Only grow on the surface, followed by a basin-like depression.	Grey-white shining growth.	No growth.	...
Spirillum Choleræ Asiaticæ.	Bent bacilli, like commas, often hanging together to form the letter S. Very motile; each rod has one cilium attached to one end.	Circular rough colonies, with granular contents. Have fine hairy extensions at periphery.	Slowly liquefies. Funnel-shaped or air bubble-like depression. Lower part of needle path remains as a thin white thread.	Grey-white shining growth.	Grows as a transparent greyish expansion on alkaline potatoes.	Acidifies and coagulates.
B. Choleroides.	Very like preceding, but movements less rapid.	Similar to above, only grows more superficially.	Only grows upon and liquefies the surface.	Grows luxuriously, giving rise to an odour of methyl-mercaptan.	...	...
Spirillum Rubrum.	Short spirilla, very like but twice as thick as those of cholera. Having shining spots, regarded as spores.	Non-liquefying and slow growing colonies, with pale red centres.	Grows along needle track as wine red colonies. No surface growth.	Moist shining grey expansion.	Deep red colonies, size hemp seed. Slow-growing.	...
Vibrio Berolinensis.	Almost identical with cholera vibrio.	Small transparent skin-like surface colonies.	Very like cholera vibrio, only it is slower in growing.	Same as cholera vibrio.	Same as cholera vibrio.	Neither acidifies nor coagulates.
Micrococcus Candicans.	Micrococci of irregular size. Not motile.	Circular smooth edged white colonies.	Turbid glutinous liquefying mass.	Dazzling white growth, like Chinese white.	White shiny expansion.	...
M. Aquatilis.	Very small cocci. Usually in groups.	Circular smooth edged porcelain white colonies. Deep colonies have rough denticulated edge.	Grows on surface and along the needle track. Non-liquefying.	Similar to gelatin.	No growth.	...
M. Concentricus.	Non-motile cocci. Often in irregular groups.	Deep colonies are small bluish-grey dots. Surface colonies are brownish discs, with an irregular edge; outside this is a lighter brown and granular ring.	Non liquefying. Blue grey surface expansion, showing concentric circles.	Greyish expansion, with a serrated edge.	Thin yellowish-grey smeary growth.	...
M. Agilis.	Diplococci, also short streptococci.	Flesh colour to pink liquefying colonies. Grows best at 20° C.	Liquefy slowly; forming a pinkish-red pigment.	Pinkish-red growth.	Pinkish-red expansion.	...

Culture Phenomena of some of the more important Micro-organisms found in Water—continued.

Species.	Microscopic Appearance.	Gelatin Plates.	Gelatin Tubes.	Agar-agar.	Potatoes.	Milk.
Staphylococcus Pyogenes aureus.	Non-motile cocci, in heaps, or chains, or as diplococci.	Orange-yellow raised colonies.	At first grey streak. This slowly liquefies with formation of an orange colour.	Similar to gelatin.	Thin whitish growth, which becomes moist and yellow.	...
M. Fuscus.	Non-motile elliptical cocci at times, very like short bacilli.	Light brown circular and liquefying colonies.	Sepia-brown surface pellicle. Smells very foully.	...	Shiny brown expansion.	...
Streptococcus Mirabilis.	Non-motile cocci. Often in long chains.	Non-liquefying and slow-growing dots.	Faint and transparent film.	Similar to gelatin.	No growth.	...
Diplococcus luteus.	Motile cocci, about 1·2 μ in diameter.	Circular bright yellow tough colonies.	Vigorous lemon-coloured growth on the surface. Very slowly liquefies.	Tough shiny yellow growth. Deeper part of agar turns brownish.	Dirty yellow expansion. Has a mouldy smell.	Coagulates.
B. Diffusus.	Thin slender bacillus, 1·7 μ long and 0·5 broad. Often in pairs or threads. Motile.	Bluish-green colonies, with a serrated and lobular margin.	Only grows on the surface as a greenish-yellow expansion. Slowly liquefies.	Yellow to cream-coloured expansion.	Thin greenish-yellow growth.	...
B. Guttatus.	Very motile short bacilli, often in pairs or in groups. Form round spores.	Small white dots. Surface colonies are smooth rimmed, with brown centres.	Bluish-white surface expansion, with round ball-like colonies in deeper parts. Liquefy very slowly.	Thin grey-white expansion.	Dull shiny yellowish-green growth.	Coagulates.
B. Iridescens.	Oscillating rods, from 3 to 5 μ long. With spores.	Irregular blue-green iridescent colonies. Surface very much convoluted and folded.	Thread like growth in depth, which slowly liquefies, forming yellow mass.	Thick shining yellow and iridescent growth.	Dark yellow dry and rough growth. Grows best at 10° to 15° C.	...
Cladothrix Dichotoma.	Long motionless filaments, branched and often united to form flaky zooglœa masses.	Small yellow dots, with brown halo. On surface form brown buttons. Slowly liquefy.	Thin grey expansion. When liquefaction sets in it turns brown.	Very adherent thick and shining growth. Agar turns brown.	...	...
M. Rosettaceus.	Irregularly round or elliptical cocci, often arranged in bunches like grapes. Non-motile.	Non-liquefying small grey dots. On the surface they form shining yellow drop-like expansions.	Grow chiefly on the surface as rosette-like expansions.	Smooth growth, with toothed border.	Yellowish-grey expansion.	...

Hygienic Value of a Water Analysis.—Some authorities have shown a desire to accept the number of micro-organisms present in a water as the measure of its pollution, but any attempt to set up a standard of purity based upon the number of micro-organisms in a given quantity is as illogical as any chemical standard. Both depend upon quantity, whilst the real point at issue is the quality. Bacteriology, like chemistry, may tell us something of risk and impurity, but neither can be depended upon to determine with certainty whether a water is actually injurious to health. To condemn one water because it yields a little more albuminoid ammonia than another, or because it contains a few more organisms than another, when we know nothing of the nature of the substance yielding the ammonia, and nothing of the character of the organisms, is obviously so illogical as to be absurd. Chemical, microscopical, and bacteriological examinations must always be associated with a thorough investigation of the source of the water to ascertain the possibility of contamination, continuous or intermittent. Then, and then only, if everything be satisfactory, we may be justified in speaking of safety and of freedom from risk; but where either the chemical, microscopical, or bacteriological examination is unsatisfactory, the inquiry into the history of the water needs to be most careful and complete, and a guardedly-expressed opinion given only after a full consideration of the bearing of the one upon the other. The possibility of accidental pollution must never be overlooked; yet it often is overlooked, though it is to such accidental pollution that outbreaks of epidemic disease are to be most frequently attributed, and of this the analysis of the water sample, prior to the occurrence of the contamination, may tell us little or nothing. The danger of such pollution does not, unfortunately, vary with the amount of any constituent found in the water; and a source yielding a water of great chemical and bacterial purity may be as much if not more liable to occasional fouling than a source yielding water containing excessive quantities of chlorides and nitrates, or even of unoxidised organic matter, or large numbers of living organisms.

Although a mere analysis cannot guarantee us purity and safety, yet it very frequently can reveal to us impurity and risk. When the source of a water, upon most careful examination, is found to be free from all danger of pollution, and the chemical examination proves that the inorganic constituents are unobjectionable both in quantity and quality, and that organic matter is absent or present in barely appreciable amount, then safety, so far as human foresight can be trusted, may be guaranteed. If organic matter be present in appreciable quantity—that is, if the water yields such a quantity of organic nitrogen and carbon, or albuminoid ammonia, or requires such an amount of permanganate for oxidation as to render it of suspicious or of doubtful purity—a study of the history of the water and of its geological source may, and generally does, enable an opinion to be formed as to the nature of the organic matter, and as to whether it is of an innocuous or dangerous character. Chemical analysis, therefore, has its use; it is only when it is made the sole arbiter between safety and risk that it is abused, and is liable to lead to errors fraught with most disastrous consequences. Let the analysis be as careful and complete as possible, but let the results always be interpreted in the light afforded by a searching examination of the source of the sample. Let all so-called standards be abandoned as absurd, and let the opinion as to whether water is dangerous or safe be based upon a full consideration of all the factors.

Fate of Micro-Organisms in Aërated Waters.—The extensive use in the present day of not only natural waters rich in carbonic acid, but also of many artificial waters prepared by forcing carbon dioxide into spring or distilled water, demands some special notice as to the fate and multiplication of micro-organisms in them. A considerable literature has arisen of late years upon this subject, the chief workers having been Hochstetter, Leone, Pfuhl, and Slater. Their observations have embraced not only the examination of aërated waters directly after their manufacture and on standing for varying periods, but also the fate and power of increase which different micro-organisms display, when introduced into waters, either naturally or artificially charged with gases, more especially carbonic anhydride. The general result of our knowledge upon this subject appears to be that, so far as carbon dioxide is concerned, this gas exercises a retarding influence on the vitality of the bacteria present in water; but that, if the carbonic acid be allowed to escape, and the water be subsequently kept under sterile conditions, a rapid multiplication of bacteria takes place. Some experiments made by ourselves indicate that the powers of increase by non-pathogenic bacteria, when introduced into a carbonated water, varied with the nature of the particular organism employed.

Thus the *B. prodigiosus* rapidly diminished in numbers, none being apparent after eleven days. The *M. violaceus* multiplied largely up to the tenth day: on the thirteenth day a distinct diminution was observed, while after eighteen days, it could no longer be detected. Attempts were made also to ascertain what effect varying degrees of pressure, under which the gas was forced in, had upon the bacteria: the results obtained seemed to indicate that this does not play any very important part. Hochstetter has observed that the bacilli of anthrax and cholera were killed by CO_2 in a few hours, but that those of enteric fever may remain alive for five days or more. Anthrax spores and some moulds, however, may retain their vitality for long periods. Though, undoubtedly, the general influence of forcing CO_2 into various kinds of water is to retard the multiplication of most forms of micro-organisms, if not in some cases to actually inhibit them, it must not be overlooked that the bacterial purity of the original water is very frequently nullified by contaminations which occur in the process of manufacture.

Bacteriological Examination of Ice.—Numerous investigations have shown the frequent impurity of ice, both natural and artificial. The chemical examination is effected by wrapping a block of ice in a cloth, breaking it up with a hammer, placing a few fragments in a beaker and melting them in a water bath. As soon as the ice is melted, the water obtained is examined just as in the case of ordinary water. About 2 per cent. of the solid constituents of the original water are said to pass into the ice.

For the bacteriological examination, a few fragments of ice are taken, passed through a Bunsen flame, and placed in a sterilised flask with a plug of cotton-wool. After thirty minutes, sufficient water will have been obtained to form plates, as in the examination of water. A very considerable number of pathogenic bacteria resist even prolonged freezing, notably, the pyogenic staphylococci and streptococci. On the other hand, the bacilli of anthrax and of septicæmia in rabbits are rather readily destroyed. The ice contains about 10 per cent. of the number of bacteria in the water from which it was obtained: the number of its contained microbes does not generally decrease on being kept any length of time. As regards its hygienic qualities, ice must be judged exactly from the same point of view as water.

Examination of a Water-filter.—Theoretically, an ordinary domestic filter aims at keeping back the suspended substances completely: in practice very few really do so, while metals are only partially arrested and organic matter even more variably affected. Very few filters arrest the micro-organisms of water for any length of time, the majority greatly diminish the number of microbes for a while, until the organisms multiply so much in the filter itself, that they grow through into the filtrate, making this latter often richer in bacteria than the original water before filtration.

The manner in which the action of a filter may be tested as regards dissolved or suspended chemical substances, naturally follows the lines of an ordinary chemical water analysis. For a bacteriological examination, the filter must be set in action in the proper manner, when plate cultures for the enumeration of the contained micro-organisms are made up simultaneously from the unfiltered water and filtrate at intervals of a few hours, then day by day, and the numbers compared. A thoroughly efficient filter should completely sterilise a water passing through it. Careful notice should be taken how the volume of water passing through the filter varies as time goes on: usually the quantity diminishes; similarly, note should be made as to the influence of pressure upon both the quantity and quality of the filtrate. Not the least important part about the examination of a filter is the ease with which it can be cleaned and re-fitted up.

To bacteriologically test a filter, it is better to work with infusions or suspensions of micro-organisms which are easily demonstrable: *Bacillus prodigiosus* and other colour-producing varieties are particularly suitable. In the case of small domestic filters, one may work with pathogenic forms, such as those of enteric fever, cholera, anthrax or their spores. Recent researches have clearly shown that few domestic filters yield a filtrate perfectly free from micro-organisms, particularly if in use for any length of time. Even the sand filters of public water-works seldom do so. They appear to only act best when the first precipitated matters, and especially a fine bacterial film, have been deposited upon the surface, and the grains of sand have become coated with a slimy mass of bacteria and more or less gelatinised products of their decomposition. Though, strictly speaking, no filter should allow any micro-organisms to pass through it at all, the presence of more than 100 microbes per cubic centimetre in any recently filtered water should be sufficient to pronounce its action distinctly unsatisfactory.

The following tables give an approximate view of the composition of drinking waters of the four classes mentioned on page 15, but it must be clearly borne in mind that they are not submitted as standards, but must be regarded merely as types of analytical results.

[TABLES.

1. *Pure and Wholesome Water.*

Character or Constituents.			Remarks.
Physical characters,	Colourless, or bluish-tint; transparent, sparkling, and well aërated; no sediment visible to naked eye; no smell; taste palatable.		Turbidity, due to very fine mineral matter, is sometimes associated with pure waters; thus, minutely divided calcium sulphate will not subside in distilled water.
Chemical Constituents.	Grains per gallon, 1 in 70,000.	Centi-grammes per litre, 1 in 100,000.	
1. Chlorine in chlorides, *under*	1·0000	1·4000	This may be exceeded if from a purely mineral source.
2. Solids in solution: total, *under*	5·0000	7·1428	The solids may be exceeded in chalk waters, where they are mostly calcium carbonate.
,, ,, volatile, *under*	1·0000	1·4000	
N.B.—The solids on incineration should scarcely blacken.			
3. Ammonia, free or saline, *under*	0·0014	0·0020	
,, albuminoid, *under*	0·0035	0·0050	
4. Nitric acid (NO_3), in nitrates. *under*	0·0226	0·0323	
Nitrous acid (NO_2), in nitrites.	nil	nil	
Nitrogen in nitrates, *under*	0·0100	0·0140	
Total combined nitrogen, including that in the free ammonia, *under*	0·0112	0·0160	
Total nitrogen, including that in the albuminoid ammonia, *under*	0·0160	0·0230	
5. Oxygen absorbed by organic matter within 15 minutes, by permanganate and acid at 80° F. (27° C.), *under*	0·0100	0·0125	The oxygen absorbed may be *doubled* in peat or upland surface waters.
Do. do. in 4 hours, at 80° F. (27° C.), *under*	0·0350	0·0500	
6. Hardness, total, *under*	6°·0	8°·5	
,, fixed, *under*	2°·0	3°·0	
7. Phosphoric acid in phosphates,	traces		
Sulphuric acid in sulphates,	traces		
8. Heavy metals,	nil		
9. Hydrogen sulphide, alkaline sulphides,	nil		
Microscopic characters,	Mineral matter; vegetable forms; with endochrome; large animal forms; no organic débris.		See remarks on biological experiments in text.

A water such as the above may generally be used with confidence, in the absence of any history of possible pollution, or of any recent and appreciable change in the amount of the organic constituents.

2. *Usable Water.*

Character or Constituents.			Remarks.
Physical characters,	Colourless or slightly greenish tint; transparent, sparkling, and well aërated; no suspended matter, or else easily separated by coarse filtration or subsidence; no smell; taste palatable.		In some usable waters, such as peat waters, the colour may be yellow or even brownish. In others the taste may be flat or only moderately palatable.
Chemical Constituents.	Grains per gallon, 1 in 70,000.	Centigrammes per litre, 1 in 100,000.	
1. Chlorine in chlorides, *under*	3·0000	4·2857	This may be much larger in waters near the sea, deep-well waters, or waters from saline strata.
2. Solids in solution: total, *under*	30·0000	42·8571	
,, ,, volatile, *under*	3·0000	4·2857	The solids may blacken, but no nitrous fumes should be given off.
3. Ammonia, free or saline, *under*	0·0035	0·0050	This may be greater in deep-well waters.
,, albuminoid, *under*	0·0070	0·0100	This may be larger in upland surface waters, peat waters, &c., when the source is chiefly vegetable.
4. Nitric acid (NO_3), in nitrates. *under*	0·3500	0·5000	The amount of nitrates varies greatly, so that an average is of doubtful value.
Nitrous acid (NO_2), in nitrites.	nil	nil	
Nitrogen in nitrates, *under*	0·0790	0·1129	
Total combined nitrogen, including that in free ammonia, . . *under*	0·0819	0·1170	
Total nitrogen, including that in albuminoid ammonia, *under*	0·0876	0·1252	
5. Oxygen absorbed by organic matter within 15 minutes, by permanganate and acid, at 80° F. (27° C.), *under*	0·0210	0·0300	The oxygen absorbed may be greater (about *double*) in upland surface waters, peat waters, &c.
Do. do. in 4 hours, at 80° F. (27° C.), *under*	0·1050	0·1500	
6. Hardness, total, *under*	12°·0	17°·3	
,, fixed, *under*	4°·0	5°·7	
7. Phosphoric acid in phosphates,	traces	traces	
Sulphuric acid in sulphates, . . *under*	2·0000	3·0000	In some waters the amount may be larger.
8. Heavy metals—Iron, .	traces	traces	
9. Hydrogen sulphide, alkaline sulphides,	nil	nil	
Microscopic characters,	Same as No. 1.		

A water such as the above will in most cases be usable, but it will be improved by filtration through a good medium such as sand.

3. *Suspicious Water.*

Character or Constituents.			Remarks.
Physical characters,	Yellow or strong green colour; turbid; suspended matter considerable; no smell, but any marked taste.		Where the impurity is mostly vegetable, the colour may be very marked in usable water.
Chemical Constituents.	Grains per gallon, 1 in 70,000.	Centigrammes per litre, 1 in 100,000.	
1. Chlorine in chlorides,	3 to 5	4 to 7	In some cases the chlorine may be greater.
2. Solids in solution: total,	30 to 50	43 to 71	
,, ,, volatile,	3 to 5	4 to 7	
3. Ammonia, free or saline,	0·0035 to 0·0070	0·0050 to 0·0100	
,, albuminoid,	0·0070 to 0·0087	0·0100 to 0·0125	
4. Nitric acid (NO_3), in nitrates.	0·35 to 0·70	0·5 to 1·0	
Nitrous acid (NO_2), in nitrites.	0·0350	0·0500	
Nitrogen in nitrates and nitrites,	0·0870 to 0·1661	0·1243 to 0·2373	
Total combined nitrogen, including that in free ammonia,	0·0871 to 0·1718	0·1247 to 0·2455	
Total nitrogen, including that in albuminoid ammonia, .	0·0879 to 0·1726	0·1255 to 0·2465	
5. Oxygen absorbed by organic matter within 15 minutes, by permanganate and acid, at 80° F. (27° C.), . .	0·0350 to 0·0700	0·0500 to 0·1000	
Do. do. in 4 hours, at 80° F. (27° C.), .	0·1500 to 0·2800	0·2000 to 0·4000	
6. Hardness, total, *above*	12°.0	17°·0	
,, fixed, *above*	4°·0	5°·7	
7. Phosphoric acid in phosphates,	heavy	traces	
Sulphuric acid in sulphates, *above*	2·0000	3·0000	This may sometimes be larger.
8. Heavy metals—iron, .	traces	traces	
9. Hydrogen sulphide, alkaline sulphides,	nil	nil	
Microscopic characters,	Vegetable and animal forms more or less pale and colourless; organic débris; fibres of clothing, or other evidence of house refuse.		

A water such as the above ought to excite suspicion: its use ought to be suspended until inquiries about it can be made; if it must be used, it ought to be boiled and filtered.

4. *Impure Water.*

Character or Constituents.			Remarks.
Physical characters,	Colour yellow or brown; turbid, and not easily purified by coarse filtration; large amount of suspended matter; any marked smell or taste.		Dark-coloured waters may be usable when the impurity is vegetable.
Chemical Constituents.	Grains per gallon, 1 in 70,000.	Centigrammes per litre, 1 in 100,000.	
1. Chlorine in chlorides, *above*	5·0000	7·1428	Chlorides *per se* are not hurtful, unless they are magnesian or in some quantity.
2. Solids in solution: total, *above*	50·0000	71·4285	
,, ,, volatile, *above*	5·0000	7·1428	
3. Ammonia, free or saline, *above*	0·0070	0·0100	
,, albuminoid, *above*	0·0087	0·0125	
4. Nitric acid (NO_3), in nitrates. *above*	0·7000	1·0000	Some waters which are organically pure contain a great excess of solids.
Nitrous acid (NO_2), in nitrites. *above*	0·0350	0·0500	
Nitrogen in nitrates and nitrites, . . *above*	0·1690	0·2415	
Total combined nitrogen including that in free ammonia, . *above*	0·1748	0·2497	
Total nitrogen, including that in albuminoid ammonia, *above*	0·1821	0·2601	
5. Oxygen absorbed by organic matter within 15 minutes, by permanganate and acid, at 80° F. (27° C.), *above*	0·0700	0·1000	In the absence of free ammonia, or much chlorine, this may be due to vegetable matter.
Do. do. in 4 hours, at 80° F. (27° C.), . *above*	0·2800	0·4000	
6. Hardness, total, *above*	20°·0	28°·5	
,, fixed, *above*	6°·0	8°·7	
7. Phosphoric acid in phosphates,	very heavy traces		
Sulphuric acid in sulphates, *above*	3·0000	4·2857	
8. Heavy metals, . .	any except iron		
9. Hydrogen sulphide, alkaline sulphides,	present		
Microscopic characters,	*Bacteria* of any kind; *fungi*; numerous vegetable and animal forms of low types; epithelia or other animal structures; evidences of sewage; ova of parasites, &c.		

A water such as the above ought to be absolutely condemned. Should stress of circumstances compel its use, it ought to be well boiled and filtered, or, better still, distilled.

BIBLIOGRAPHY AND REFERENCES.

Adams, "Lead in Water," *Brit. Med. Jour.*, 1889, ii. p. 459. Arnould, *Traité d'Hygiene*, Paris, 1892. Aslanoglow, "The Significance of Nitrites in Potable Water," *Chem. News*, Nov. 16, 1894.

Bailey-Denton, *On the Supply of Water to Villages and Farms*, Lond., 1888. Barry, Report to the Local Government Board, 1893, "On an Outbreak of Enteric Fever in the Tees Valley." Bateman, Beggs, and Rendle, *On Constant Water Supply*, London, 1867. Bischop, "On Putrescent Organic Matter in Potable Water," *Proc. Roy. Soc.*, No. 80, 1877. Bolton, "Uber das Verhalten Verschiedener Bacterienarten in Trinkwasser," *Zeitsch. f. Hyg.*, vol. i., 1886. Buck, *Hygiene*, New York, 1888.

Cameron, *Manual of Hygiene*, 1876; also "On an Organism found in Water which is supposed to have caused an Outbreak of Enteric Fever," *Dubl. Jour. Med. Science*, Sept. 1894, p. 193. Colin, L., *De l'Ingestion des eaux Marecageuses comme cause de la Dysentérie et des Fievres Intermit.*, Paris, 1872. Cunningham, *Reports of the Sanitary Commissioner with the Government of India.*

Davies, "On the Connection between Milk Supply and Disease," *Prov. Med. Jour.*, 1889. Deacon, "The Constant Supply and Waste of Water," *Jour. Soc. Arts*, vol. xxx. p. 738, 1882. De Rance, *Water Supply of England and Wales*, Lond., 1882. Downes, A., "Diphtheria communicated by Drinking Vessels," *San. Rec.*, 1879–80, vol. xi. p. 51. Downes, "Enteric Fever caused by an Overflow of Non-Enteric Sewage into a Well," *Lancet*, 27th April 1872. Drown, "Interpretation of the Chemical Analyses of Water," *Report on Water and Sewage to the Massachusetts State Board of Health*, 1890. Dunbar, "Uber den Typhus Bacillus und den Bacterium coli communis," *Zeitsch. f. Hygiene*, vol. xii., 1892, p. 485. Dupuit, *Etudes sur le mouvement des Eaux*, Paris, 1875.

Ekin, *Potable Water*, Lond., 1890. Evans, *Our Homes*, Cassell & Co., Lond., 1883, pp. 807, 809.

Fanning, *On Hydraulic and Water Supply Engineering*, New York, 1889. Farlow, *Supplement to First Annual Report of State Board of Health, Massachusetts*, 1877, p. 143. Farr, "Report on the Cholera Epidemic of 1866 in England," *Supplement to the 29th Annual Report of the Registrar-General*, 1868. Field, "Pollution of Well Water from Cemeteries," *Trans. San. Inst.*, vol. viii. p. 254. Flugge, "Micro-organisms," *New Syd. Soc.*, Lond., 1890. Frankland, E., *Water Analyses for Sanitary Purposes*, Lond., 1880. Frankland, P., *Third Report to the Royal Society Water Research Committee*, Nov. 1894; also "Multiplication of Micro-organisms," *Proc. Roy. Soc. Lond.*, 1886; also "Recent Bacteriological Research in connection with Water Supply," *Jour. Chem. Industries*, 1887; also "Hygienic Value of the Bacteriological Examination of Water," *Trans. Internat. Congress of Hygiene and Demog.*, London, 1891; also "Experiments on the Vitality and Virulence of Sporiferous Anthrax in Potable Water," *Proc. Roy. Soc. London*, 1893; also *Micro-organisms in Water*, London, 1894. Fränkel, "Uber den Bakteriengehalt des Eisens," *Zeitsch. f. Hygiene*, Bd. 1. Frendenreich, "Uber die Durchlässigkeit der Chamberland'schen Filter für Bakterien," *Centr. f. Bakt.*, vol. xii., 1892, p. 240. Fuller, "Differentiation of the Bacillus of Typhoid Fever," in *Report of State Board of Health, Massachusetts*, 1891.

Gibb, "Pollution of Cisterns by Sewage, *Brit. Med. Jour.*, Oct. 1870. Gore, "Diarrhœa caused by Impure Water," *Army Med. Rep.*, vol. v. p. 428. Grange, "On Analysis of Water," *Ann. de Chimie et de Phys.*, vol. xxiv. p. 364. Greenhow, "Diarrhœa caused by Water which had absorbed Sewer Gases," in *Second Report of the Med. Off. of the Priv. Council*, 1860, p. 153. Günther, *Cholera in Saxony* or *Die indische Cholera in Sachsen im Jahre* 1865, p. 125.

Harvey, *Food, Water, and Air*, Lond., 1872, p. 68. Hawksley, *Report of the Rivers Pollution Commissioners*, vol. vi. p. 233. Hirsch, *Geographical and Historical Pathology*, translated by C. Creighton, M.D., 1886, vol. iii. pp. 340–43. Hochstetter, "Uber Mikro-organismen im Kunstlichen Selterswasser," *Arbeiten aus dem Kais. Gesundheitsamt*, ii.

Johnson, "On Goitre and Water," *Edin. Monthly Jour.*, May 1855.

Kirchner, "Uber die Brauchbarkeit der Berkefeld Filter," *Zeitschrift für Hygiene*, xiv., 1893, p. 307. Koch, *Berliner Klin. Wochenschrift*, 1884, Nos. 31, 32, and 32a; also "Water filtration and Cholera," translated from the German, *Practitioner*, vol. li., 1893, p. 146. Krieger, "Die Beurtheilung von Trinkwasser nach dem Ergebniss der chemischen und bakteriologischen Untersuchungen," *Arch. f. öffentlich. Gesundheitspfl. in Elsass-Lothringen*, Bd. xvi., 1895, hft. 2, p. 132. Kynsey, *Report on Anæmia or Beri-beri of Ceylon*, Colombo, 1887.

Leffmann and Beam, *Examination of Water for Sanitary and Technical Purposes*, London, 1895. Leone, "Untersuch. uber die Mikro-organismen," *Achiv. f. Hyg.*, iv. Letheby, "On the Quantity of Water used in London," *Report of the East London Water Bills Committee*, 1867. Leuckart, *Die Menschlichen Parasiten*, band ii. p. 220. Lewis and Cunningham, "Cholera in Relation to certain Physical Phenomena," Calcutta, 1875. Lewis, *Service Chemistry*, London, 1892. Luksch, "Zur Differenzial diagnose des Bacillus typhiabdom. und des Bact. coli communis," *Central. f. Bak.* xii., 1892. Lustig, *Diagnostik der Bakterien des Wassers*, Jena, 1893.

MacAdam, "Cholera and Impure Water," *Trans. Roy. Scot. Soc. of Arts*, vol. vii. p. 341. Macnamara, *Asiatic Cholera*, Lond., 1876. Macé, *Traité pratique de Bacteriologie*, Paris, 1892. Miquel, *Manuel pratique d'Analyse bacteriologique des eaux*, Paris, 1891. Moore, "On Malarial Fever produced by Water," *Indian Annals*, 1867. Mori, "Uber pathogene Bakterien im Canalwasser," *Zeitsch. f. Hyg.*, vol. iv., 1888, p. 47. Muir, "Water Supply to London," *Report on the East London Water Bills Committee*, 1867. Murray, "On the influence of Lime and Magnesia in Drinking Water in the production of Disease," *Brit. Med. Jour.*, 1872, vol. ii. p. 349.

North, W., "Lectures on Malarial Fevers and Local Conditions as affecting their Distribution, as studied in the Province of Rome," *Brit. Med. Jour.*, vol. i., 1887, p. 931. Notter, "Sanitary Notes on Potable Water," *Sanitary Record*, vol. x. p. 237.

Oldekop, "On Cholera and Impure Water," *Virchow's Archiv.*, band. xxvi. p. 117.

Page, "Enteric Fever at New Herrington, Durham," *Local Gov. Board Reports*, Sept. 1889. Parent-Duchatelet, "On Diarrhœa caused by Sulphate of Lime and other Purgative Salts in Water," *Hygiene Publique*, t. i. p. 236. Parietti, "Metodo di ricerca del Bacillo dil tifo nelle acque potabili," *Revista d'Igiene e Sanita publica*, 1890. Pettenkofer, *Ueber Cholera und deren Beziehung zur parasitären Lehre*, 1880; also "Cholera at Hamburg," *Lancet*, vol. ii., 1892, p. 1182. Piefke, *Die Principien der Reinwassergewinnung vermittelst Filtration*, Berlin, 1887. Pfuhl, "Bakterioschopische Untersuch. im Winter 1884–5," *Deutzch Militärarztl Zeitsch.*, 1886, xv. Heft. 1. Pistor, "Cholera Epidemic of 1873–74," *Report of the Cholera Commissioners of the German Empire.* Power, "On the Plumbo-solvent Action of Water," *Supp. to Local Gov. Report for 1887*, also *Supp. to 23rd Report*, 1894, p. 332. Pouchet, "Analyses bactériologiques des Eaux de Vichy," *Annales d'Hyg. Publique*, 1894, vol. ii. No. 3, p. 198. Prudden, "On Bacteria in Ice," *New York Medical Record*, March 26th and April 2nd, 1887.

Radcliff, "On Cholera in East London," *Report of the Medical Officer to the Privy Council*, 1865. Richardson, "On Calculi at Norwich," *Medical Times and Gazette*, 1864, p. 100. Richmond, "Notes on Pathogenic Spirilla," *Lancet*, 1894, vol. ii. No. 12, p. 681. Reidel, "Die Vermehrung der Bakterien im Wasser," *Arbeiten aus dem Kaiserlichen Gesundheitsamte*, vol. i. Reinsch, "Die Bakteriologie im Dienst der Sandfiltrations-technik," *Centr. f. Bak.*, Bd. xvi. No. 22. Roscoe and Lunt, "On Schutzenberger's Method for the Determination of Oxygen in Water," *Journal Chemical Society*, 1889, vol. i. p. 552. Routh, *Fœcal Fermentation as a Cause of Disease*, London, 1856, p. 34. Roux, *Precis d'Analyse Microbiologique des Eaux*, Paris, 1892.

Sanarelli, "Les Vibrions des eaux et l'Etiologic du Cholera," *Annales de l'Institut Pasteur*, vol. vii., 1893. Seyler, "Notes on Water Analysis," *Chemical News*, August 31st and Sept. 7th, 1894. Slater, "Investigation of Artificial Mineral Waters," *Jour. Path. and Bacteriology*, vol. i., 1893, p. 468. Smart, "Malarious Poisoning through Water," see *A. M. D. Reports*, vol. xix. p. 19. Simon, *Public Health Reports*, London, 1887. Smith, A., *Air and Rain*, London, 1872. Smith, F., *A Manual of Veterinary Hygiene*, London, 1893.

SNOW, *On the Mode of Communication of Cholera*, London, 1855. STEINER, "Sodawasser," *Archiv. für Hygiene*, vol. ii. p. 436. SUTTON, *Volumetric Analysis*, London, 6th Ed., 1891.

THORNE, "On Enteric Fever at Caterham and Redhill," *Loc. Gov. Reports*, 1878. THORPE, *Dictionary of Applied Chemistry*, London, 1893. THRESH, "A New Method for the Estimation of Oxygen in Water," *Jour. Chem. Soc.*, March 1890. TIEMANN and GÄRTNER, *Die Chemische u. mikroskopisch-bacteriologische Untersuchungen des Wassers*, Braunschweig, 1889. TRILLICH, *Zeitschrift für angewand. Chemie*, 1889, p. 337.

UFFELMANN, *Berliner Klinische Wochenschrift*, 1891.

WANKLYN, *Water Analysis*, 8th Ed., London, 1891. WARD (MARSHALL), "Action of Light upon Bacteria," *Proc. Roy. Soc. Lond.*, 1893; also *Chem. News*, Nov. 9th and 16th, 1894. WARRINGTON, "On the Nitrifying Organism," *Bulletin of the Rothamsted Experimental Station*, No. 8, 1891. WEIBEL, "Untersuchungen über Vibrionen," *Central. f. Bacteriologie*, vol. iv., 1888. WHALLEY, "Malarious Poisoning through Water," *Brit. Med. Jour.*, Nov. 1884. WHITE, "On Lead in Water," *Brit. Med. Jour.*, 1889, ii. p. 459. WILSON, *Handbook of Hygiene*, 7th Ed., London, 1892. WINKLER, *Berichte der chem. Gesellschaft*, 1888, hft. 2843. WOLFFHÜGEL, "Wasserversorgung," *Handbuch der Hygiene*, Herausgegeben von v. Pettenkofer u. Ziemssen, Leipzig, 1882; also "Erfahrungen uber den Keimgehalt brauchbarer Trink und Nutzwasser," *Arbeiten a. d. Kais. Gesund.*

ZIMMERMANN, *Die Bakterien unserer Trink und Nutzwasser insbesondere des Wassers der Chemnitzer Wasserleitung*, Chemnitz, 1890.

CHAPTER II.

AIR.

It might be inferred from the physiological evidence of the paramount importance of proper aëration of the blood, that the breathing of air rendered impure from any cause is hurtful, and that the highest degree of health is only possible when to the other conditions is added that of a proper supply of pure air. Experience strengthens this inference. Statistical inquiries on mortality prove beyond a doubt that of the causes of death which are usually in action, impurity of the air is the most important. Individual observations confirm this. No one who has paid any attention to the condition of health, and the recovery from disease of those persons who fall under his observation, can doubt that impurity of the air marvellously affects the first, and influences, and sometimes even regulates, the second. The average mortality in this country increases tolerably regularly with density of population. Density of population usually implies poverty and insufficient food and unhealthy work; but its main concomitant condition is impurity of air from overcrowding, deficiency of cleanliness, and imperfect removal of excreta, and when this condition is removed a very dense and poor population may be perfectly healthy. The same evidence of the effect of pure and impure air on health and mortality is still more strikingly shown by horses; for in that case the question is more simple, on account of the absolute similarity, in different periods or places, of food, water, exercise, and treatment. Formerly, in the French army, the mortality among the horses was enormous. Rossignol states that previous to 1836 the mortality of the French cavalry horses varied from 180 to 197 per 1000 per annum. The enlargement of the stables, and the increased allowance of air, has reduced the loss in the present day to 24·2 per 1000.

In the English cavalry (and in English racing stables) the same facts are well known. The annual mortality of cavalry horses (which was formerly great) is now (1895) reduced to 23·7 per 1000. Glanders and farcy have disappeared, and if a case occurs it is generally contracted in billets.

The food, exercise, and general treatment being the same, this result has been obtained by cleanliness, dryness, and the freest ventilation. The ventilation is threefold—ground ventilation, for drying the floors; ceiling ventilation, for discharge of foul air; and supply of air beneath the horses' noses, to dilute at once the products of respiration.

In cow-houses and kennels similar facts are well known; disease and health are in the direct proportion of foul and pure air.

The air may affect health by variations in the amount or conditions of its normal constituents, by differences in physical properties, or by the presence of impurities. While the immense effect of impure air cannot be for a moment doubted, it is not always easy to assign to each impurity its definite action. The inquiry is, in fact, in its infancy; it is difficult, and demands a more searching analysis than has been given, although an important commencement has been made by means of biological tests. When impure air does not produce any very striking disease, its injurious effects may be overlooked. The evidences of injury to health from impure air are found in a larger proportion of ill-health—*i.e.*, of days lost from sickness in the year—than under other circumstances; an increase in the severity of many diseases, which, though not caused, are influenced by impure air; and a higher rate of mortality, especially among children, whose delicate frames always give us the best test of the effect of food and air. In many cases accurate statistical inquiries on a large scale can alone prove what may be in reality a serious depreciation of public health.

THE COMPOSITION AND PHYSICAL PROPERTIES OF AIR.

The following may be taken as the composition of average air :—

Oxygen,	209·6 per 1000 volumes.
Nitrogen, . . .	790·0 ,,
Carbonic acid (or carbon dioxide).	0·4 ,,
Watery vapour,	varies with temperature.
Ammonia, . .	trace.
Organic matter (in vapour or suspended, organised, unorganised, dead, or living),	variable.
Ozone,	
Salts of sodium,	
Other mineral substances,	

This air, when pure, is free from colour, taste, or smell, and is not a chemical combination of the different factors which compose it, but a mere mechanical mixture. That such is the case, is proved by the facts that the gases, of which the air is made up, do not exist in it in their proper combining proportions, nor in any multiple of these, and that the relative amounts of these gases in the air cannot be expressed by any chemical formula. Moreover, on mixing the gases of which air is composed together in the same proportions as they exist in air, there is no manifestation either of heat, electricity, or change of volume, such as would result were the air a chemical compound. The mixing of these constituents is so perfect, that analyses of the ordinary outer air, in all parts of the world, give results which vary but little from the above figures. This uniformity of composition is due to the diffusion of gases, to changes of temperature, to the influence of air-currents, and also to the reciprocal action of animals and plants upon the air; it obtains, however, only in places where the air is free to move in every direction, either by the action of differences of temperature or of winds. In inclosed spaces, like courts, where winds have little or no action, and where decomposition of organic matters is often going on, various substances may be added to the air, which, both from their amount and influence upon health, have to be regarded as impurities.

Nitrogen, which is the main constituent of our atmosphere, constitutes 79 per cent. of the air by volume, and 76·9 per cent. by weight. It is a chemical element found everywhere in nature, particularly in the tissues of all animals and plants, and is essential to the existence of all forms of life. In the air, nitrogen appears to act as a diluent of the oxygen, evidently reducing its strength and rapidity; it is also probable that it may serve to supply plants with a certain amount of nourishment in the form of oxides, which are washed down out of the air into the soil after storms of rain; but on this point, as yet, very little is known.

The recent researches of Rayleigh and Ramsey indicate that, of what hitherto has been considered nitrogen in the air, some 1 per cent. is a remarkable elementary gas, termed, by these observers, *argon.* It is the most inert body known, and, so far as has yet been ascertained, cannot be made to combine with any other body. Its atomic weight is apparently 39·6, its density 19·9; its freezing point is – 189°·6 C., that of nitrogen being – 214° C. Argon possesses a double spectrum, in this respect resembling nitrogen and certain other elements.

Oxygen.—Although practically only constituting one-fifth of the atmosphere, oxygen is the most important component of the air, being necessary for the maintenance of every kind of combustion and life. It exists in the air in a free state, and is not chemically combined with the nitrogen of the atmosphere, but only mixed with it. The amount of oxygen in pure mountain air is usually 20·96, by volume, per cent. and 23·20 by weight; while in the air of towns these figures may fall as low as 20·87 and 23·10 respectively.

A modification of oxygen occurs in small traces in the atmosphere, and is known by the name *ozone.* This is a gas considered to be an allotropic form of oxygen, three volumes being condensed into two, thus, $3O_2 = 2O_3$. It is believed to be produced from the oxygen of the air, either by electrical currents generated during thunderstorms, or by weak currents of frictional electricity generated by the friction of large masses of water, such as the sea, against the air, or possibly by the evaporation of water in the presence of sunlight. By whatever process ozone may be produced, it is impossible to convert all the oxygen into ozone, that is, it cannot be obtained in a pure state, but always contains admixed oxygen, a mixture containing about 20 per cent. of ozone to 80 per cent. of oxygen, being about the strongest that has ever been made. As prepared in the laboratory, ozone has a specific gravity of 24, and is heavier than air; it is characterised by a special odour and by having special oxidising powers; it is non-combustible and slightly soluble in water. If present in large quantities, ozone proves fatal to animals, and in lesser amounts is an irritant to the eyes, nose, and respiratory tract. Owing to the unreliability of methods for testing the presence of this gas, some doubt has arisen whether this supposed allotropic oxygen really exists in the free atmosphere. Ilosva's experiments indicate that much, if not all, of what has been supposed to be the characteristics of ozone in the air are really due to nitrous acid.

Carbon Dioxide.—One of the most conspicuous products which result from the action of oxygen upon animal tissues is the carbon dioxide thrown off from the lungs in the process of respiration. This gas, also known as carbonic acid gas and choke damp, is always formed when carbon in any form is burnt with a free supply of air. It is one of the gases evolved from volcanoes and in certain places from fissures in the earth, as near Naples and in Java. Under the influence of sunlight, all plants which contain chlorophyll have the power of taking up carbonic acid, making use of it in their tissues, and yielding oxygen to the air as an excretory product. In this way a constancy in the proportion of these gases in the atmosphere is largely maintained. Speaking generally, an average of from 3 to 4 parts in 10,000 parts of air may be taken as the normal amount of carbon dioxide in the atmosphere, but under certain conditions this amount may vary considerably; it increases slightly up to 11,000 feet of elevation, then decreases; it is augmented under certain circumstances, as in sea-air by day, though not at night; the difference being between 0·54 and 0·33 per thousand (Levy).

Fodor found the CO_2 at Buda-Pesth, during the years 1877–8–9, very constant in quantity, the mean being 0·3886 per 1000 vols. He gives the limits as 0·200 to 0·600, outside which cases occur very seldom, or depend upon errors; the seasonal range is lowest in winter, an increase in spring, again a diminution in summer, and the highest point is reached in autumn. There is less near the sea-shore and more in the middle of the continent; it appears to increase in snow and frost, but to diminish with rain, thaw, and wind; the north wind brings less CO_2 with it than the south. Fodor attributes the greatest influence on the variation of carbon dioxide in the atmosphere to its rising from the ground air, the CO_2 being always greater at the ground level than one metre above it. Levy gives the mean carbon dioxide at the observatory of Montsouris at 0·302 per 1000 vols. in a series of five years' observations. In Dundee, Carnelley, Haldane, and Anderson found an average of 0·390 and a range of 0·220 to 0·560,—the mean of day-time being 0·380 and night-time 0·410;—this was in open places; in close places at night the mean was 0·420. In the suburbs the mean was only 0·280, with a range of 0·180 to 0·350; and in the outskirts of Perth a mean of 0·310, with a range of 0·290 to 0·350.

A tendency is noticeable throughout the later observations upon the amount of carbon dioxide, present in the air, to record a smaller mean proportion than was found by the earlier observers. Thus the earlier results by Saussure and others show a mean of 0·485 per 1000 volumes of air, while the mean of recorded analyses during the past decade gives but 0·324 per 1000 volumes of air. While it is probable that certain local conditions may play a part in causing differences in the proportion of CO_2 found in different places, still it is more probable that the true explanation of these discrepancies is the employment, in recent years, of more accurate methods of analysis than were possible some eighty or ninety years ago, when the earlier observations were made.

Several observers have found monthly, daily and hourly variations in the proportions of this gas, present in the air, but were not able to demonstrate that these changes were a constant accompaniment of any one condition. The following table, from Billings, indicates the monthly variations in the proportion of free carbon dioxide in the air of different places, expressed as volumes of CO_2 in 10,000 volumes of air.

Months.	Montsouris, 1871–85.	Buda-Pesth, 1877–79.	Florence, 1879.	Rostock, 1886–87.	Dorpat, 1888–89.	Orange Bay, Cape Horn, 1882–83.
January,	3·04	3·72	2·92	3·65	2·69	2·55
February,	2·97	3·65	2·98	3·68	2·81	2·71
March,	2·96	4·08	2·99	3·61	2·79	2·55
April,	2·98	3·66	2·95	3·50	2·50	2·54
May,	2·99	3·84	3·07	3·51	2·57	2·65
June,	3·03	3·87	3·59	3·42	2·50	2·50
July, .	2·99	3·73	3·28	3·30	2·61	2·75
August,	2·95	3·89	3·30	3·28	2·83	...
September,	2·97	4·06	3·20	3·34	2·67	...
October,	2·90	4·02	3·00	3·54	2·56	2·50
November,	2·87	4·03	3·04	3·63	2·72	2·60
December,	2·94	4·03	2·99	3·67	2·50	2·53

Ammonia.—This, the most conspicuous of the nitrogenous products of decomposition, is always present in the air, either free or combined. Most commonly, it is only present in the minutest traces; the proportion present is at its minimum in winter, increasing in the spring, and being highest in summer. Plant life derives part of its nitrogen from this source. Though the presence of this gas is largely influenced by local conditions, its mean relative proportion may be stated to be 0·03 milligramme in one cubic metre of air. Moisture and temperature largely affect the amount of ammonia present in the air: it diminishes regularly with rainy weather and a fall of temperature, and increases as the temperature rises after rain. Fodor has shown that it does not come from the ground air, while observations made in this country indicate that the more densely populated a locality is, and the greater the extent of manufacture going on, the higher is the proportion of atmospheric ammonia. The chief factor in causing irregularities in the relative quantity of ammonia in the air is rain, as with every shower some of it is washed from the atmosphere, as evidenced by its presence in the collected rain-water and its diminution in amount present in the air.

Organic and Suspended Matter.—Though more often to be regarded as an impurity, these matters are rarely absent from normal air. For the most part, they are simple microscopic particles of inorganic matter, existing as dust from the earth's surface, but they may be of organic origin, and, as either moulds, yeasts or bacteria, be not wanting in distinct biological characteristics. The actual amount of this suspended matter in normal air will naturally depend upon local conditions, but it may be generally accepted that, excepting in the air of rooms or hospitals, the organic and suspended matter in the atmosphere is chiefly of an innocent nature.

Watery vapour is always present in air, the average amount being from 8 to 10 parts per 1000 volumes, but depending, as it does, so much upon temperature and facilities existing for the atmosphere to take up water, this is perhaps the most variable normal constituent of the air. It is very rarely that there is as much vapour in the atmosphere as is possible for it to hold; when such does exist, the air is said to be "saturated": and in proportion as it is more or less removed from the point of saturation, and not in proportion to the precise amount of water it contains, is air said to be dry or moist. Thus, if air can hold 100 parts of watery vapour, but actually holds only 75 parts, it is said to be only three-quarters moist, or to have 75 per cent. of humidity.

The amount of watery vapour varies in different countries greatly, from about 30 per cent. of saturation to perfect saturation; or, according to temperature, from 1 to 11 or even 12 grains in a cubic foot of air. During the rains in the tropics, that amount is not unfrequently exceeded. The best ratio for health has not been determined, but it has been supposed it should be from 65 to 75 per cent.; in many healthy climates, however, it is much more, and in some much less than this.

The following table shows roughly the weight of watery vapour which a cubic foot of air can hold at different temperatures:—

At 10° F.	1·1 grains.	At 65° F.	6·8 grains.
15° ,,	1·3 ,,	70° ,,	7·9 ,,
20° ,,	1·5 ,,	75° ,,	9·2 ,,
25° ,,	1·8 ,,	80° ,,	10·7 ,,
30° ,,	2·1 ,,	85° ,,	12·4 ,,
35° ,,	2·5 ,,	90° ,,	14·3 ,,
40° ,,	3·0 ,,	95° ,,	16·6 ,,
45° ,,	3·6 ,,	100° ,,	19·1 ,,
50° ,,	4·2 ,,	110° ,,	25·5 ,,
55° ,,	4·9 ,,	120° ,,	34·0 ,,
60° ,,	5·8 ,,	130° ,,	42·5 ,,

Or in another way, it can be said that a quantity of completely moist air at 32° F. holds in suspension an amount of vapour equal to $\frac{1}{160}$th part of its own weight, at 59° F. $\frac{1}{80}$th, at 86° F. $\frac{1}{40}$th, at 113° F. $\frac{1}{20}$th, and at 140° F. $\frac{1}{10}$th. Expressed mathematically, it can be said that while the temperature advances in arithmetical progression, the power of the air to retain vapour increases with the rapidity of a geometrical series having a ratio of two.

When watery vapour mixes with dry air, the volume of the latter is increased: if the weight of the original volume of dry air be known, it will be found that, for the same volume, the addition of the water vapour has lessened the weight, and that the diminution in weight is proportionate to the amount of vapour added. The weight of a cubic foot of dry air at 50° F., and under a pressure of 29·92 inches of mercury, is 546·8 grains, and that of a cubic foot of vapour at the same temperature and same pressure is 4·10 grains: the two together should weigh 550·9 grains; but owing to the increase in volume of the air, which the addition of water vapour causes, namely, an increase from unity to 1·0121, we find that a cubic foot of saturated air at 50° F. weighs only 544·3 grains. In other words, dry air is heavier than moist air, and the diminution in weight, which follows the addition of watery vapour, is proportionate to the temperature, because the higher the temperature of the air, the greater is the amount of vapour that it can take up.

Watery vapour, as it exists in the atmosphere, exerts an elastic or expansive force in all directions. This is sometimes called the *tension of aqueous vapour*, and is dependent upon temperature, it is also capable of doing work, as expressed by the height in inches of a column of mercury which it can support. The elastic force or tendency to escape from containing vessels, which vapour has, increases with a rise in temperature, until the boiling point of water is reached, when it exactly equals the normal pressure of the atmosphere.

The amount of moisture in the air can be determined by causing a current of air to flow slowly through tubes containing hygroscopic substances, such as caustic potash or hydrochloric acid, and then, by weighing, to note the exact increase in weight which has taken place, and knowing the exact volume of air which has been passed through, to calculate the moisture present as a percentage. It is more usual, however, to determine the atmospheric moisture by means of instruments called "hygrometers," particulars of which are given in a subsequent chapter. The amount of aqueous vapour occurring in the air, at different places, naturally varies very much, less being found inland with a low temperature than out at sea with a high temperature. For the same locality, daily fluctuations of atmospheric humidity take place, depending in most cases upon changes of temperature; thus on the sea coast the absolute humidity of the air increases from sunrise until about 2 P.M., when a corresponding diminution sets in and continues until sunrise again. Inland, the same sequence of events occurs during the winter months, but in the summer there is usually a slight fall followed by a rise between the hours of 4 and 6 P.M. After 6 o'clock the decrease of vapour is gradual until sunrise the next morning.

Important as are the facts relating to the chemical composition of the air, still, when considered in special reference to the mechanics and problems of ventilation, the physical properties of air are more important. The reason of this is, that the movements of air currents, with which ventilation is intimately concerned, depend upon differences in weight between adjacent equal volumes of air.

Weight of Air.—That air has weight is shown by the fact that if a glass globe of known capacity be taken, exhausted of all air by means of an air-pump and then weighed, its weight then will be less than it would be if air were allowed to enter it. If the capacity of the globe be known, the difference between the two weights is the weight of that volume of air. The weight, however, of a given volume of air differs under varying circumstances. We have already seen how, if the temperature and pressure be the same, a cubic foot of air weighs heavier when dry than when moist. Similarly, if the moisture and pressure be the same, it weighs more at a lower temperature than at a higher one, and its weight increases with the pressure, if the temperature and moisture be the same. Hence to determine the weight of a given volume of air, by comparing it with a standard fixed by experiment, we must know not only the proportion of contained watery vapour, but also the temperature and pressure.

Effects of Temperature.—When air, under constant pressure, is heated, it expands or increases in volume according to a definite law (Charles), which is, that for each degree of temperature added to its heat, it expands a certain constant fraction of its own volume, this fraction being known as the co-efficient of expansion. For each degree Centigrade from 0° to 100°, this co-efficient is for air 0·003667; for each degree on the Fahrenheit scale, between 32° and 212°, it is 0·002036; thus, 1 litre of air at 0° C. will become 1·003667 litre at 1° C., and 1·03667 litre at 10° C.; or at any given temperature t, it will become $1+(0{\cdot}003667t^{\circ})$ litre. In the same way, 1 cubic foot of air at 32° F. will be 1·002036 cubic foot at 33° F., and at any given temperature t above 32° F. its volume will be found by the formula, $V=1+(0{\cdot}002036\times(t-32))$. To find, therefore, what the observed volume of air or gas v', at the observed temperature, t° C., would be when reduced to 0° C., we have,

$$v^{\circ} : v' = 1 : 1+(0{\cdot}003667t^{\circ})$$
$$v^{\circ} = \frac{v' \; 1}{1+(0{\cdot}003667t^{\circ})}$$

Effects of Pressure.—Under varying conditions of pressure, but a constant temperature, the volume of a gas is inversely proportionate to the pressure (Boyle's law). If a litre of gas at one atmosphere be subjected to the pressure of two atmospheres, its volume will be but half a litre; if the pressure be increased to four atmospheres, the volume will be reduced to one quarter of a litre, and so on. This can be expressed in another way, thus, if under a pressure of p millimetres or inches of mercury, the volume of air be v, its reduced volume v'', under normal conditions of 760 mm. or 29·92 inches of mercury, may be found by the following equation:—

$$v : v'' = 760 : p$$
$$\therefore v'' = \frac{v \, . \, p}{760}.$$

As the temperature and pressure always exist together, both these factors must be taken into account in reducing volumes of air or gas to standard conditions of temperature and pressure; that is, to 0° C. or 32° F., and to 760 mm. or 29·92 inches of mercury respectively. In actual practice it is more convenient to make these two corrections together, and write a single formula, thus:—

$$v = \frac{v' \, . \, p}{760(1+(0{\cdot}003667t^{\circ}))}, \text{ in which}$$

v = volume of air required under normal conditions of temperature and pressure,
v' = observed volume of air,
p = observed pressure under which the air exists.

An example may make this more evident.

Example.—A volume of air at 20° C. and 720 mm. pressure measures 1000 litres; what will be its volume under standard conditions?

Applying the formula, we get,

$$v = \frac{1000 \times 720}{760(1 + (0 \cdot 003667 \times 20))} = 882 \cdot 6 \text{ litres.}$$

Although Boyle's law tells us that, the temperature remaining the same, the volume of a given quantity of gas is inversely proportional to the pressure to which it is subjected, still, as the quantity of the gas remains the same, its density must obviously increase as its volume diminishes; therefore, it follows that for the same temperature, the density of a gas, and therefore its weight, is proportional to its pressure. By Charles' law, on the other hand, though the volume increases directly with temperature, the density or weight varies inversely. If we remember, therefore, that a litre of dry air at 0° C. and 760 mm. weighs 1·293 grammes, and that density varies inversely as absolute temperature, and directly as pressure, it is obvious that for any volume v, at any pressure p, and at any temperature $t°$, the weight W will be:—

$$W = \frac{1 \cdot 293 \times v \times p}{760(1 + (0 \cdot 003667 \times t))}.$$

Example.—Thus, 1000 litres of dry air which, at 0° C. and 760 mm., weigh 1293 grammes, would only weigh 1141 grammes at 20° C. and 720 mm., because,

$$W = \frac{1 \cdot 293 \times 1000 \times 720}{760(1 + (0 \cdot 003667 \times 20))} = 1141 \text{ grammes.}$$

In the case of a volume of moist air, the calculation of the weight is not quite so simple. As this determination involves a knowledge of the hygrometric condition of the atmosphere, and references to tables of the tension of aqueous vapour, it will be more conveniently considered in a subsequent chapter.

Diffusion of Air.—The diffusibility of gases is well known, being, according to the law of Graham, "inversely as the square roots of the densities." Thus, if we take two vessels of equal size, the one containing oxygen and the other hydrogen, and separate them by means of a porous plug, we shall find diffusion take place in the proportion of 4 parts of the hydrogen into the oxygen to every 1 part of the oxygen into the hydrogen. This exact ratio of diffusion is explained by the fact that the density of the hydrogen is 1 as compared with the 16 of the oxygen, consequently the diffusion force is inversely as the square roots of these numbers, that is, it is inversely as 1 is to 4, or just four times as great in the one which has one-sixteenth the density of the other.

It is this faculty of diffusion, possessed by the air and all gases, which conduces so largely to the composition of air being kept constant, and which enables the carbon dioxide so freely formed in our large towns and cities, by combustion and respiration, to be rapidly removed from where it is formed to other parts, where the processes of vegetation and sunlight can break it up into carbon for the food of plant life and oxygen for the use of men. Apart from this, the variations in density of different masses of air play an important part in the maintenance of ventilation.

The velocity with which a mass of air, of known density, diffuses into a vacuum is expressed by the formula, $v = \sqrt{2gh}$; in which h represents the pressure under which the air flows, expressed in terms of the height of a column of air, which would exert the same pressure as does the effluent air. Thus, if air, under standard pressure, were to flow into a vacuum, this pressure or h is equal to that exerted by a column of air capable of counterpoising the weight of a column of mercury 760 mm. high. As mercury is about 10,500 times denser than air, the equivalent column of air would be $10{,}500 \times 760 = 7980$ metres. In the formula, g represents the accelerative force of gravity per second, being in these latitudes 32 feet or 9·8 metres. The velocity, then, with which air, under ordinary pressure, would flow into a vacuum would be, $v = \sqrt{2 \times 9{\cdot}8 \times 7980} = 395{\cdot}5$ metres per second. This, however, would only be in the first second of time, and owing to a gradual accumulation in the vacuum, a gradual diminution in the difference of pressure between the inside and outside of the vacuum would ensue for each succeeding second. Hence, if during the act of diffusion the pressure in both spaces be noted at certain intervals and be expressed by h, h', the velocity of diffusion at each of these periods would be more correctly calculated from the formula:—

$$v = \sqrt{2 \times g \times (h - h')}.$$

In actual practice, the chief cause of the alterations in the relative densities of the two masses of air, and consequently of their motion, is the elevation in the temperature of one body of air over that of the other; hence, to determine the velocity with which one diffuses into or rushes to occupy the space of the other, we must further modify the formula, thus:—

$$v = \sqrt{2 \times g \times (h - h') \times (t - t') \times a},$$

in which t is the temperature of the warmer volume and t' that of the colder volume of air; while a is the co-efficient for expansion of gases.

As we shall see, later on, this formula is purely theoretical, and needs to be only employed after certain corrections for friction, curves, and changes in size or shape of openings have been applied.

Besides the diffusion and movement of adjacent volumes of air, caused by different densities, there is a constant tendency towards diffusion between similar bodies of air, even though apparently separated one from the other. In this case, the current occurs, not through free openings, like doors, windows, or shafts, but through the capillary pores of the separating medium; and may be from the cooler and denser toward the warmer and rarer body, or *vice versa*.

IMPURITIES IN AIR.

A vast number of substances, vapours, gases or solid particles continually pass into the atmosphere. Many of these substances can be detected neither by smell nor taste, and are inhaled without any knowledge on the part of those who breathe them. Others are smelt or tasted at first; but in a short time, if the substance remains in the atmosphere, the nerves lose their delicacy; so that, in many cases, no warning, and in other instances slight warning only, is given by the senses of these atmospheric impurities.

As if to compensate for this, a constant series of processes occur in the atmosphere or on the earth, which keep the air in a state of purity.

Gases diffuse, and are carried away by winds, and thus become so diluted as to be innocuous; or are decomposed if compound, or are washed down by rain; solid substances lifted into the air by winds, or by ascensional force of evaporation, fall by their own weight; or if organic, are oxidised into simple compounds, such as water, carbon dioxide, nitric acid, and ammonia; or dry and break up into impalpable particles, which are washed down by rain. Diffusion, dilution by winds, oxidation, and the fall of rain, are the great purifiers; and, in addition, there is the wonderful laboratory of the vegetable world, which keeps the carbon dioxide of the atmosphere within certain limits. If it were not for these counterbalancing agencies, the atmosphere would soon become too impure for the human race. As it is, it is wonderful how soon the immense impurity, which daily passes into the air, is removed, except when the perverse ingenuity of man opposes some obstacle, or makes too great a demand even upon the purifying powers of Nature.

The air passing into the lungs in the necessary and automatic process of respiration is drawn successively through the mouth and nose, the fauces, and the air-tubes. It may consist, according to circumstances, of matters perfectly gaseous (as in pure air), or of a mixture of gases and solid particles, mineral or organic, which have passed into the atmosphere.

The truly gaseous substances will doubtless enter the passages of the lungs, and will meet there with the delicate tufts of blood-vessels, through which the blood flows with great velocity, and from which they are separated only by a most delicate epithelium; there the gases will be absorbed, and if, as has been calculated, the surface of the air-cells is as much as from 10 to 20 square feet, we can well understand the ease and rapidity with which gaseous substances will enter the blood.

The solid particles or molecules entering with the air may lodge in the mouth or nose, or may pass into the lungs, and there decompose, if of destructible nature; or may dissolve or break down if of mineral formation; or may remain as sources of irritation until dislodged; or perhaps become covered over with epithelium like the particles of carbon in the miner's lung, or may pass into the epithelium, and enter the body through the lymphatics.

If such particles lodge in the mouth or nose they may be swallowed, and pass into the alimentary canal, and it is even more probable that this should be the case with all except the lightest and most finely divided substances, than that they should pass into the lungs. Although incapable of present proof, there is some reason to think that some of the specific poisons, which float about in an impure atmosphere, such as those which arise from enteric or cholera evacuations, may produce their first effects, not on the lungs or blood, but on the alimentary mucous membrane, with which they are brought into contact when swallowed.

Though no very precise classification can be made of the various impurities which vitiate the air, for practical purposes it is convenient to divide them into (1) Suspended matters; (2) Gaseous and other offensive substances yielded by factories, workshops, mines, sewers, marshes, and cemeteries; (3) Products from combustion or artificial lighting; (4) Products from respiration and perspiration.

Suspended Matters.—An immense number of substances, organic or inorganic, may be suspended in the atmosphere. From the soil the winds lift silica, finely powdered silicate of aluminum, carbonate and phosphate of calcium, and peroxide of iron. Volcanoes throw up fine particles of carbon, sand, and dried mud, which, passing into the higher regions, may be carried over hundreds or even thousands of miles.

The animal kingdom is represented by the débris of the perished creatures which have lived in the atmosphere, and also it would appear that the ascensional force of evaporation will lift even animals of some magnitude from the surface of marsh water.

From the vegetable world pass up seeds and débris of vegetation, pollen, spores of moulds and bacteria, as well as innumerable volatile substances or odours.

From the sea the wind lifts spray, and the chloride of sodium becoming dried is so diffused through the atmosphere that it is difficult, on spectrum analysis, to find a spectrum without the yellow line of sodium.

The works and habitations of man, however, furnish matters probably of much greater importance from a hygienic point of view.

In the external air, the suspended matters are partly mineral, partly organic. The mineral matters consist largely of silica, iron, chalk, clay, soot, salt, &c. As rain not only prevents such particles being lifted by the wind, but also washes suspended matters out of the air, it naturally follows that there are more present in the atmosphere during dry weather. The organic suspended matters are principally pollen, algæ, fragments of wood, hair, straw, stable manure, débris of insects, &c. In warm climates diatoms may be found; while in the large manufacturing towns of this and other countries the air is often laden with soot and dust of organic origin, which floats in considerable quantities near the ground surface. Even in country districts the suspended matters are not inconsiderable in the outer air, such substances as epidermis of hay, fragments of wood, linen and cotton fibres, feathers, carbon, mineral grains and epithelium having been collected.

The number of bacteria in the external air depends largely upon local conditions, particularly whether there is moisture, nutritive material, and a suitable degree of warmth (at least 60° F.). They seem to be chiefly derived from the soil surface by the agencies of wind and traffic movements: this explains why they are so numerous in towns, but comparatively scarce in high mountains, over desert plains, or on the sea. It is not known definitely how far bacteria can be carried by wind, but as dust can be conveyed to an almost indefinite distance, it is not unnatural to presume that bacteria may also be carried over considerable distances, particularly if adhering to dust particles. Fischer states that he could find no bacteria in the air at a greater distance than 120 miles from land. Dry winds and drought appear to favour an increase of bacteria in air, while moisture lessens them. These results are possibly due partly to an increased dispersion of micro-organisms from the soil in dry weather, and partly to a condensation and sinking of dust by aqueous vapour which washes the air and brings back the greater number of bacteria to the earth. All observations show that in the outer air the pathogenic bacteria are comparatively few as compared with the saprophytic. As a mean of six years' observations, Miquel found at Montsouris 450 micro-organisms per cubic metre of air; in Paris streets the average number was 900. In the Dundee experiments of Carnelley, Haldane, and Anderson the average number of organisms was less than one per litre of air; the proportion to moulds being as 1 to 3.

The present state of our knowledge goes to show that in the open air the dilution of bacteria is so great, and the number of pathogenic forms so small, that no danger is to be feared from them unless they originate from local sources of impurity.

Rooms inhabited by Healthy Persons.—In all inhabited rooms which are not perfectly ventilated, the presence of scaly epithelium, single and tesselated; round cells like nuclei, portions of fibres (cotton, linen, wool), portions of food, bits of human hair, wood, and coal, can be found in addition to the bodies which are present in the external air, though mineral matters and vegetable matters are not so plentiful, as the comparative stillness of the air allows them to fall. Carnelley, Haldane, and Anderson show that there is an enormous increase of *bacteria* in crowded and ill-ventilated rooms, whilst the *moulds* do not increase to the same extent. When the *moulds* and *bacteria* in the external air were as 2 to 6, in houses of four rooms and upwards they were as 4 to 85, in two-roomed houses as 22 to 430, and in one-roomed houses as 12 to 580. These are the actual numbers found per 10 litres of air.

In some cases articles of furniture may furnish certain substances; the flock wall-papers, coloured green by arsenical preparations, give off little particles of arsenical dust into the room; and it has been shown by Fleck that the arsenious acid in the Schweinfürth green, when in contact with moist organic substances, and especially paste or size, forms arseniuretted hydrogen, which diffuses in the room, and is no doubt the cause of some of the cases of arsenical poisoning from green papers.

Sick Rooms.—In addition to being vitiated by respiration, the air of sick rooms is contaminated by the abundant exhalations from the bodies of the inmates, and by the effluvia from discharged excretions. The amount of organic matter is known to be large, but it is difficult at present to give a quantitative statement. The peculiar smell of a hospital is indeed very remarkable, and its similarity in hospitals of different kinds seems to show that the odorous substance has a similar composition in many cases. The reaction of ozone is never given in such an atmosphere.

The scaly and small round epithelia found in most rooms are in large quantity in hospital wards; and probably, in cases where there is much expectoration or exposure of pus or puriform fluids to the air, the quantity would be still larger.

In the well-ventilated wards of the Dundee Royal Infirmary, Carnelley, Haldane, and Anderson found a very small number of micro-organisms.

Considering that the pleuro-pneumonia of cattle is probably propagated through the pus and epithelium cells of the sputa passing into the air cells of other cattle; that even in man there is evidence of a pneumonic or phthisical disease being contagious, the presence in the air of these cells, which possibly may contain the tubercle *Bacillus* or its spores, is worthy of all attention.

The strong evidence adduced by Ransome and others shows that tuberculosis attaches itself to particular small localities; while Cornet has demonstrated the bacilli to be present not only in the air and dust but also on the walls of rooms occupied by phthisical persons. The organism causing erysipelatous inflammation has also been found in the air and in the dust from beneath the floor of a room occupied by persons suffering from erysipelas. In small-pox wards Bakewell also found unequivocal evidence of small-pox matter in the air.

Workshops, Factories, and Mines.—Grinding of steel and iron, and stones; making metallic and pearl buttons; melting zinc; melting solder; carding and spinning textile fabrics of all kinds; grinding paint; making cement, and in fact almost innumerable trades cause more or less dust, derived from the fabrics and materials, to pass into the air.

Sigerson found a black dust composed of carbon, iron and ash, in metal shops. In the air of a printing office there was enough antimony to be chemically detected. In the air of stables were equine hairs, epithelium, moth-cells, ovules, and various fungi.

In addition to these suspended matters, which vary with the kind of work, the air of workshops is largely contaminated by respiration and by the combustion of gas.

In mines the suspended matters are made up of the particles of the particular substance which is being worked, or of rock excavated to obtain metals, of sooty matters from lamps and candles, and of substances derived from blasting.

It is noticeable that in all these cases it is the solid inorganic suspended matters of the air, consisting of dust of various kinds, which are so injurious to health: as a rule, these are only so by virtue of their mechanical irritating influences upon the mucous membranes, particularly the lungs. It is their physical conditions as to roughness, angularity or smoothness, rather than their mere nature, which influences their power for evil; though possibly in some cases they may also serve as vehicles for conveying specific infective disease factors, more especially that of tubercle.

Offensive Gases from Trades.—In the neighbourhood of certain factories or industries more or less dangerous and offensive gases are frequently to be found polluting the air. In some instances these impurities have only the effect of diluting the oxygen in the air, being themselves physiologically harmless. Examples of this exist in the excess of hydrogen and choke-damp in mines, which appear to do more harm by lessening the atmospheric oxygen for respiration than by any special power of their own. In other cases, where many chemical agents are used, extremely noxious gases are frequently emitted into the air. The gaseous waste products of the chief industries are as follows:—

Hydrochloric acid gas, from alkali works.
Sulphur dioxide and sulphuric acid, from copper works—bleaching.
Hydrogen sulphide, from several chemical works, especially of ammonia.
Carbon dioxide, carbon monoxide, and hydrogen sulphide, from brick-fields and cement-works.
Carbon monoxide, from iron furnaces, may amount to from 22 to 25 per cent., from copper furnaces, 15 to 19 per cent.
Organic vapours, from glue refiners, bone-burners, slaughter-houses, knackeries.
Zinc fumes, from brassfounders.
Arsenical fumes, from copper smelting.
Phosphoric fumes, from manufacture of matches.
Carbon disulphide, from some india-rubber works.

The majority of the gaseous products from industries are both irrespirable and offensive, the more markedly hurtful being the vapours of chlorine, iodine, bromine, arsenic and phosphorus, with carbon monoxide, sulphuretted hydrogen and the compounds of carbon and sulphuric acid. It is true that, unless favoured by particular conditions of wind and weather, in most instances the presence of these gases is not noticed by any one outside the factories in which they are produced; still the majority are so irritating as to constitute, if present in any appreciable quantity, very serious atmospheric impurities.

Air in Mines.—In the metalliferous mines the air, according to Angus Smith, is poor in oxygen (205 per 1000 sometimes) and very rich in carbon dioxide (7·85 per 1000 volumes on a mean of many experiments). It also contains organic matter, giving, when burnt, the smell of burnt feathers, in uncertain amount. These impurities arise from respiration, combustion from lights, and from gunpowder blasting. This latter process adds to the air, in addition to carbon dioxide, carbon monoxide, hydrogen and hydrogen sulphide, various solid particles, consisting of suspended salts, which may amount to as much as 6 or 7 milligrammes in each cubic metre of air. These suspended substances are principally potassium sulphate, carbonate, hyposulphite, sulphide, sulphocyanide, and nitrate, carbon, sulphur, and ammonium sesquicarbonate. Much of this may be avoided by the process of getting coal by means of compressed quicklime, which is slaked in holes drilled in the coal.

Nasmyth's investigations upon the air of coal mines show that the average amount of carbon dioxide present in moderately deep mines is 1·81 per 1000, and in deep mines of over 100 fathoms, 2·19 per 1000; the oxygen in deep mines was 204 vols. per 1000; and the amount of oxygen required to oxidise oxidisable matter, both in the deep and moderately deep mines, was 30 vols. per million. In shallow pits the air at the bottom of the downcast shaft appears to be very good indeed, but in the deeper pits the air samples were never as good as obtained from shallow ones. The oxidisable matter seems to vary, but the methods available for this determination explain the differences in the different results. Although micrococci and bacteria, as well as yeasts and moulds, were readily demonstrated as being present in large numbers in the air of all mines, still the micro-organisms do not seem to follow any fixed rule, as in one very bad sample of air, as regards carbon dioxide, there were none, while the same air soon after yielded twenty colonies per litre. In mines, stagnation of air and high temperature are the most favourable circumstances for their growth, but the presence of men and horses is more so.

The relative humidity of the air in mines varies from 85 to 95 per cent.: practically, it is nearly always saturated. This excessive humidity is certainly not desirable from a sanitary point of view, but there is no evidence that it conduces to bad health among the miners. The temperature of mine air is wonderfully uniform, there being neither the great vicissitudes of temperature as above ground nor the frosts.

Haldane's inquiries into the cause of death in mines after explosions show that death chiefly results from suffocation due to the deficiency of oxygen, which becomes displaced by the products of the explosion, *i.e.*, after-damp. Suffocation by deficiency of oxygen occurs when the respired air contains less than 8 per cent. of oxygen, being ushered in by an extremely sudden attack of muscular paralysis, so that there is little warning of the danger when air is inspired deficient in oxygen, and little chance of escape owing to the muscular failure. Suffocation through excess of carbon dioxide is quite different, as it is preceded by gradual respiratory distress in which the neuro-muscular system is aroused to greater activity. In mines, after explosions, in addition to the deficiency of oxygen, danger exists from the after-damp containing often at least two noxious gases in fatal quantities, these being carbon monoxide and hydrogen sulphide.

Black-damp, sometimes also called choke-damp, is one of the gases often found in coal mines. It is distinguished from fire-damp by the fact that it is not explosive when mixed with air, but extinguishes fire, and from after-damp by the fact that it is not the product of an explosion, but collects in the workings under ordinary conditions. Like fire-damp and after-damp, it produces fatal effects when inhaled in sufficient concentration. Haldane's observations show that undiluted black-damp consists of nitrogen containing a seventh of its volume of carbonic acid. A mixture of about 16 per cent. of black-damp and 84 per cent. of air extinguishes lights, whereas a mixture of about 60 per cent. of the black-damp and 40 per cent. of air are required to produce immediate danger to life. Black-damp is the residual gas left on slow oxidation of the carbon and hydrogen of coal by air. Its dangerous physiological action is due to deficiency of oxygen, not to excess of carbonic acid. The effect first appreciable when increasing proportions of black-damp are breathed is due, however, to carbonic acid alone.

Air of Sewers.—The air of cesspools, and especially of the cemented pits, which are still common in many continental towns, and which receive little beyond the solid and liquid excreta and some of the house water, is generally highly impure. Lévy refers to an extreme case, in which the oxygen was lessened to 20 per 1000, the nitrogen being 940 and the carbon dioxide 40. In this case apparently no other gases were present; but in most instances there is a variable amount of hydrogen sulphide, ammonium sulphide, nitrogen, carbon dioxide, and carburetted hydrogen, in addition to fœtid organic matters. These organic matters are in large amount; 62 feet of the air of a cesspool destroyed, in Angus Smith's experiments, as much potassium permanganate as 176,000 cubic feet of pure air, though perhaps some hydrogen sulphide may have been also present.

In sewers the products of decomposition are variable, as not only solid and liquid excreta and house water, but the washings and débris of the streets, the refuse of trades, &c., pass into the sewers. As a rule, the products of decomposition of sewage appear to be much the same as noted above—viz., fœtid organic matters, carbo-ammoniacal substances condensing with the water of the air on the cold walls, carbon dioxide, nitrogen, and hydrogen sulphide. The proportions of these gases are variable; the most common are carbon dioxide and nitrogen; marsh gas is found when oxidation is impeded, and hydrogen sulphide and ammonium sulphide, which form in the sewage in most cases, are liberated from time to time. The gases, however, are, as a rule, of far less importance than the fœtid organic matters, the exact nature of which it would be most desirable to examine more thoroughly.

The organic vapour is carbo-ammoniacal; the putrid substance in the sewage appears, from Odling's observations, to consist largely of amines.

The composition of sewer air will, of course, vary infinitely with the amount of gases disengaged and the degree of ventilation in the sewer. The quantity of oxygen is sometimes in normal amount; it may, however, be diminished in very badly constructed sewers. Parent-Duchâtelet gave an analysis of the air of a choked sewer in Paris, which contained only 137·9 per 1000 of oxygen, and no less than 29·9 per 1000 of hydrogen sulphide. Excluding this analysis, the greatest impurity in the old Parisian sewers was 34 per 1000 of carbon dioxide and 12·5 per 1000 of hydrogen sulphide. The lowest amount of oxygen was 174 per 1000. Hydrogen sulphide was present in 18 out of 19 cases, the mean of the whole 19 cases being 8·1 per 1000. The mean amount of carbon dioxide in 19 cases was 23 per 1000. In the present London sewers of good construction the air is much less impure. Letheby found only 5·32 per 1000 of CO_2, a good deal of ammonia, and only traces of hydrogen sulphide and marsh gas. Miller's experiments in 1867 gave a mean of only 1·06 per 1000 of CO_2 in 18 analyses, and 3·07 per 1000 in 6 other instances, the oxygen 207·1 per 1000. No hydrogen sulphide was present. Russell examined the air in the sewers of Paddington; the most impure air contained 207 oxygen, 787·98 nitrogen, and 5·1 volumes of carbon dioxide per 1000; there was very little ammonia, and no hydrogen sulphide. In 1877 Beetz, in Munich, found 3·14 vols. CO_2, and 0·22 vol. NH_3 per 1000, as an average of 5 analyses.

It is evident that, if we take the carbon dioxide and hydrogen sulphide as indices, sewer air has no constant composition. It is sometimes almost as pure as the outside air, while at other times it may be highly impure. But these gases are probably the least important ingredients of sewer air; that organic matters are present is evident from the peculiar fœtid smell, and in some cases they are in large amount; 8000 cubic feet of the air of a house into which sewer air had penetrated destroyed more than 20 times as much potassium permanganate as the same quantity of pure air (Angus Smith). *Fungi* and *bacteria* grow rapidly in such air, and meat and milk soon taint when exposed to it.

We must also suppose, for facts leave us no other explanation, that those agencies which produce enteric fever may also be present. Whether small-pox, scarlet fever, &c., can own a similar channel of distribution is uncertain, although they are no doubt aggravated by it; that dysentery and diarrhœa may also be caused by exhalations proceeding from a foul sewer we cannot doubt, but the precise agency is here also unknown. Diphtheria and acute follicular tonsillitis are also associated with sewer air; and, if the disease does not originate *de novo*, when once it breaks out, its tendency is to spread where the air and soil are polluted by sewage.

The experiments of Frankland show that solid or liquid matter is not likely to be scattered into the air from the sewage itself by any agitation it is likely to undergo, until gas begins to be generated in it. He found that no ordinary agitation (even greater than sewage is likely to meet with) would scatter particles of lithia solution into the air, but that the bursting of bubbles of carbon dioxide was sufficient to effect it. Hence he argues (with apparent truth) that sewage becomes dangerous in this way only after the setting in of decomposition, so that if we take proper steps to carry away sewage at once the danger becomes reduced to a minimum.

J. D. Robertson, of Penrith, has made bacteriological investigations into the air of sewers, and has found various forms of *cocci*, *bacteria*, and *bacilli* to be present, besides moulds. The most common forms were *bacilli*, which showed a great preponderance over *micrococci*; whereas in the open air, *cocci* forms were more numerous than *bacilli*. The average number of micro-organisms per litre was 4·2 in sewer air (15 experiments) and 5·7 in open air (10 experiments).

The experiments of Carnelley and Haldane on the air in the sewers of the Houses of Parliament, and in Dundee, led them to the following conclusions:—(1) That the air of the sewers was much better than might have been expected; (2) that the carbonic acid was about twice, and the organic matter rather more than three times as great as in the outside air at the same time, whereas the number of micro-organisms was less; (3) that, in reference to the *quantity* of these three constituents, the sewer air was in a very much better condition than that of naturally ventilated schools, and that, with the notable exception of organic matter, it had likewise the advantage of mechanically ventilated schools; (4) that the sewer air contained a much smaller number of organisms than any class of house.

In the Westminster sewer the CO_2 ranged from 0·49 to 0·89 per 1000 vols., the oxygen required for oxidisable matter from 1 to 12·9 vols. per 1,000,000, and the micro-organisms from 0·5 to 38 per litre; in the Dundee sewers these numbers were respectively 0·55 to 1·09, 3·1 to 18·2, and 2·5 to 25. The average results of the whole series were—

	CO_2.	Oxygen.	Micro-organisms.
In sewers,	0·75	7·2	8·9
In outside air,	0·37	2·2	15·9

They consider that the carbon dioxide is chiefly due to the oxidation of organic matter in the sewage and sewer air, and that the micro-organisms present in sewer air are derived from the outside air and not from the sewage itself. These observations have been recently confirmed by Parry Laws; while Arthur has shown that bacteria can undoubtedly grow up the sides or walls of the damp nutrient sewers, and if these latter become at all dry, air currents readily detach and disperse them. Possibly in this way some micro-organisms may get set free in sewer air from the actual sewage, and that the micro-organisms present in sewer air are not so much derived from the outside air as has hitherto been thought. The truth probably lies between the two.

Air of Marshes.—The air of typical marshes contains usually an excess of carbon dioxide, which amounts, perhaps, to 0·6 or 0·8 or more per 1000 volumes. Watery vapour is usually in large quantity. Hydrogen sulphide is present, if the water of the marsh contains sulphates, which in presence of organic matter are converted into sulphides, from which SH_2 is derived by the action of vegetable acids. Marsh gas is also often present, and occasionally free hydrogen and ammonia, and, it is said, hydrogen phosphide.

Organic matter also exists in considerable quantity, and seems to have much the same character always. It blackens sulphuric acid when the air is drawn through it; gives a reddish colour to nitrate of silver; has a flocculent appearance, and sometimes a peculiar marshy smell, and, heated with soda-lime, affords evidence of ammonia.

Besides the organic matter, various vegetable matters and animals, floating in the air, are arrested when the air of marshes is drawn through water or sulphuric acid, and débris of plants, *infusoria*, insects, and even, it is said, small *crustacea*, are found; the ascensional force given by the evaporation of water seems, indeed, to be sufficient to lift comparatively large insects into the air.

Although the researches of Klebs, Tommasi-Crudeli and Laveran have clearly demonstrated malaria to be dependent upon the presence of a micro-organism in the blood, still it has not been so far demonstrated outside the body; and nothing has ever been found in either the air of marshes or other malaria disposed localities which in any way appear to be associated with or throw any light upon the life history of this micro-organism.

Marsh air has been said to be deficient in ozone, but the observations of Burdel do not confirm this.

Impurities from Cemeteries.—The decomposition of bodies gives rise to a very large amount of carbon dioxide. It has been calculated that, when intramural burial was carried on in London, 2½ millions of cubic feet of carbon dioxide were disengaged annually from the 52,000 bodies then buried. Ammonia and an offensive putrid vapour are also given off. The air of most cemeteries is richer in CO_2 than ordinary air (0·7 to 0·9 per 1000), and the organic matter is perceptibly larger when tested by potassium permanganate. In vaults, the air contains much carbon dioxide, carbonate or sulphide of ammonium, nitrogen, hydrogen sulphide and organic matter.

Impurities from Fires and Artificial Lights.—As coal is the chief material used for combustion in our fires, it constitutes the main source of impurities to the atmosphere from various means of heating. For the complete combustion of 1 ℔ of coal at least 160 cubic feet of air are required by theory, but in actual practice from half to twice as much air must be supplied, making the average amount required per pound of coal to be from 240 to 300 cubic feet. During combustion about 1 per cent. of the coal is given off into the air as soot and tarry products, with large quantities of carbon dioxide and carbon monoxide. The actual amounts of these gases given off will depend upon the degree of perfection of the combustion; but it has been calculated that for every ton of coal burnt in London something like three tons of carbon dioxide are produced. In addition to these impurities, the atmosphere receives from the burning of coal, carbon disulphide, ammonium sulphide, water, and occasionally sulphuretted hydrogen, as well as sulphur, sulphur dioxide, and sulphuric acid. Ordinary coal contains from half to seven per cent. of sulphur, and it is not unusual to find in the outer air, in manufacturing districts, from half to one grain of sulphuric acid per 1000 cubic feet of air.

Wood produces, on combustion, carbon dioxide and monoxide, with more water but less sulphur compounds than coal does. The impurities from coke and peat are somewhat similar to those from coal. In cases where the combustion is incomplete or the supply of oxygen is insufficient, much of the carbon becomes incandescent in an atmosphere highly charged with and practically consisting of carbon dioxide, combining with it to form carbon monoxide, thus, $C_2 + 2CO_2 = 4CO$. The blue flames so often seen at the top of a well-drawing clear fire consist of burning carbon monoxide, which has been produced by the carbon dioxide, formed at the lower part of the fire, having to pass over the red-hot coal on its upward way to the chimney. This carbon monoxide is largely given off from charcoal fires and "slow combustion" stoves, and is, moreover, very much more poisonous than the dioxide.

The products of the combustion of coal and wood pass into the atmosphere, and usually are at once largely diluted. Diffusion and the ever-moving air rapidly purify the atmosphere from carbon dioxide.

It is not so, however, with the suspended carbon and tarry matters, which are too heavy to drift far or to ascend high. As a rule, the particles of carbon are not found higher than 600 feet; and the way they accumulate in the lower strata of the atmosphere can be seen by looking at any lofty building in London. The air of London is so loaded with carbon, that even when there is no fog, particles can be collected on an aëroscope when only a very small quantity of air is drawn through.

Sulphurous and sulphuric acids also appear to be less rapidly removed, as Angus Smith found a perceptible quantity in the air of Manchester; and the rain-water is often made acid from this cause.

With regard to the impurities added to the air, consequent on artificial lighting, we find that the chief sources of light are candles, oil, and coal gas, and that the chief products from the more or less complete combustion of these illuminants are carbon dioxide and water, with the addition, in the case of gas, of several products from the combustion of sulphur. Now, the unit adopted in this country for the measurement and comparison of all lights is a sperm candle of a size known as "sixes," burning 120 grains per hour, and which gives a light known as "one candle power." Such a candle, on analysis, contains:—

Carbon,	80·0 per cent.
Hydrogen,	13·0 ,, ,,
Oxygen,	6·0 ,, ,,

and, on complete combustion, yields equal volumes of carbonic acid and water to the air, namely, 0·41 cubic foot.

The French unit of light is the light given out by one Carcel burner, and equals 9·3 English standard candles.

What is known as Harcourt's standard flame gives a light equal to that of one English standard candle. It consists of an air-gas flame, $2\frac{1}{2}$ inches in height, rising from an opening $\frac{1}{4}$ inch in diameter. The flame is that of a mixture of air and pentane: 576 volumes of air being mixed with one of liquid pentane at 15°·6 C. (60° F.); or if both are in the form of gas, 20 of air to 7 of pentane.

Although various kinds of oil have been employed for illuminating purposes, paraffin, owing to its cheapness and high illuminating value, is the only one now in extensive use. Ordinary paraffin, on analysis, gives the following composition:—

Carbon,	86·0 per cent.
Hydrogen,	14·0 ,, ,,

When burnt in the better kinds of lamps, the average consumption per candle power of this oil is just 62 grains per hour, giving off on combustion in that time 0·28 cubic foot of carbonic acid and 0·22 of a cubic foot of water vapour. In the inferior class of lamps, the consumption of oil is often double the above amount, accompanied by the production of 0·5 of a cubic foot of carbon dioxide and the consumption of the oxygen of about 3·2 cubic feet of air.

The chief popular illuminant is gas. Ordinary coal gas is a mixture of gases, consisting mainly of hydrogen and hydrocarbons, produced by the dry or destructive distillation of coal. The coal is heated, without contact of air, in iron retorts, and the products of its destructive distillation are made to pass, firstly, through condensers in which, as a result of the cooling they are subjected to, the heavy coal tar and the lighter ammoniacal tar-liquor are condensed, and are then collected in tanks; and secondly, the gas is led through purifying chambers, containing either moist slaked lime or ferric oxyhydrate spread on shelves, either of which removes the gaseous impurities containing sulphur, the former removing carbon dioxide as well; finally the gas is passed into a gasometer for storing purposes.

The following statement of the analysis of two London gases may be accepted as fairly representing the composition of coal gas generally:—

	South Metropolitan Gas Company.	The Gaslight and Coke Company.
Hydrogen, .	50·16	53·36
Saturated hydrocarbons,	36·25	32·69
Unsaturated hydrocarbons,	3·50	3·58
Carbon monoxide,	5·68	7·05
Carbon dioxide,	0·00	0·61
Nitrogen,	4·10	2·50
Oxygen,	0·31	0·21
	100·00	100·00

In some analyses the carbon monoxide has been as high as 11 per cent., and the light carburetted hydrogen 56; in such cases the amount of hydrogen is small. As much as 60 grains of sulphur have been found in 100 cubic feet of gas. According to the standard of the Metropolitan Gas Referees, all gas must be wholly free from H_2S, the maximum of sulphur (in compounds other than H_2S) allowable is 17 grains per 100 cubic feet, and the maximum of ammonia is 4 grains per 100 cubic feet. In badly purified gas there may be a great number of substances in small amount, especially hydrocarbons and alcohols, such as propylene, butylene, amylene, benzole, xylol, some of the nitrogenous oily bases, such as pyrrol, picoline, &c.

The constituents of coal gas may be divided into three groups, *diluents*, *illuminants*, and *impurities*. The diluents are gases which, without conferring much luminosity on coal gas when burnt, yet serve the important purpose of diluting down the heavy hydrocarbons, which by themselves would yield a smoky flame; the diluents are hydrogen, methane, or marsh gas, and carbonic oxide: they constitute about 90 per cent. by volume of the coal gas. The illuminants are hydrocarbon gases or vapours rich in carbon, and to their presence the luminosity of coal gas when burnt is due; they are ethene or olefiant gas, acetylene, and benzene vapour: they constitute about 6 per cent. by volume of the coal gas. The impurities constitute the remaining four volumes, and consist of nitrogen derived from a little air getting into the retorts when opened for recharging, and of some carbon dioxide, with traces of sulphur compounds which may have escaped removal in the purifiers.

When the gas is partly burnt, the hydrogen and light and heavy carburetted hydrogens are almost destroyed; nitrogen (67 per cent.), water (16 per cent.), carbon dioxide (7 per cent.), and carbon monoxide (5 to 6 per cent.), with sulphur dioxide and ammonia, being the principal resultants. And these products escape usually into the air of rooms. With perfect combustion there will be little carbon monoxide.

Every cubic foot of ordinary coal gas yields, on combustion, roughly half its own volume, or 0·52 cubic foot of carbon dioxide, and 1·34 cubic foot of water vapour: therefore, knowing how much gas per hour each burner consumes, the average being from 3 to 6 cubic feet, there is no difficulty in calculating the vitiation of air from these sources. Combustion, however, in ordinary burners is never absolutely complete: and even with a 16-candle gas very slight traces of carbon monoxide will generally escape combustion, whilst with a rich gas distinct traces of acetylene are also given off. In other words, the actual products of combustion given off by gas will vary much with the quality of the gas used, and the completeness of the process; the usual products being carbon dioxide, carbon monoxide, compounds of ammonia, watery vapour, and various compounds of sulphur. These latter, if present, are particularly injurious to health, but there is reason to believe that their existence in gas-lit rooms has been much exaggerated. For every 100 cubic feet of gas consumed, containing 20 grains of sulphur, there would be 0·032 cubic foot of sulphur dioxide formed, while with an impurer gas, containing 30 grains of sulphur per 100 cubic feet, the sulphur dioxide resulting would amount to 0·048 cubic foot. Except under very unusual circumstances, ventilation would reduce these quantities in nearly the same ratio as the carbon dioxide, the total volume of sulphur dioxide due to the combustion of the gas being reduced to very minute traces, or something like 0·0625 grain of sulphur as sulphurous acid per 100 cubic feet of air.

Speaking generally, it may be said that each cubic foot of gas, burnt per hour from the ordinary burners, vitiates as much air as would be rendered impure by the respirations of an individual; it, at the same time, will raise the temperature of 31,290 cubic feet of air 1° F., and yields 217 calories (a kilogramme of water heated 1° C.), or 860 British heat units (a pound of water heated 1° F.). The following table shows the relative amounts of oxygen removed from the air, and carbon dioxide, watery vapour, and heat calories produced, per hour, by various forms of artificial light: with these facts are also incorporated the candle power, and the number of adults who would exhale the same amount of carbon dioxide in the same time.

	Quantity consumed.	Candle power.	Oxygen removed.	CO_2 produced.	Moisture produced.	Heat Calories produced.	Vitiation equal to Adults.
Tallow candles,	2200 grains.	16	10·7 c. ft.	7·3 c. ft.	8·2 c. ft.	1400	12·0
Sperm candles,	1740 ,,	16	9·6 ,,	6·5 ,,	6·5 ,,	1137	11·0
Paraffin oil lamp,	992 ,,	16	6·2 ,,	4·5 ,,	3·5 ,,	1030	7·5
Kerosene oil lamp,	909 ,,	16	5·9 ,,	4·1 ,,	3·3 ,,	1030	7·0
Coal gas, No. 5 batswing burner,	5·5 c. ft.	16	6·5 ,,	2·8 ,,	7·3 ,,	1194	5·0
Coal gas, Argand burner,	4·8 ,,	16	5·8 ,,	2·6 ,,	6·4 ,,	1240	4·3
Coal gas, regenerative burner, .	3·2 ,,	32	3·6 ,,	1·7 ,,	4·2 ,,	760	2·8
Coal gas, Welsbach incandescent,	3·5 ,,	50	4·1 ,,	1·8 ,,	4·7 ,,	763	3·0
Electric incandescent light,	0·3 ℔ coal.	16	0·0 ,,	0·0 ,,	0·0 ,,	37	0·0

It is sufficiently obvious from the above facts that the most hygienic source of light is the electric incandescent lamp, inasmuch as all other sources of artificial illumination, being dependent on the absorption of oxygen from the air, result in the vitiation of the atmosphere by products which are more or less injurious to health. The electric arc light, which is not contained in a closed globe, is said to vitiate the air by the formation of nitric acid, but even if so, its effects in this direction are much less hurtful than gas, oil, or candles.

Of the various forms of light derived from coal gas, that yielded by the Welsbach or incandescent gas-burner stands out pre-eminently as the best. In view of the fact that the use of these burners has recently increased in a remarkable manner, some observations upon their general construction and hygienic value may not be inappropriate.

The Welsbach incandescent gas-burner (fig. 8), when complete, may be said to consist of two essential parts. The first is an ordinary but carefully adjusted burner of the Bunsen type, in which air is mixed with the gas before it burns in the proportion of 30 of gas to 70 of air, producing a colourless or faintly blue flame. The second part is a fine gauze-like mantle composed of nitrates of the rare earths, cerium, lanthanum, thorium, and zirconium, which is suspended in the flame by means of a forked support of magnesian silicate, itself luminous when hot. The flame and mantle are inclosed in a chimney of glass or other transparent material, which, besides serving as a protection for the fragile mantle from accident, keeps the flame perfectly steady.

The principle of the Welsbach burner is similar to that of other systems of lighting in use, which depend upon the light emitted by an incandescing body. Incandescence is "the brilliant glow given out by certain refractory bodies when they are heated up to a definite point." The light from an ordinary flame is due to the incandescing particles of carbon which are set free from the decomposition of the hydrocarbons during the stages of combustion. Lewes explains the various changes taking place in a luminous gas flame in the following way:—"In the inner zone of the flame, the constituents of the gas undergo various decomposition and interactions, which culminate in the conversion of the heavier hydrocarbons into acetylene, carbon monoxide being also produced; and these, with the products of combustion and residual hydrogen, pass into the next phase of action. Here the acetylene, formed in the inner zone, becomes decomposed by heat, with liberation of carbon, which at the moment of production is heated to incandescence by the combustion of the carbon monoxide and hydrogen and gives luminosity to the flame." In the Welsbach burner, the incandescence is due to the heating of a net-work of oxides of certain rare earths, which emit, at the temperature of the Bunsen flame, a bright, steady, and powerful white light. It affords, in fact, an admirable illustration of the conversion of heat into light rays. The Bunsen flame, though very hot, is without luminosity, because "the nitrogen of the air acts in the normal flame by so diluting and protecting the hydrocarbons that a far higher temperature is needed for their decomposition: this action gives time for the oxygen of the air to consume them, without liberation of carbon, and hence without luminosity" (Lewes). In the incandescent burner, however, by allowing the flame to play upon a refractory body, in the form of a mantle, the heat undergoes a change into the closely allied phenomenon of light. From the hygienic standpoint, the Welsbach burner is simply an ordinary Bunsen burner, over the flame of which is hung a network of incombustible material that is intensely luminous when raised to the temperature of the Bunsen flame.

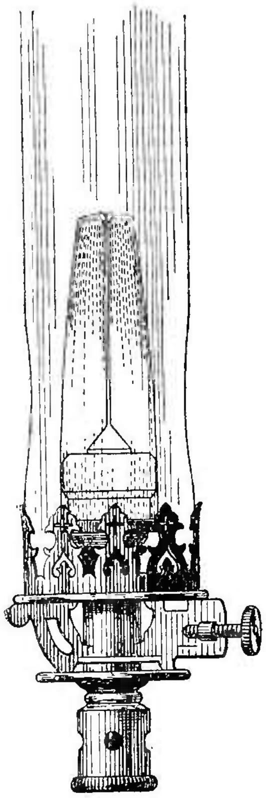


Fig. 8.

In the Clamond system of incandescent gas-lighting, a similar result is obtained by a hood of magnesia and zirconia, which is heated to incandescence by an atmospheric burner; in the Lewis system, again, there is a small hood of platinum; so, in the Sellon light, a cone of metal gauze is used; while in the Swedish system of Farnehjelm there is an extensive use of small pencils of magnesia and zirconia, fixed to a frame in the form of a comb over the flame of a water-gas burner.

The complete combustion of a given volume of coal gas must, of course, on theoretical grounds, give rise to the production of exactly the same products of combustion in whatever burner the gas is burned. "It follows, therefore, that if the consumption of gas be low, the evolution of products will be proportionately reduced, so that, apart from mere questions of economy, a burner that consumes a relatively small amount of gas, to say nothing of the superior light it gives, must be preferable on that account from the hygienic point of view." The marked hygienic advantages offered by the Welsbach burner, in this direction, are well shown in the foregoing tabular statement, based upon the vitiating effects and varying rates of consumption of different forms of artificial light.

It should be observed in addition, however, that the vitiation of air with carbonic acid gas by one Welsbach burner, giving a 50 candle power light and consuming 3·5 cubic feet of gas, is less than one-half that produced by an oil lamp of 16 candle power, and consuming a little over two ounces of oil.

As clearly demonstrated in a very lucid report, upon the incandescent gas light, published by the *Lancet* on Jan. 5th, 1895, and to which we are indebted for the following figures, the Welsbach burner affects the atmosphere far less for evil, judging from the carbonic acid and heat produced, than any other existing type of burner. Thus, "while the increase of carbonic acid per candle power is only 0·365 in the case of the Welsbach light, it is 1·9 in the case of Argand burners, 2·86 in the batswing, and 1·56 in oil lamps"; and the increase of temperature in a room with a Welsbach burner per candle power is "only 0·116° compared with the Argand, 0·59°, the batswing, 0·807°, and oil lamps, 0·468°"

Of all the systems of artificial lighting in common use at the present time, we are bound to place, for reasons already detailed, the incandescent electric light in the first rank from the point of view of health. "From the same point of view we are bound to place next, the incandescent gas-light in its present improved form. It is less productive of carbonic acid gas than the average oil lamp, and consumes not quite one-half less gas than the ordinary burners, giving rise, therefore, to the evolution of half the heat, and half the amount of carbon dioxide, while its illuminating power expressed in candles is more than three times as great as the best ordinary gas-burners or incandescent electric light, each of which rarely exceed 16 candle power." The only gas-light which at all approaches it, in its hygienic advantages, is Siemen's regenerative burner, but that has one-third less illuminating power and is less well adapted for general domestic use. The relative merits of the other forms of artificial light are sufficiently manifest from the figures given above to require no special criticism.

Carnelley and Mackie have shown that the combustion of coal exercises a marked effect on the organic matter in the air of towns; but that the combustion of coal gas in a room has not much effect in increasing the organic matter, whereas a burning oil lamp has a marked effect.

In tobacco smoke are contained particles of nicotine or its salts (Heubel), and probably of picoline bases. There is also much carbon dioxide, ammonia, and butyric acid.

Ripley Nichols has investigated the air in smoking cars on American railways, and found the CO_2 to range from 0·98 to 3·35 per 1000, with a mean of 2·278: in ordinary non-smoking cars the CO_2 varied from 1·74 to 3·67, with a mean of 2·32, so that there was not much difference as far as carbon dioxide went. As regards ammonia, however, the difference was great, for (taking the external air ratio as 100) he found in the smoking car from 310 to 575, whilst in the ordinary cars it was only 135 to 175. None of the peculiar products of the combustion of tobacco were found.

Summing up, we may say that the chief changes produced in the air by the use of artificial lights are elevation in temperature, the addition of moisture, carbonic oxide, carbon dioxide, nitric and nitrous acid, compounds of ammonia, and of sulphur, marsh gas, carbon particles and acids of the fatty group. Apart from these added impurities, the air suffers by the withdrawal of a certain amount of oxygen.

Impurities from Respiration.—It will materially aid our conception of the nature and amount of the impurities added to the air by respiration if we contrast the chemical composition of 100 parts of ordinary atmosphere with 100 parts of expired air, in respect of their chief constituents.

	Ordinary air.	Expired air.
Oxygen,	20·96	16·40
Nitrogen, .	79·00	79·19
Carbon dioxide,	0·04	4·41

From this it will be seen that the expired air contains more than a hundred times more CO_2, nearly five per cent. less O_2, and a small amount of N_2 more than the atmospheric air. Hence, during respiration more oxygen is taken into the body from the air than carbon dioxide is given off; so that the volume of the expired air is from $\frac{1}{40}$ to $\frac{1}{50}$ smaller than the volume of the air inspired, both being calculated as dry, at the same temperature and pressure. This diminution of the volume of expired air is, however, far more than compensated by the warming which the inspired air undergoes in the respiratory passages, so that eventually the volume of the expired air is really one-ninth greater than the air inspired. The relation of the O_2 absorbed to the CO_2 given off is as 4·57 : 4·38. This is expressed by the "respiratory quotient":—

$$\frac{CO_2}{O_2} = \frac{4{\cdot}38}{4{\cdot}57} = 0{\cdot}905.$$

This ratio, between the amount of oxygen absorbed and the amount of carbon dioxide exhaled, varies in different animals; being for man 0·87 to 0·9, for horses 0·97, for oxen and sheep 0·98, and for dogs and cats about 0·75. The changes produced, therefore, in air by respiration are, elevation in temperature, increase of moisture, increase in volume and changes in chemical composition.

An average adult gives out at each respiration 22 cubic inches of air, and, assuming that he breathes eighteen times a minute, the total quantity of air which passes out of the lungs in the twenty-four hours is 570,240 cubic inches, or 330 cubic feet. If we further assume that the expired air contains 4·4 per cent. of *carbon dioxide*, the average adult at rest evolves 14·52 cubic feet of this gas in the twenty-four hours, or 0·6 cubic foot per hour; this amount is, however, largely increased by exertion, and may, in the case of a man doing hard work, reach 37 cubic feet in the twenty-four hours, or, say, 1·6 cubic foot of carbon dioxide exhaled per hour. In the case of big men, say 12 stones in weight and at rest, the CO_2 given off hourly from the lungs is not less than 0·72 cubic foot. Women give off less, about 0·6; while children and old people give off a smaller amount. The quantity given off by women, say 0·6, may be adopted for a mixed community.

The amount of carbon dioxide in pure air being assumed to be on an average 0·4 per 1000, the quantity in the air of the rooms vitiated by respiration varies within wide limits, and many analyses will be found in books. The following table is a part of the numerous experiments on barrack-rooms by de Chaumont on this point, in which the amount of carbon dioxide in the external air was simultaneously determined. The analyses were made at night, when the men were in the rooms. The cubic space per head was 600 feet in the barracks and from 1200 to 1600 in the hospitals:—

	CO_2 in External Air.	CO_2 in Room.		Mean Respiratory Impurity.
		Largest Amount found.	Mean Amount.	
BARRACKS.				
Gosport New Barracks,	0·430	1·846	0·645	0·215
Anglesey Barracks,	0·393	1·971	1·404	1·011
Aldershot,	0·440	1·408	0·976	0·536
Chelsea, .	0·470	1·175	0·718	0·248
Tower of London, .	0·420	1·731	1·338	0·898
Fort Elson (Casemate), .	0·425	1·874	1·209	0·784
Fort Brockhurst (Casemate),	0·422	1·027	0·838	0·416

	CO_2 in External Air.	CO_2 in Room.		Mean Respiratory Impurity.
		Largest Amount found.	Mean Amount.	
MILITARY AND CIVIL HOSPITALS.				
Portsmouth Garrison Hospital,	0·306	2·057	0·976	0·670
Portsmouth Civil Infirmary,	0·322	1·309	0·928	0·606
Herbert Hospital,	0·424	0·730	0·472	0·048
Hilsea Hospital, .	0·405	0·741	0·578	0·173
St Mary's, Paddington,	0·560	1·534	0·847	0·287
MILITARY AND CIVIL PRISONS.				
Aldershot Military Prison—Cells,	0·409	3·484	1·651	1·242
Gosport Military Prison—Cells,	0·555	2·344	1·335	0·780
Chatham Convict Prison—Cells,	0·452	3·097	1·691	1·239
Pentonville Prison—Cells—Jebb's system,	0·420	1·926	0·989	0·569

The last column of the table shows the condition of the ventilation as measured by the carbon dioxide; it is very satisfactory in the newer barracks (Gosport and Chelsea), but is much less so in the older barracks and casemates. The Herbert and Hilsea military hospitals show excellent ventilation, while the old-fashioned Portsmouth garrison hospital is in this respect indifferent. The prison cells show, in all cases, a very high degree of respiratory impurity, and this must be one of the depressing influences of long cell confinement. Wilson gives some important information on this point. In cells (in Portsmouth Convict Prison) of 614 cubic feet, always occupied, he found the $CO_2 = 0·720$ per 1000; the prisoners were healthy and had a good colour. In cells of 210 cubic feet, occupied only at night by prisoners employed outside during the day, he found 1·044 per 1000 of CO_2: the occupants were all pale and anæmic.

The carbon dioxide of respiration is equally diffused through the air of a room; it is very rapidly got rid of by opening windows, and in this respect differs from the organic matter, and probably from the watery vapour; neither appears to diffuse rapidly or equably through a room.

The amount of carbon dioxide is often much greater than in the above instances. In a boys' school, with 69 cubic feet per head, Roscoe found 3·1 parts of CO_2 per 1000. In one-roomed houses in Dundee 3·21 per 1000 was found as a maximum by Carnelley, Haldane, and Anderson; this was 2·63 above the external air. In a schoolroom, naturally ventilated, with an average of 168 cubic feet per head, the mean CO_2 was 1·86 and the maximum 3·78; in another, with the same space, but mechanically ventilated, the average was 1·23 and the maximum 1·96. In the Dundee Royal Infirmary (space per head from 1034 to 3182) the CO_2 ranged from 0·41 to 0·78, or a range of respiratory impurity between 0·06 and 0·37.

In a horse stable at the École Militaire the amount was 7 per 1000. At Hilsea, with a cubic space of 655 cubic feet per horse, the amount was 1·053; and in another stable, with 1000 cubic feet per horse, only 0·593 per 1000 (de Chaumont). Märcker found 8·5 in a stable in Göttingen, and no less than 17·07 in a byre.

F. Smith has shown that the carbon dioxide determinations in stables are greatly influenced by the amount of ammonia in the air interfering with the reaction, thus indicating a factitious purity of atmosphere.

The amount of *water* given off to the air by respiration of course varies with the temperature and condition of humidity of the inspired air, as well as with the size of, and work being done by, each individual; but as an average for twenty-four hours, the amount may be taken as being 10 ounces, or 284 grammes. To this must be added some 20 ounces more of moisture given off by the skin. This is equivalent to about 550 grains per hour. If we assume the average temperature of occupied rooms to be 15°·6 C. (= 60° F.), this means that enough moisture is given off by the human body, in repose, every hour sufficient to saturate 90 cubic feet of air. It is this tendency to become saturated with moisture from the lungs and skin that makes the air of crowded rooms so uncomfortable. Carnelley's experiments show that for every part of carbon dioxide found in the air, 2·7 volumes, or 1·1 part by weight, of moisture have been given off by each person inhabiting the room.

The *organic matters* contained in expired air are small in quantity and of unknown nature. If a large quantity of such air be drawn through distilled water, or if its moisture be condensed by cold, the liquid thus produced contains nitrogenous matter, has a peculiar, unpleasant odour, and usually soon putrefies. This organic matter is apparently partly suspended, and is made up of small particles of epithelium and fatty matters detached from the skin and mouth, and partly of an organic vapour from the lungs and mouth. The organic matter from the lungs, when drawn through sulphuric acid, darkens it; through permanganate of potash, decolourises it; and through pure water, renders it offensive. Collected from the air by condensing the watery vapour on the sides of a globe containing ice, it is found to be precipitated by nitrate of silver, to decolourise potassium permanganate, to blacken on platinum, and to yield ammonia. It is therefore nitrogenous and oxidisable. It has a very fœtid smell, and this is retained in a room for so long a time, sometimes for four hours, even when there is free ventilation, as to show that it is oxidised slowly. It is probably in combination with water, for most hygroscopic substances absorb it largely. It is absorbed most by wool, feathers, damp walls, and moist paper, and least by straw and horse-hair. The colour of the substance influences its absorption in the following order:—black most, then blue, yellow, and white. It is probably not a gas, but is molecular, and floats in clouds through the air, as the odour is evidently not always equally diffused through a room. In a room, the air of which is at first perfectly pure, but is vitiated by respiration, the smell of organic matter is generally perceptible when the carbon dioxide reaches 0·8 per 1000 volumes, and is very strong when the carbon dioxide amounts to 1 per 1000.

Carnelley, Haldane, and Anderson found that there was a general relationship, so that a high carbon dioxide is, as a rule, accompanied by a high organic matter, and *vice versâ*, although this is by no means always the case.

When the air of inhabited rooms is drawn through pure water, and the free ammonia got rid of, distillation with alkaline permanganate, by the method of Wanklyn, gives a perceptible quantity of "albuminoid ammonia." In a bed-room at 9 P.M., A. Smith found 0·1901 milligramme in 1 cubic metre of air; at 7 A.M. there were 0·3346 milligramme in each cubic metre.

The average of eight observations in the external air (at Portsmouth) gave 0·0935 of free ammonia and 0·0886 of albuminoid ammonia in milligrammes per cubic metre. In the Portsmouth General Hospital the free ammonia was as high as 0·855, and the albuminoid 1·307.

The Dundee experiments, already cited, state the organic matter in vols. of oxygen required to oxidise it per 1,000,000. This is equal to c.c. per cubic metre, each c.c. of oxygen weighing 1·43 of a milligramme. The results are much higher than those of previous observers, the mean oxygen for organic matter in the external air in the town being 8·9, and in the suburbs 2·8 vols. per 1,000,000; they would equal 12·7 and 4 milligrammes respectively. In dwellings it was found to increase, though not to the marked extent that was observed in *bacteria*, but the increase was sufficiently proportionate to the carbon dioxide to support the view that they are generally coincident, although varying much in individual cases. On the other hand, there seems little relation between the carbon dioxide and the number of micro-organisms.

In 1888, Brown-Séquard and d'Arsonval reported, as the result of repeated experiments, that the condensed liquid from expired air contains a volatile poison resembling a ptomaine; and if a few cubic centimetres of this liquid be injected into rabbits they rapidly die. Earlier observers had obtained similar results by enclosing animals in glass cases, absorbing the carbon dioxide produced, and supplying oxygen: yet death ensued.

The experimental results of Hermann, Dastre, Loye, and others are suggestive of the condensed fluid being without any toxic qualities. Lehmann and Jessen state that neither the condensed vapour of expired air nor its distillate, when injected either subcutaneously or into the peritoneal cavity of rabbits, has any effect upon their health. They also have shown that individuals can inspire with impunity air that has passed through the condensed vapour of expiration. According to them, no analytical methods at their disposal could detect the presence of poisonous alkaloids in the water condensed from expired air: it contains, however, traces of ammonia, small portions of organic matter, some hydrochloric acid, and yields a peculiar odour on being heated.

On the other hand, Merkel has published an account of experiments which appear to be inconsistent with the belief that no volatile poison, other than carbon dioxide, is present in expired air. The more recent investigations upon this point in this country, notably by Haldane and Smith at Oxford, indicate that the results by both the injection and ventilation methods of Brown-Séquard, d'Arsonval, and Merkel must be capable of some other interpretation than that expired air contains organic matter which is of the nature of a volatile poison. Their chief conclusions are to the effect that (1) the immediate dangers from breathing air highly vitiated by respiration arise from the excess of carbonic acid and deficiency of oxygen, and not from any special poison; (2) that any hyperpnœa which ensues is due to excess of carbon dioxide, and not to the corresponding deficiency of oxygen; the hyperpnœa usually appears when the carbon dioxide is present to the extent of from 3 to 4 per cent.; (3) that the frontal headache so commonly produced by vitiated air is due to the excess of carbon dioxide; (4) that hyperpnœa from defect of oxygen begins to be appreciable when the oxygen in the air breathed has fallen to a point which appears to differ in different individuals.

Very similar conclusions have been formulated by Bergey, Weir Mitchell, and Billings as the result of their inquiry into "the composition of expired air and its effects upon animal life." They believe that the discomfort produced by crowded, ill-ventilated rooms in persons not accustomed to them is not due to the excess of carbon dioxide, nor to bacteria, nor, in most cases, to dusts of any kind. The two great causes of such discomfort, though not the only ones, are excessive temperature and unpleasant odours. These odours, which are perceptible to most persons on passing from the outer air into a crowded unventilated room, may be due in part to volatile products of decomposition contained in the expired air of persons having decayed teeth, foul mouths, or certain disorders of the digestive apparatus, and in part to volatile fatty acids produced from the excretions of the skin, and from clothing soiled with such excretions. The direct and indirect effects of odours of various kinds upon the comfort, and perhaps also upon the health, of men are probably more considerable than are indicated by any tests now known for determining the nature and quantity of the matters which give rise to them. Though the matter is one which still requires more elucidation, still the weight of evidence is greatly against the older view that the so-called organic matter of expired air possesses any toxic properties, but much in favour of the belief that it is the excessive presence of carbon dioxide and diminished amount of oxygen which renders air vitiated by respiration so hurtful.

DISEASES PRODUCED BY IMPURITIES IN AIR.

As possible and actual causes of diseased conditions, the impurities present in the air may be considered as to whether they exist (1) in the form of dust or particulate matter from fields, rooms, mines, or workshops; (2) in the form of gases or volatile effluvia arising from factories, drains, sewers, graveyards, or brickfields; (3) in the form of products of normal respiration and perspiration.

Effects of Dust and Particulate Matter.—The effect which is produced on the respiratory organs by substances inhaled into the lungs has long been known. Ramazzini and several other writers in the last century, and Thackrah more than fifty years ago in this country, directed special attention to this point, and since that time a great amount of evidence has accumulated, which shows that the effect of dust of different kinds in the air is a far more potent cause of respiratory diseases than is usually admitted. Affections of the digestive organs are also caused, but in a much slighter degree. The respiratory affections are frequently recurring catarrhs (either dry or with expectoration) and bronchitis, with subsequent emphysema, although this sequence appears from the figures given by Hirt to be not quite so frequent as was supposed, perhaps from the cough not being violent. Acute pneumonia, and especially chronic non-tubercular phthisis are also produced. The suspended matters in the air which may produce these affections may be mineral, vegetable, or animal; but it would seem that the severity of the effects is chiefly dependent on the amount of dust and on the physical conditions as to angularity, roughness, or smoothnes of the particles, and not on the nature of the substance, except in some special cases. A large number of the unhealthy trades are chiefly so from this cause. That summer catarrh or hay fever is produced in many person by the pollen from grasses, especially *Anthoxanthum odoratum*, trees o flowers, is now generally admitted. It is also known that the spores o certain fungi may cause skin diseases in men, and that some forms of *Tinea* and also *Favus* are thus sometimes spread seems certain. The probabl diffusion of malaria by a particulate organism is very generally recognised while that the infective matters of such diseases as scarlet fever, small-pox measles, typhus, enteric fever, plague, pertussis, influenza, and others ma in some cases reach the person through the medium of air, as well as b water or food, cannot be doubted. Whether some of these contagia ca find nourishment, and thus grow in the air, is yet doubtful, but it seem clear, however, that they can retain the powers of growth for some time, a shown by the fact that the small-pox and scarlet fever poisons are able to infect the air of rooms for weeks and months.

The specific poisons manifestly differ in the ease with which they are oxidised and destroyed. The poison of typhus is very readily got rid of by free ventilation, by means of which it must be at once diluted and oxidised, so that a few feet give, under such circumstances, sufficient protection. This is the case also with the poison of oriental plague, while, on the other hand, the poisons of small-pox and scarlet fever will spread in spite of very free ventilation, and retain their power of causing the same disease for a long time. In the case of malaria the poison can certainly be carried for long distances, but how far this is dependent upon the action of winds alone, apart from the aid of insects (mosquitoes), is at present uncertain. Some have supposed also that the poison of cholera can be diffused by the wind over considerable areas, but the most recent observations on its mode of spread lead to the conclusion that the portability of the poison in this way has been greatly overrated, if it is not absolutely non-existent.

But the specific poisons are not the only suspended substances which thus float through the atmosphere.

There can be no doubt that while purulent and granular ophthalmia most frequently spread by direct transference of the pus or epithelium cells, by means of towels, &c., and that erysipelas and hospital gangrene, in surgical wards, are often carried in a similar way, by dirty sponges and dressings, another mode of transference is by the passage into the atmosphere of disintegrating pus cells and putrefying organic particles, and hence the great effect of free ventilation in ophthalmia and in erysipelas and hospital gangrene. In these diseases great evaporation from the walls or floor seems in some way to aid the diffusion, either by giving a great degree of humidity or in some other way. The practice of frequently washing the floors of hospitals is well known to increase the chance of erysipelas, and this might be explained by the moisture and subsequent drying helping the development and subsequent dissemination of minute organisms.

The effects upon health of air which is rendered impure by mineral dust and dust from fabrics is clearly shown by the experiences of miners, flock-dressers, paper-makers, feather-dressers, shoddy-grinders, weavers, wire-grinders, masons, file-cutters, button-makers, and various other classes of artisans. The case of miners is particularly instructive.

Writing, in 1862, upon the conditions under which miners worked, Sir J. Simon states that the air of coal-mines, "besides being chemically insufficient for respiration, also carries with it into the miner's lungs more or less irritant material—material which, though the air were ever so well oxygenated, would itself tend to produce bronchitis—namely, soot, grit, and the acid fumes of combustion." He further goes on to show that at that time, with one exception, the miners in England as a class break down prematurely from bronchitis and pneumonia caused by the atmosphere in which they live and work. The one exception which he gives is the case of the Durham and Northumberland colliers, who, owing to the mines in those counties being exceptionally well ventilated, do not appear to suffer from an excess of pulmonary disease, or do so only slightly. Other writers show equally that, thirty years ago at any rate, the air of mines was bad not only from respiratory vitiation, but from suspended matter, and its effect on the health of the miners was correspondingly bad.

In the present day, owing to sanitary legislation, the air of mines generally may be said to be fairly good. Ventilation is more or less efficiently carried out, particularly in the mines of the North of England, which are less dusty, and at the same time more readily ventilated than those of the Midland counties and of South Wales. Statistics show that phthisis, contrary to general opinion, is not an excessively common disease among miners.

The special decrease in diseases of the lungs among the South Staffordshire colliers, following improved ventilation of the mines, has been pointed out by Underhill; while Nasmyth, in a report upon the air of some Scotch coal-mines, considers that miners now have as good health, if not better, than above-ground labourers, at least so far as regards respiratory diseases. Arlidge, however, dissents from this opinion.

Although, thanks to the introduction of efficient ventilation, of shortened hours of labour, and to the increased attention given to the hygiene of mines, the general health of miners is better than it was a generation ago, still much dust is present in the air of even the best managed mines, and the underground workers not only necessarily breathe large amounts of it, but suffer from its effects. The extreme fineness of coal dust diffused in pit workings is shown by its liability to take fire and cause explosions. This dust when inspired enters within the lung tissue, colours it both superficially and deeply in proportion to the amount and duration of its inhalation, and provokes subinflammatory lesions ending in fibrosis, and marked by symptoms of chronic bronchitis and by dyspnœa. Usually a considerable time elapses before the lungs take much notice of the foreign matter. When cough is established, expectoration follows. The curious delay in the appearance of expectoration, especially that of a purulent character, is a feature that helps to separate cases of dust-diseased lung from the tuberculous. In like manner does the usual absence of hæmoptysis. Again, lung lesions from dust are not provocative of fever, as is tuberculosis; diarrhœa is no feature of them, nor is aphonia.

The pathology of the morbid changes in these cases is that of a slowly generated fibrosis of the lung; it is not peculiar to coal mining, but follows the continuous inhalation of other dusts besides that of coal.

In the pottery trade all classes of workmen are exposed to dust, especially, however, the flat-pressers. So common is emphysema that it is called "the potters' asthma."

So also among the china scourers; the light siliceous dust disengaged in great quantities is the cause of much disease.

The grinders of steel, especially of the finer tools, suffer perhaps the most of all from the effects of dust, though of late years the evil has been somewhat lessened by the introduction of wet-grinding in some cases, by the use of ventilated wheel-boxes, and by covering the work with linen covers when practicable. The wearing of masks and coverings for the mouth appears to be inconvenient, otherwise there is no doubt that a great amount of the dust might be stopped by very simple contrivances.

Button-makers, especially the makers of pearl buttons, also suffer from chronic bronchitis, and from the so-called fibroid phthisis. So also pin-pointers, some electro-plate workmen, and many other trades of the like kind, are more or less similarly affected.

In some of the textile manufactures much harm is done in the same way. In the carding rooms of cotton, and wool, and silk spinners there is a great amount of dust and flue, and the daily grinding of the engines disengages also fine particles of steel. Since the cotton famine, a size composed in part of china clay (35·35 grains of clay in 100 of sizing on an average) has been much used in cotton mills, and the dust arising has produced injurious effects on the lungs of the weaver.

In order to communicate the necessary amount of humidity, without which the warp thus sized with china clay could not be woven, of late years steam has been injected into the weaving sheds, so that the weavers, instead of breathing in dust, fill their lungs with moisture, and work all day in damp clothes, becoming very liable to bronchitis, &c., on leaving the over-heated factory.

In flax factories a very irritating dust is produced in the process of hackling, carding, line preparing, and tow-spinning. In shoddy factories, also, the same thing occurs. These evils appear to be entirely and easily preventible. In some kinds of glass-making, also, the workmen suffer from floating particles of sand and felspar, and sometimes potash or soda-salts.

The makers of grinding-stones suffer in the same way; and children working in the making of sand-paper are seriously affected, sometimes in a very short time, by the inhalation of fine particles of silica into the lungs.

In making Portland cement, the burnt masses of cement are ground down, and then the powder is shovelled into sacks; the workmen doing this cough a great deal, and often expectorate little masses of cement. Some of them have stated that if they had to do the same work every day it would be impossible to continue it on account of the lung affection. Sir Charles Cameron has called attention to the fatal effects of vapours of silicon fluoride in making superphosphate; it forms a gelatinous deposit on the mucous membrane of the air-passages, and causes death by suffocation.

The makers of matches, who were exposed to the fumes of phosphorus, suffered formerly from necrosis of the jaw, if there were any exposed part on which the fumes could act. This, however, is now obviated by the use of amorphous or red phosphorus, which is harmless.

In making bichromate of potash, the heat and vapour employed carry up fine particles, which lodge in the nose and cause great irritation, and finally ulceration, and destruction of both mucous membrane and bone. Those who take snuff escape this. The mouth is not affected, as the fluids dissolve and get rid of the salt. The skin is also irritated if the salt is rubbed on it, and fistulous sores are apt to be produced. No effect is noticed to be produced on the lungs. Washing the skin with subacetate of lead is the best treatment.

In the process of sulphuring vines the eyes often suffer, and sometimes (especially when lime is used with the sulphur) decided bronchitis is produced.

In some trades, or under special circumstances, the fumes of metals, or particles of metallic compounds, pass into the air. Brassfounders suffer from bronchitis and asthma as in other trades in which dust is inhaled; but in addition they also suffer from the disease described as "brassfounder's ague." It has been thought to have been produced by the inhalation of fumes of zinc oxide; the symptoms are tightness and oppression of the chest, with indefinite nervous sensations, followed by shivering, an indistinct hot stage, and profuse sweating. These attacks are not periodical. They are probably due to an admixture of zinc and copper poisoning.

Coppersmiths are affected somewhat in the same way, by the fumes arising from the partly volatilised metal, or from the spelter (solder).

Tinplate workers also suffer occasionally from the fumes of the soldering.

Plumbers, also, are now and then affected by the fumes of solder, of which lead is a principal ingredient, as well as by handling the metal itself. Nausea and tightness of the chest are the first symptoms, and then colic and palsy.

Manufacturers of white lead inhale the dust chiefly during the handling of the jars containing the converted metal—the carbonate—and during the process of crushing. Its subsequent grinding is done wet.

House painters also inhale the dust of white lead to a certain extent, though in these, as in former cases, much lead is swallowed from want of cleanliness of the hands in taking food.

Workers in tobacco factories suffer in some cases, and there are persons who can never get accustomed to the work; yet with proper care and ventilation it appears that no bad effects ordinarily result.

Workers in mercury, silverers of mirrors, and water gilders (men who coat metal with an amalgam of mercury and gold) are subject to mercurialismus. Electricity has rendered gilding with the aid of mercury to some extent obsolete; while modern invention has replaced the older method of silvering mirrors by one largely devoid of its evils, namely, by precipitating metallic silver upon the surface of the glass from a tartrate of the metal.

Workmen who use arsenical compounds, either in the making of wall papers or of artificial flowers, &c., suffer from slight symptoms of arsenical poisoning, and many persons who have inhaled the dust of rooms papered with arsenical papers have suffered from both local and constitutional effects. Arsenic has been detected in the urine of such persons.

From an account of the diseases among workmen in France employed in making patent fuel, a mixture of coal-dust and pitch, it appears that they suffer from melanodermy, cutaneous eruptions, and epithelial cancers, affections of the eyes, ears, and nose; bronchitis with pulmonary pseudomelanosis; and gastro-entero-hepatic disorders. Hirt also mentions some of the diseases produced among workmen by the various tar-products.

Effects of Gases and Volatile Effluvia.—The evidence regarding the influence of gases and other emanations upon health is both indefinite and discursive. It will, however, be most conveniently considered in the following manner:—

Ammoniacal Vapours.—An irritating effect on the conjunctiva seems to be the most marked effect of the presence of these vapours. There is no evidence showing any other effect on the health.

Hydrochloric Acid Vapours in large quantities are very irritating to the lungs; when poured out into the air, as was formerly the case in the alkali manufactures, they are so diluted as apparently to produce no effect on men, but they completely destroy vegetation. In some processes for making steel, hydrochloric, sulphurous and nitrous acids, and chlorine are all given out, and cause bronchitis, pneumonia, and destruction of lung tissue, as well as eye diseases.

Carbon Disulphide.—In certain processes in the manufacture of vulcanised india-rubber a noxious gas is given off, supposed to be the vapour of carbon disulphide. It produces headache, giddiness, pains in the limbs, formication, sleeplessness, nervous depression, and complete loss of appetite. Sometimes there is deafness, dyspnœa, cough, febrile attacks, and even amaurosis and paraplegia. The effects seem due to a direct anæsthetic effect on the nervous tissue.

Carburetted Hydrogen.—A large quantity of carburetted hydrogen can be breathed for a short time,—as much, perhaps, as 200 to 300 volumes per 1000. Above this amount it produces symptoms of poisoning, headache, vomiting, convulsions, stertor, dilated pupil, &c.

Breathed in small quantities, as it constantly is by some miners, it has not been shown to produce any bad effects; but there, as in so many other cases, it is to be wished that a more careful examination of the point were made. Without producing any marked disease, it may yet act injuriously on the health. Hirt says that cases of chronic poisoning are not uncommon. Corfield has also noticed this.

Carbon Monoxide.—Of the immense effect of carbon monoxide there is no doubt. Less than 3 vols. per 1000 have produced poisonous symptoms, and more than 10 per 1000 is rapidly fatal to animals. It appears that the gas, volume for volume, completely replaces the oxygen in the blood, and cannot be again displaced by oxygen, so that the person dies asphyxiated; but Pokrowsky has shown that it may gradually be converted into carbon dioxide, and be got rid of. It seems, in fact, as Hoppe-Seyler conjectured, to completely paralyse, so to speak, the red corpuscles, so that they cannot any longer be the carriers of oxygen. Observations show that, in addition to loss of consciousness and destruction of reflex action, it causes complete atony of the vessels, diminution of the vascular pressure, and slowness of circulation, and finally paralysis of the heart. A very rapid parenchymatous degeneration takes place in the heart and muscles generally, and in the liver, spleen, and kidneys. Hirt says that at high temperatures (25° to 32° C. = 77° to 90° F.) it produces convulsions, but not at low temperatures (8° to 12° C. = 46° to 54° F.).

Two cases of poisoning by this gas occurred at Leeds in 1889: the men were found dead in a cabin, where there had been an escape of "water gas," which contains from 30 to 40 per cent. of carbon monoxide. The gas being inodorous and unirritating, produces its poisonous effects insidiously, one of the early symptoms being loss of the power of movement, or even of the desire to make any exertion. It is stated that one part per 1000 of CO, corresponding approximately to 2·5 per 1000 of water gas, is injurious. Water gas being inodorous, requires to be "odorised" to be used with safety: mercaptan and pyridine are employed for this purpose. Many cases of water-gas poisoning, due to carbon monoxide, have lately been reported in America.

Hydrogen Sulphide.—The evidence with regard to this gas is contradictory. While dogs and horses are affected by comparatively small quantities, and suffer from purging and rapid prostration, men can breathe a larger amount.

When inhaled in small quantities, and continuously, it has appeared in some cases harmless, in others hurtful. Thackrah, in his inquiries, could trace no bad effects. It is said that in the Bonnington chemical works, where the ammoniacal liquor from the Edinburgh gasworks is converted into sulphate and chloride of ammonium, the workmen are exposed to the fumes of ammonium and hydrogen sulphides to such an extent that coins are blackened; yet no special malady is known to result. The same observations have been made at the Britannia-metal works, where a superficial deposit of sulphide is decomposed with acids.

Hirt has no doubt of the occurrence of chronic poisoning among men who work among large quantities of the gas. The symptoms are chiefly weakness, depression, perfect anorexia, slow pulse, furred tongue, mucous membrane of the mouth pale, as is also the face. Sometimes there is a furunculoid eruption on different parts of the body. In some cases there are vertigo, headache, nausea, diarrhœa, emaciation, and head symptoms. He notices differences of susceptibility, which is also sometimes increased with custom.

So large a quantity of hydrogen sulphide is given out from some of the salt marshes at Singapore that slips of paper moistened in acetate of lead are blackened in the open air; yet no bad effect is found to ensue.

On the other hand, some of the worst marshes in Italy are those in which hydrogen sulphide exists in large quantity in the air; and it has been supposed that the highly poisonous action of the marsh gas is partly owing to the sulphuretted hydrogen. Again, in the making of the Thames Tunnel, the men were exposed to hydrogen sulphide, which was formed from the decomposition of iron pyrites: after a time they became feeble, lost their appetites, and finally passed into a state of great prostration and anæmia: several died. Nor, so far as is known, was there anything to account for this except the presence of this gas.

Roburite, a mixture of di-nitro-benzene, chloro-nitro-benzene, and ammonium nitrate, has lately been used as an explosive in coal-mines, as it has the advantage of not producing any flame such as might ignite coal dust, or any inflammable gas in the mine. Miners making use of this compound have been found to suffer from pains in the head and stomach, difficulty of breathing on exertion, and loss of muscular power; with, in severe cases, blueness of lips, high-coloured urine and loss of consciousness. These symptoms may be acute or chronic: they are characteristic of nitro-benzene poisoning. Other persons, not handling the roburite cartridges, but exposed to its fumes, suffered from headache, tightness across the forehead, loss of muscular power, drowsiness, and occasionally vertigo, followed by vomiting. Carbon monoxide is produced by its explosion, and every care should be taken to remove the fumes by thorough ventilation.

Somewhat similar symptoms, but especially marked cyanosis, have been noted in connection with the manufacture of the "Sicherheit explosive."

Nitro-benzol, formed by the action of nitric acid upon benzol and used in some manufactures, is closely allied to the foregoing. Long exposure to its vapour produces stupor; if the vapour is inhaled in a concentrated form, the drowsiness passes in a short time into complete coma. The mind remains clear until the stupor suddenly comes on, when the insensibility is usually complete. Death frequently ensues in a few hours. Letheby, who had considerable experience of these fumes, attributed the symptoms which they produced to the conversion within the body of nitro-benzol into aniline, but this view has not been confirmed by experimental facts.

Myrbane is a form of nitro-benzol, having only slightly poisonous properties, unless taken or inhaled in large amount. Owing to its bitter-almond odour and taste, it is used as a scent for soaps and pomades, also to give flavour to sweetmeats.

Sulphur Dioxide.—The bleachers in cotton and worsted manufactories, and storers of woollen articles, are exposed to this gas, the amount of which in the atmosphere is, however, unknown. The men suffer from bronchitis, and are frequently sallow and anæmic.

When sulphur dioxide is evolved in the open air, and therefore at once largely diluted, as in copper smelting, it does not appear to produce any bad effects in men, and indeed persons living in volcanic countries have sometimes a notion that the fumes of this gas are good for the health; de Chaumont was told so by the people in the neighbourhood of Vesuvius. When, however, it is washed down with rain, it affects herbage, and, through the herbage, cattle; it is then said to cause affections of the bones, falling off of the hair, and emaciation.

A table (from Lehmann) is given below, which shows the concentrations at which some important industrial gases occasion injury to health.

	Concentrations which rapidly cause dangerous injury.	Concentrations bearable for 30 to 60 minutes without grave effects.	Concentrations which occasion only trifling symptoms after an action of some hours.	Authorities.
Hydrochloric acid,	1·5 to 2 per 1000	0·05 to 0·1 per 1000	0·01 per 1000	Matt, Dissertation Wurzburg, 1889.
Sulphur dioxide,	0·5 per 1000	0·05 or less per 1000	...	Ogata, *Archiv. f. Hyg.*, iii.
Carbon dioxide,	About 30 per cent.	6 to 8 per cent.	1 to 2 per cent.	Emmerich and Herter, *Zeit. f. phys. Chemie*, ii.
Ammonia,	2·5 to 4·5 per 1000	0·3 per 1000	0·1 per 1000	Matt, *loc. cit.*
Chlorine and Bromine,	0·04 per 1000	0·004 per 1000	0·001 per 1000	Matt, *loc. cit.*
Iodine,	...	0·003 per 1000	0·005 per 1000	Matt, *loc. cit.*
Hydrogen sulphide, .	0·5 per 1000	0·2 per 1000	0·1 per 1000	Lehmann, *Zeit. f. Hyg.*, xiv.
Carbon di-sulphide,	0·01 per 1000	0·002 per 1000	0·001 per 1000	Lehmann, *Bericht der Bay. Akad.*, March 3, 1888; also *Arch. f. Hyg.*, xv.
Carbon monoxide,	2–3 per 1000	0·5 to 1 per 1000	0·2 per 1000	Max Gruber, *Arch. f. Hyg.*, ii.

Effects of Effluvia from Brickfields and Cement Works.—The fumes from burning bricks differ in composition according as to whether they are burnt in kilns or clamps. In kiln burning, the bricks are burnt by the aid of coal, no combustible material being mixed with the bricks. In clamp burning, the green bricks are mixed with a small proportion of ashes or other débris, and then arranged in layers alternating with breeze, so as to form a quadrangular pile. The breeze is set alight by means of small wood and coal fires. Clamp burning is distinctly offensive, as, in addition to the ordinary gases of combustion, certain pyroligneous matters are emitted which have an intensely disagreeable odour; these objectionable effects mainly result from the use of household refuse in the construction of the clamps. The effluvia from brick clamps and kilns are usually acid, irritating and injurious to vegetation. Clamp burning should not be permitted in populous neighbourhoods. Kiln burning, if carried out in well constructed kilns provided with a long chimney shaft, can be conducted with but little offence.

The manufacture of the so-called Roman cement, made from the *septaria* nodules found in the London clay, creates little nuisance, as the stones are calcined in open kilns like lime kilns. The manufacture of Portland cement is less satisfactory. This cement is made from a mixture or wet mud composed of chalk and clay, and the chief nuisance arises during the burning of this mixture, whereby large quantities of carbon dioxide, carbon monoxide, hydrogen sulphide and volatile cyanides are emitted. The evolution of cyanides is particularly intense when the clay used contains much nitrogenous matter. Experience shows that the emanations from open kilns in the manufacture of Portland cement are clearly injurious to health. The fumes should always be discharged from a tall chimney, not less than 150 feet high.

Effects of Effluvia from Offensive Trades.—The chief industries in which offensive effluvia are generated are:—Pig, horse, and cow keeping, tanning and leather dressing, glue or size making, fell-mongering, the manufacture of oxalic acid, paper and wood pulp, also the making of sal-ammoniac and coal gas, the distillation of tar and of palm oil, also the manufacture of carbolic acid, alkali, salt, sulphuric acid, picric acid, and the various aniline dyes.

In the majority of these trades large quantities of very disagreeable vapours are constantly produced, which often spread for long distances, and are at the same time most offensive. In the case of businesses involving the keeping of animals, impregnation of the atmosphere with ammonia is the chief offence. In tanning and leather dressing, glue or size making, and fell-mongering, ammonia and other products of the decomposition of animal matters generally are objectionably obvious. From india-rubber factories the chief smell is a peculiar india-rubber odour, together with an odour of tar oil and sulphuretted hydrogen. The making of oxalic acid from sawdust entails the evolution of very acid and irritating fumes; similarly, in the making of paper and wood pulp, a peculiar and offensive odour of an indefinite nature is a constant feature. The presence of alkaline sulphide vapours is the chief objection to the making of sal-ammoniac, coal gas, carbolic acid, and the distillation of tar. The extremely irritating acrolein vapours are the product of linoleum factories, and distilleries of palm oil, "foots," and other kinds of grease. From alkali works, the acid fumes produced are sulphuric acid, sulphurous acid, nitric acid, various other noxious oxides of nitrogen, sulphuretted hydrogen and chlorine. In the case of the making of sulphuric acid, the chief effluvia are caused by the escape of sulphurous acid and the higher oxides of nitrogen; while fumes of hydrochloric and sulphurous acids largely result from the manufacture of salt, and the heavy odour of essence of myrbane with nitrous acid is the chief effluvium from the making of picric acid and the aniline colours.

Although these industrial gases frequently constitute a nuisance, it is difficult in the greater number of instances to bring forward any positive evidence of insalubrity. The odours, however, in most cases are so bad that rules have to be enforced to secure the conveyance in covered carts or receptacles, of all offensive matters in or about the business premises. Similarly, in order to prevent nuisance from the vapours given off in boiling processes, all such operations need to be conducted in closed vessels, each having a pipe to lead the steam into a furnace flue. In other cases, the arrest of offensive gases is secured by condensation in a special apparatus, or their absorption is effected by lime and other chemical means.

Effects of Effluvia from Sewers and House Drains.—Cases of asphyxia from hydrogen sulphide, ammonium sulphide, carbon dioxide, and nitrogen (or possibly rapid poisoning from organic vapours), occasionally occur both in sewers and from the opening of old cesspools. In a case at Clapham, the clearing out of a privy produced in twenty-three children violent vomiting and purging, headache and great prostration, and convulsive twitching of the muscles. Two died in twenty-four hours.

These are instances of mephitic poisoning in an intense degree; but when men have breathed the air of a newly-opened drain in much smaller amounts, marked effects are sometimes produced; languor and loss of appetite are followed by vomiting, diarrhœa, colic, and prostration. The effluvia which have produced these symptoms are usually those arising from a drain which has been blocked for some time. When the air of sewers penetrates into houses, and especially into bed-rooms, it certainly causes a greatly impaired state of health, especially in children. They lose appetite, become pale and languid, and suffer from diarrhœa; older persons suffer from headaches, malaise, and feverishness; there is often some degree of anæmia, and it is clear that the process of aëration of the blood is not perfectly carried on.

In some cases decided febrile attacks lasting three or four days, and attended with great headache and anorexia, have been known. Houses into which there has been a continued escape of sewer air have been so notoriously unhealthy that no persons would live in them, and this has not been only from the prevalence of fever, but from other diseases.

The effect on the men who work in sewers which are not blocked, or temporarily impure from exceptional disengagement of hydrogen sulphide from any cause, has been subject to much debate. The air in many sewers in London is not very impure; the analyses of Letheby and Miller, and those of Carnelley, have shown that generally the amount of carbon dioxide is very little in excess of that in the external air, and that there is hardly a trace of hydrogen sulphide or of fœtid organic effluvia. The air in the house drains is often, in fact, more impure than that of the main sewers. This is the case also in other places, and is to be accounted for by the numerous openings in the sewers, by the porosity of the walls, by the continual ventilation produced by the air being drawn into houses, and by the amount of water in the sewers being often so great, and its flow so rapid, as to materially lessen deposits and other sources of generation of gas. The evidence is, on the whole, opposed to the view that sewer-men suffer in health in consequence of their occupation.

A more recent inquiry conducted into the health of the sewer-men in London did not detect any excess of disease among them, and in Liverpool also the sewer-men are said to have good health. The workmen employed at the various sewage outfalls, who, though not in the sewers, breathe the effluvia arising from the settling tanks, do not find it an unhealthy occupation.

It does not appear, therefore, that at present the workmen connected with fairly ventilated sewers show any excess of disease; at the same time, it must be allowed that the inquiry has not been very rigorously prosecuted, and that the length of time the men work in sewers, their average yearly mortality, discharge from sickness, loss of time from sickness, and the effect produced on their expectation of life, have not been perfectly determined.

The air of sewers passing into houses aggravates most decidedly the severity of the exanthemata, more especially such diseases as erysipelas, hospital gangrene, and puerperal fever; it has probably an injurious effect on all diseases. That pneumonia may be connected with effluvia from sewers and house drains was shown in the epidemic at Middlesborough, where Ballard found good reason for attributing considerable influence to defective drainage as an agency in the incidence of the disease.

Three diseases in particular have been supposed to arise from the air of sewers and fæcal emanations, viz., *diarrhœa*, *enteric fever*, and *diphtheria*.

With regard to the production of diarrhœa from fæcal emanations, it would seem that the autumnal diarrhœa of this country is intimately connected with the temperature of the soil, and usually commences when this reaches 56° F. at a depth of 4 feet from the surface. It is worst in the badly sewered districts, and is least in well-drained districts, and in wet years. It has been checked in London by a heavy fall of rain. All those points seem to connect it with fæcal emanations reaching a certain rapidity of evolution in consequence of high temperature, deficient rain, and perhaps relative dryness of the atmosphere. At the same time, there is a connection between this disease and impure water. It may own a double origin, and in a dry season both causes may be in operation.

That enteric fever may arise from the effluvia from sewers is a doctrine still generally held in this country, but is supported by imperfect evidence. There are several cases on record in which this fever has constantly prevailed in houses exposed to sewage emanations, either from bad sewers or from want of them, and in which proper sewerage has completely removed the fever. Many of these occurred before the water-carriage of enteric fever was recognised, and it is open to argument whether the amelioration in health, which followed the introduction of well constructed sewers and drains in these cases, was not due to the removal of sources of pollution to local water supplies rather than to the removal of facilities for the entrance of sewer air and gas into the houses.

In other cases where stress has been laid upon the influence of sewer air and sewer gases escaping into dwellings as the probable cause of subsequent cases of enteric fever occurring therein, it has been frequently overlooked that concurrent circumstances often were an intermittent water-supply, and infection of the drinking water by specifically tainted matter sucked up into cisterns or pipes from the trapping bends of faultily planned and constructed drains. The well-known outbreak of enteric fever at Caius College, Cambridge, investigated by the late Sir G. Buchanan, was traced by him to a broadly similar cause. The outbreak in question was mainly limited to a particular section of the College, known as Tree Court: and owing to the extraordinary arrangement of the water-supply and water-closets in this part of the College, the system of pipes for the water-supply became, at times, not only the means of ventilating the sewers and drains into the building, but were also the means by which, if a certain trap happened to be full of excrement, that excrement was sucked up into the water-main of Tree Court, and subsequently distributed with the water throughout the Court. In this case, the entrance of excretal matter into the water-supply was surely an etiological factor of greater importance than the escape of sewer gas or air into the building?

The view that there is a connection between sewer air and enteric fever has been much combated by German writers, notably by Soyka and Nägeli. Their contention is that enteric fever is not due to the influence of sewer air, because it is rare that such air gets into houses; and experiments are cited to prove this. It is, however, admitted and demonstrated by Soyka, in the table which he gives, that a similar improvement in the health of towns has followed the introduction of proper drainage in the cities of Germany as has been observed in this country. This he attributes to the cleansing of the soil and local sources of water-supply by the removal of sewage matter. Nägeli positively denies the possibility of specific disease being conveyed through emanations from drains or cesspools.

Although it seems difficult not to admit that the effluvia from sewers and drains may predispose towards the incidence of enteric fever, there are yet some remarkable facts which can be cited on the other side.

Thus it has been repeatedly denied that enteric fever is more common among sewer-men than others, and later inquiries among the sewer-men of

London seem to bear out the assertion. But, as already stated, the air of London sewers is really very pure; and some of the men may be protected by previous attacks, for enteric fever is a most common disease among the poorer children in London.

The evidence is very strong that the men employed at the sewage tanks and on the sewage farms, and their families, do not show an unusual amount of enteric fever; nor do the persons living in adjacent houses. Now, if sewage emanations can cause enteric fever, it might be expected that we should by this time have had plenty of evidence of this special effect in connection with sewage farms generally.

The possibility that the adult persons submitted to sewage emanations may have had enteric fever in early life, and are therefore insusceptible, may explain some cases of escape, even when fæcal emanations are constantly breathed. But it would be impossible to extend this argument to the cases of immunity in children, unless we suppose that enteric fever in children is constantly overlooked, and is as common as measles, which seems unlikely.

There are, however, still some other difficulties. The investigations of Andrewes and Parry Laws show that sewage, even in the absence of the normal micro-organisms which it contains, is clearly an unfavourable medium for the growth of the enteric fever germ, and that sewer air is by no means rich in micro-organisms, and is particularly poor in those forms which are most commonly met with in sewage itself. From the inquiries of these observers and of others, it would appear that, so far as bacteriological analysis goes, there is no ground for believing that sewer air plays any part in the conveyance of enteric fever; but are the conditions under which the bacteriological examinations of sewage and of sewer air are made such as to give us absolute assurance on these points? In spite of its apparent bacteriological innocuousness, no one entertains the least doubt that sewer air is a constant source of ill-health, and if this is not to be referred to micro-organisms, to what may it be ascribed? There is undoubtedly a poisonous agency at work when sewer gas is inhaled, which, though it may not directly act, yet so prepares the soil that the system is unable to resist the invading organism when it comes.

The spread of *diphtheria* has been ascribed to the pollution of air by emanations from sewers, and certainly in many outbreaks there has been a connection between the sanitary condition of a district and the incidence of the disease; houses or groups of houses to which sewer gas has gained access through faulty traps having especially suffered.

Direct proof of such a causal connection has not yet been afforded, and it must be admitted that diphtheria has up to recent years been a disease of country districts rather than of regularly sewered towns; at the same time, if the sewerage arrangements are defective, allowing the escape of sewer air into dwellings, especially sleeping-rooms, it is *a priori* probable that the sewer gases, by giving rise to a relaxed and unhealthy condition of the mucous lining of the throat, may increase the liability to attack by diphtheria in the event of exposure to specific infection.

In connection with the possible relation of sewer air to specific diseases, some very original investigations by Alessi are of value. He has noted the effect of inhaling sewer air and the gases from putrefying materials upon animals; rats, rabbits, and guinea-pigs being selected. After exposure to sewer air, which was accomplished by placing them in a box with a perforated bottom communicating directly with a drain, they were inoculated with a small quantity of only a slightly virulent cultivation of the enteric fever bacillus, whilst other animals were similarly treated, except that they were not compelled to inhale sewer air, but were kept in their ordinary surroundings. Rats, after breathing this more or less foul air, began to lose their vivacity, and after a time grew thin, although they ate voraciously, and out of forty-nine which were inoculated with the enteric fever bacillus, thirty-seven died, exhibiting the typical symptoms of enteric fever infection. Of those forty-one rats, however, which, although infected with enteric fever, had not breathed sewer air, only three succumbed. Thus, the inspiration of drain air had so far predisposed these animals to infection from enteric fever, that a small dose of an almost harmless growth of this organism proved very fatal to them. Guinea-pigs and rabbits, exposed in like manner to gases from materials in a condition of active decomposition, also acquired a predisposition to typhoid infection, for out of seventy-two guinea-pigs inoculated, fifty-seven died, whilst not one of those treated with the infective agent of enteric fever in ordinary surroundings succumbed. Similarly, every one of eleven rabbits, treated and exposed to sewer air, died, but not one of the inoculated animals when kept in fresh air. Alessi also found that the inhalation of gases from putrid substances enabled a small dose of a weakened culture of the *B. coli communis*, normally present in the intestine, to produce fatal results when purposely introduced into the animals thus exposed.

He also ascertained that it was during the first two weeks of exposure to noxious gases that the animals were most easily predisposed to enteric fever infection, for no less than 90 per cent. of all the animals inoculated during the first fortnight died, whilst 76 per cent. succumbed of those inoculated in the third week. This fact, Alessi says, may partly explain how it is that some people who habitually breathe contaminated air do not appear to suffer any evil results, having gradually in course of time become accustomed to it, whilst a stranger exposed to the same conditions, without previous experience, may suffer very severely. The personal factor, or degree of predisposition, however, whilst varying in different animals, would also vary in different people. These investigations and results, without being considered conclusive, must be regarded as a noteworthy and an important contribution to our knowledge of the distribution of disease, and in some respects affording a remarkable experimental confirmation of the wisdom of a policy of sanitation which is dictated equally by instinct and intuition.

Effects of Emanations from Fæcal Matter thrown on the Ground.—Owing, doubtless, to the rapid movement of the air, there is no doubt that the excreta of men and animals thrown on the ground and exposed to the open air are less hurtful than sewer air, and probably in proportion to the dilution.

When there are accumulations in close courts, small back-yards, &c., the same effects are produced as by sewer air. When fæcal matters are used for manure, and are therefore speedily mixed with earth, they seldom produce bad effects. Owing, doubtless, to the great deodorising and absorbing powers of earth, effluvia soon cease to be given off. An instance is, however, on record, in which two cases of enteric fever were supposed to arise from the manuring of an adjacent field. Clouston has also shown by evidence, which seems very strong, that dysentery was produced in an asylum by the exhalations from sewage, which was spread over the ground (a stiff brick clay subsoil) about 300 yards from the asylum. The case seems a very convincing one, as the possibility of the action of other causes (impure water, bad food, &c.) was excluded; but it appears to have been due to the improper treatment of the sewage, which was allowed to become putrid and form a filthy morass. It is stated in some works that disease is frequently produced by the manuring of the ground, but there seems to be no satisfactory evidence of this. Carpenter has shown, from the history of the Beddington sewage farm, that no harm to the neighbourhood had accrued from the irrigation with the Croydon sewage during twenty years, and subsequent experience has only confirmed his statements. It has been said that if the sewage matter can be applied while perfectly fresh to the ground, no harm results; but if decomposition has fully set in, it is not so completely deodorised by the ground. In China, where fæcal matter is so constantly applied in agriculture, the air is often filled with very pungent effluvia, yet no bad effect is produced.

Effects of Emanations from Streams polluted by Fæcal Matter.—The evidence on this point is contradictory. Parent-Duchâtelet investigated the effect produced on the health of the inhabitants of the Faubourg St Marceau, in Paris, by the almost insupportable effluvia arising from the Bièvre, which received a large portion of the sewage of the quarter. He asserts that the health was not at all damaged, though he admits that there is truth in the old tradition at the Hôtel Dieu, that the cases from St Marceau were more severe than from any other place. The opinion of the late W. Stokes, as to the slight influence of the effluvia from the river Liffey on the health of the residents along the quays in Dublin, is to the same effect.

M'William found that the emanations from the Thames had no deleterious effect on the health of the Custom-House men employed on the river. The amount of diarrhœa was even below the average.

Sir R. Rawlinson states that a careful house-to-house visitation had been made in some of the worst districts of Lancashire (in Manchester, on the banks of the Medlock, for instance) without finding any great excess of disease.

On the other hand, in the reports of Sir Lyon Playfair is some strong evidence that the general health of the people suffered from the emanations of the putrid streams of the Frome and the tributaries of the Irk and Medlock; that they were pale, in many cases dyspeptic; that fevers (enteric) prevailed on the banks is asserted by some observers, but rather doubted by others; but none seem to have any doubt that the fevers when they occurred were much worse. Cholera in Manchester was severe along the banks of some of these streams, but that was probably due to the water being drunk.

It is very likely that the discrepancy of evidence may arise from the amount of water which dilutes the fæcal matter being much greater in some cases than in others. In the case of the Thames, the dilution was after all very great, and this was the case, in part at any rate, in the Bièvre, as the stream was in some places 6 and 7 feet deep. The evaporation from such a body of water, however offensive it may be, must be a very different thing from the effluvia coming off from the masses of organic matter laid bare by the almost complete drying up of streams into which quantities of fæcal matter are discharged. When sewage matter is poured into the sea, and washed back by the tide, it becomes a source of danger.

It was remarkable in the evidence given before the Royal Commission on Metropolitan Sewage Discharge, 1882–84, how little direct proof of specific disease, due to the pollution of the Thames, was obtained, although there was no doubt about the production of nausea and diarrhœa, and other minor evils. Indeed, the Commissioners themselves had good proof of this, for, after a trip of inspection from Woolwich to Greenhithe in July 1884, three of them and their clerk were seized with griping pains and smart diarrhœa the same night, caused apparently by the offensive state of the river.

Effect of Manure Manufactories.—The manure manufactories at present existing in this country do not appear to produce any bad effects. They are generally at some little distance from towns, and the effluvia are soon diluted. But if situated in towns they are nuisances, and may be hurtful. In 1847 evidence was given to show that a manure manufactory situated in Spitalfields, and about 100 feet from the workhouse, caused bad diarrhœa whenever the wind blew in that direction. The cases of disease in the workhouse infirmary also acquired, it is said, a malignant and intractable character. In France the workmen engaged in the making of "poudrette" do not in any way suffer, except from slight ophthalmia. When the poudrette is decomposing, and large quantities are brought into small spaces, as on board ship, serious consequences may certainly result, the chief symptoms produced being intense pain in the head and limbs, with vomiting, great prostration and diarrhœa. In bone manure factories it has been shown that arsenic is given off in the fumes in considerable quantity, arising from the use of impure sulphuric acid.

Effects of the Air of Graveyards.—There is some evidence that the disturbance of even ancient places of sepulture may give rise to disease. Vicq d'Azyr refers to an epidemic in Auvergne caused by the opening of an old cemetery; the removal of the old burial-place of a convent in Paris produced illness in the inhabitants of the adjoining houses. In India, the cantonment at Sukkur was placed on an ancient Mussulman burial-ground, and the station was most unhealthy, especially from fevers.

The effect of effluvia from comparatively recent putrefying human bodies has been observed by many writers. Rammazzini states that sextons entering places where there are putrefying corpses are subject to malignant fevers, asphyxia, and suffocating catarrhs; and Tardieu has collected a very considerable number of cases, not only of asphyxia, but of several febrile affections produced by exhumations and disturbance of bodies. The late Sir E. Chadwick, and the General Board of Health, also summed up evidence, which showed that in churchyards thickly crowded with dead, vapours were given off which, if not productive of any specific disease, yet increased the amount both of sickness and mortality. In some instances, this might have been from contamination of the drinking water; but in other cases, as in the houses bordering the old city graveyards, where the water was supplied by public companies, the air also must have been in fault. In the houses which closely bordered the old city yards, which were crowded with bodies, cholera was very fatal in 1849, and, according to some practitioners, no cases recovered. All other diseases in these localities were said to have assumed a very violent and unfavourable type. Hirt says, on the other hand, that when grave-diggers are protected from the acute effects of carbon dioxide, their calling is not unhealthy; their death-rate he gives at 17 per 1000, and their mean duration of life at 58 to 60 years. This, however, is in Germany, where, as he admits, there is less crowding of graveyards than in England or France. Nägeli, arguing probably from similar data, thinks that graveyards may exist in the midst of towns without danger to health, provided precautions be taken with reference to the drainage and ventilation of the soil, and the safe-guarding of the water-supply.

Effects of Air vitiated by Respiration.—If we disregard the presence, in expired air, of the so-called and more or less hypothetical organic matter, the chief causes of discomfort, following the use of air vitiated by respiration, are the deficiency of oxygen, excess of carbon dioxide, and increased heat and moisture. The influence of a deprivation of oxygen, in producing a condition of hyperpnœa, appears to be largely subordinate to that of an excessive presence of carbon dioxide. The normal quantity of this latter gas, in air, being from 0·3 to 0·4 volume per 1000, it produces fatal results when the amount reaches from 50 to 100 per 1000 volumes; while at an amount much below this, say 15 to 20 per 1000, it produces, in some persons at any rate, severe headache. Some persons can inhale, for a brief period, considerable quantities of carbon dioxide without injury; and animals can be kept for a long time in an atmosphere highly charged with it, provided the amount of oxygen be also increased. In the air of respiration, headache and vertigo are produced when the amount of carbon dioxide is not more than 1·5 to 3 volumes per 1000; but then organic matters, and possibly other gases, are present in the air, and the amount of oxygen is also lessened. Well-sinkers, when not actually disabled from continuing their work by carbon dioxide, are often affected by headache, sickness, and loss of appetite; but the amount of carbonic acid has never been actually determined in these cases.

The effect of constantly breathing an atmosphere containing an excess of carbon dioxide (up to 1 or 1·5 per 1000 volumes) is not yet perfectly known.

Angus Smith attempted to determine its effect *per se*, the influence of the so-called organic matter of respiration being eliminated. He found that 30 volumes per 1000 caused great feebleness of the circulation, with, usually, slowness of the heart's action: the respirations were, on the contrary, quickened. These effects lessened when the amount was smaller, but were perceptible when the amount was as low as 1 volume per 1000—an amount often exceeded in dwelling rooms. At the same time, this is not the case always, for in the air of a soda-water manufactory, when the carbon dioxide was 2 per 1000, Smith found no discomfort to be produced. The effects noticed by Smith have not been observed in experiments upon animals by Demarquay, Müller, and Eulenberg, nor in other cases in men, as in the bath at Oeynhausen, where no effect is produced by the air of the room in which the bathers remain for 30 to 60 minutes, although it contains a large percentage. Hirt finds no symptoms of chronic poisoning by CO_2, even in trades where acute poisoning occasionally occurs.

The presence of a very large amount of carbon dioxide in the air may lessen its elimination from the lungs, and thus retain the gas in the blood, and in time possibly may produce serious alterations in nutrition.

The importance of the *rôle* played by the heat and capacity for moisture of air vitiated by respiration is often overlooked. We have already seen that expired air is practically of the same temperature as the body, 37° C. (= 98°·6 F.), and saturated with water vapour, consequently any volume of air much vitiated by respiration soon becomes heated air and more or less saturated with moisture. Now air which is loaded with moisture transmits, in each unit of time, much more heat than air which is dry. Hence, when air, at a high temperature, is saturated with watery vapour, it communicates heat to the body, producing an oppressive sensation; but when the temperature of the saturated air is lower than the temperature of the body, the transfer of heat is the other way, producing a sensation of cold. A low temperature with a dry atmosphere is therefore more comfortable than a higher temperature when the air is loaded with moisture, for no other reason than that it favours the prompt and regular removal of body heat by combined conduction and evaporation. It is precisely in this quality that air, vitiated by respiration, is so wanting, with the result that it causes a sense of unpleasant oppression so characteristic of ill-ventilated and overcrowded rooms.

The effect of air much fouled by respiration is very marked upon many people, producing heaviness, headache, inertness, and in some cases nausea. When the air has been rendered very impure, it is commonly rapidly fatal, as in the cases of the Black Hole at Calcutta; of the prison in which 300 Austrian prisoners were put after the battle of Austerlitz (when 260 died very rapidly); and of the steamer "Londonderry." This vessel left Sligo for Liverpool on the 2nd December 1848, and stormy weather coming on, the captain forced 200 steerage passengers into their cabin, which measured 18 feet by 11 feet, and 7 feet in height. The hatches were battened down and covered with tarpaulin. When the cabin was opened 72 persons were found dead, and several expiring.

The poisonous agencies which probably bring this sequence of events about appear to be a deficiency of oxygen coupled with an excess of carbon dioxide, though the symptoms are not those of pure asphyxia. If the persons survive, a febrile condition is usually left behind, which lasts three or four days, followed often by boils and other evidences of affected nutrition.

When air more moderately vitiated by respiration is breathed for a longer period, and more continuously, its effects become complicated with those of other conditions. Usually a person who is compelled to breathe such an atmosphere is at the same time sedentary, and, perhaps, remains in a constrained position for several hours, or possibly is also under-fed or intemperate. But allowing the fullest effect to all other agencies, there is no doubt that the breathing the vitiated atmosphere of respiration has a most injurious effect on the health. Persons soon become pale, and partially lose their appetite, and after a time decline in muscular strength and spirits. The aëration and nutrition of the blood seem to be interfered with, and the general tone of the system falls below par. Of special diseases it appears pretty clear that pulmonary affections are more common.

Such persons do certainly appear to furnish a most undue percentage of phthisical cases, that is, of destructive lung-tissue disease of some kind. The production of phthisis from impure air (aided most potently, as it often is, by coincident conditions of want of exercise, want of good food, and excessive work) is no new doctrine. Baudelocque long ago asserted that impure air is the great cause of scrofula (phthisis), and that hereditary predisposition, syphilis, uncleanliness, want of clothing, bad food, cold, and humid air, are by themselves non-effective. Carmichael, in his work on scrofula, gave some most striking instances, where impure air, bad diet, and deficient exercise concurred together to produce a most formidable mortality from phthisis. In one instance, in the Dublin House of Industry, where scrofula was formerly so common as to be thought contagious, there were in one ward, 60 feet long and 18 feet broad (height not given), 38 beds, each containing four children; the atmosphere was so bad that in the morning the air of the ward was unendurable. In some of the schools examined by Carmichael the diet was excellent, and the only causes for the excessive phthisis were the foul air and the want of exercise. Carnelley, Haldane, and Anderson show that in Dundee the ratio of phthisis and other disorders of a similar character increases with the crowding and foulness of the air; being at the rate of 3·26 per 1000 in houses of 4 rooms and upwards; 5·52 in houses of 3 rooms; in two-roomed houses, 6·41; and in one-roomed houses, 7·44.

In prisons, the great mortality which formerly occurred, as for example at Millbank (Baly), seemed to be owing to bad air, conjoined with inferior diet and moral depression.

The now well-known fact of the great prevalence of phthisis in most of the European armies (French, Prussian, Russian, Belgian, and English) can scarcely be accounted for in any other way than by supposing the vitiated atmosphere of the barrack-room to have been chiefly in fault. This is the conclusion to which the Sanitary Commissioners for the army came in their well-known report. And if we must also attribute some influence to the pressure of ill-made accoutrements, and to the great prevalence of syphilis, still it can hardly be doubted that the chief cause of phthisis among soldiers has to be sought somewhere else, when we see that, with very different duties, a variable amount of syphilis, and altered diet, a great amount of phthisis has prevailed in the most varied stations of the army, and in the most beautiful climates: in Gibraltar, Malta, Ionia, Jamaica, Trinidad, Bermuda, &c., in all which places the only common condition was the vitiated atmosphere which our barrack system everywhere produced. And, as if to clench the argument, there has been of late years a most decided decline of phthisical cases in these stations, while the only circumstance which has notably changed in the time has been the condition of the air. So also the extraordinary amount of consumption which has prevailed among the men of the Royal and Merchant Navies, and which, in some men-of-war, has amounted to a veritable epidemic, is attributable to the faulty ventilation and to contagion following on this.

Formerly the deaths from phthisis in the Royal Navy averaged 2·6 per 1000 of strength, and the invaliding 3·9 per 1000. The amount of consumption and of all lung diseases was remarkably different in the different ships. Bryson traced this clearly to overcrowding and vitiation of the air, noticing also that in several cases the disease appeared to be propagated from person to person.

The production of phthisis in animals confirms this view. The case of the monkeys in the zoological gardens, narrated by Arnott, is a striking instance. Cows in close stables frequently die from phthisis, or at any rate from a destructive lung disease (not apparently pleuro-pneumonia); while horses, who in the worst stables have more free air, and get a greater amount of exercise, are little subject to phthisis. But not only phthisis may reasonably be considered to have one of its modes of origin in the breathing an atmosphere contaminated by respiration, especially by the respiration of those affected with pulmonary tuberculosis, but other lung diseases, bronchitis and pneumonia, appear also to be more common in such circumstances. Both among seamen and civilians working in confined close rooms, who are otherwise so differently circumstanced, we find an excess of the acute lung affections. The only circumstance which is common to the two classes is the impure atmosphere.

In addition to a general impaired state of health, arising, probably, from faulty aëration of the blood, and to phthisis and other lung affections, which may reasonably be believed to have their origin in the constant breathing of air vitiated by the organic vapours and particles arising from the dried sputa of infected persons, it has long been considered, and apparently quite correctly, that such an atmosphere may cause a more rapid spread of several specific diseases, especially diphtheria in schools, also typhus, plague, small-pox, scarlet fever, and measles. This may arise in several ways: the specific poisons may simply accumulate in the air so imperfectly changed, or they may grow in it (for though there may be an analogical argument against such a process, it has never been disproved, and it is evidently not impossible); or the vitiated atmosphere may simply render the body less resisting or more predisposed.

The air of a sick ward, containing as it does an immense quantity of organic matter, is well known to be most injurious. The severity of many diseases is increased, and convalescence is greatly prolonged. This appears to hold true of all diseases, but especially of the febrile. The occurrence of erysipelas and hospital gangrene is, in fact, a condemnation of the sanitary condition of the ward. It has been asserted that hospital gangrene is a precursor of exanthematic typhus, but probably the introduction at a particular time of the specific poison of typhus was a mere coincidence. But, doubtless, the same foul state of the air which aids the spread of the one disease would aid also that of the other.

Of the products of combustion which pass into the general atmosphere, the carbon dioxide and monoxide are so largely and speedily diluted that it is not likely they can have any influence on health. The particles of carbon and tarry matter, and the sulphur dioxide, must be the active agents if any injury results. It has been supposed that the molecular carbon and the sulphur dioxide, instead of being injurious, may even be useful as disinfectants, and we might *a priori* conclude that to a certain extent they must so act; but certainly there is no evidence that the smoky air of our cities, or of our colliery districts, is freer from the poisons of the chief specific diseases than the air of other places. The solid particles of carbon, and the sulphur dioxide, may, on the other hand, have injurious effects. It is not right to ignore the mechanical effect of the fine powder of coal so constantly drawn into the lungs, and even the possibility of irritation of the lungs from sulphur dioxide. Certain it is, that persons with bronchitis and emphysema often feel at once the entrance into the London atmosphere; and individual experience will probably lead to the opinion that such an atmosphere has some effect in originating attacks of bronchitis and in delaying recovery. But statistical evidence of the effect of smoky town atmospheres in producing lung affections on a large scale cannot be given, so many are the other conditions which complicate the problem. There is, however, no doubt of the evil effect of the London atmosphere during dense fogs: witness the effect upon the animals at the cattle show at Islington in December 1873, and the increased mortality from lung diseases during foggy weather.

The effect of breathing the products of combustion, of gas especially, is more easily determined. In proportion to the amount of contamination of the air, many persons at once suffer from headache, heaviness, and oppression. Bronchitic affections are frequently produced, which are often attributed to the change from the hot room to the cold air, but are really probably owing to the influence of the impure air of the room on the lungs.

The effects of constantly inhaling the products of gas combustion may be seen in the case of workmen whose shops are dark, and who are compelled to burn gas during a large part of the day; the pallor, or even anæmia and general want of tone, which such men show is owing to the constant inhalation of an atmosphere so impure.

EXAMINATION OF AIR.

For hygienic purposes, in the practical examination of air, the chief points to which attention needs to be directed are, the collection of the sample, the examination of the air by the senses, estimation of oxygen, estimation of carbon dioxide, determination of the oxidisable and organic matter, estimation of carbonic oxide, the presence of ozone, the determination of aqueous vapour and an examination of the suspended matter and micro-organisms.

Collection of the Sample.—All air samples should be collected at the time when the atmosphere will afford its greatest evidence of pollution, as, for instance, in the case of a bedroom, the air should be taken when its usual occupants have been in it some hours. For the actual collection of the sample, large, wide-mouthed, glass-stoppered jars, holding from three to four litres, are the most convenient. These need to be most thoroughly cleansed with distilled water before use, inverted to run dry, and stoppered, a label being finally attached for stating the current temperature and pressure. To fill the jar with the air sample, either of the two following methods may be employed.

1. The air may be blown in by bellows which are provided with a long nozzle capable of reaching to within an inch of the bottom of the jar: this insures that the air which originally filled the jar will be entirely displaced from below upwards.

2. The jar may be accurately filled with distilled water, then inverted, emptied and allowed to drain dry in the room, the air of which it is desired to collect; as the water flows out, some of the air rushes in to fill its place. Special care needs to be observed that no breath is introduced into the jar. The vessel is at once closed with an air-tight stopper or india-rubber cap, and the label inscribed with the current temperature, barometric pressure, and cubical capacity of the jar.

Examination by the Senses.—From a practical point of view, this is of the first importance, as although carbon dioxide, carbonic oxide, marsh gas, and several other vapours cannot be detected by the smell, still minute quantities of organic effluvia, traces of sulphuretted hydrogen, of coal gas, of carbon disulphide, and of various other substances are readily noticed by the sense of smell, particularly if at all trained or cultivated to acuteness. The special value of the sense of smell in recognising the peculiar fœtid odour so characteristic of occupied rooms, was first clearly shown by de Chaumont, who further indicated the importance of observing it on first entering a room from the open air. He also pointed out the marked influence which atmospheric humidity has in rendering the smell of organic matter perceptible, an increase of 1 per cent. in the humidity being as powerful, in this respect, as a rise of 2°·32 C. (4°·18 F.). As the sense of smell soon becomes blunted, it is important, when attempting any examination of the air by the senses, to record the impression received immediately after entering the suspected or vitiated air from the open, and not to delay it until one has been in the apartment some length of time.

As a preliminary procedure, the *reaction* of an air sample may be noted. Although the air over open country and the sea is really neutral, cases do occur in which ammonia may be present in such amount as to produce a faint alkaline reaction, or, as in the case of some towns, so much sulphurous acid may be present as to make the air distinctly acid. The observations can be most readily made by exposing, for an hour or two, pieces of moistened litmus and turmeric papers, and then noting the colour changes that take place.

Estimation of Oxygen.—For this determination there are three well-known methods, namely, the pyrogallic acid process, the combustion process with excess of hydrogen, and the nitric oxide method. As neither of the first two are strictly available in presence of carbon dioxide, the third procedure is the one most readily applicable for hygienic estimations.

The most convenient apparatus is Hempel's gas burette and absorption pipette. It consists of two upright glass tubes, one of which is graduated into cubic centimetres, and the other plain. The graduated tube is narrowed almost to capillarity at the top, and drawn out so as to take an india-rubber connecting-tube. Both tubes are fitted into stands at the bottom, and connected with each other by a wide rubber tube. The graduated upright burette is designed for the reception and measurement of the air or gas. The plain upright burette is the pressure-tube, its function being to regulate the pressure in the other tube (see fig. 9).

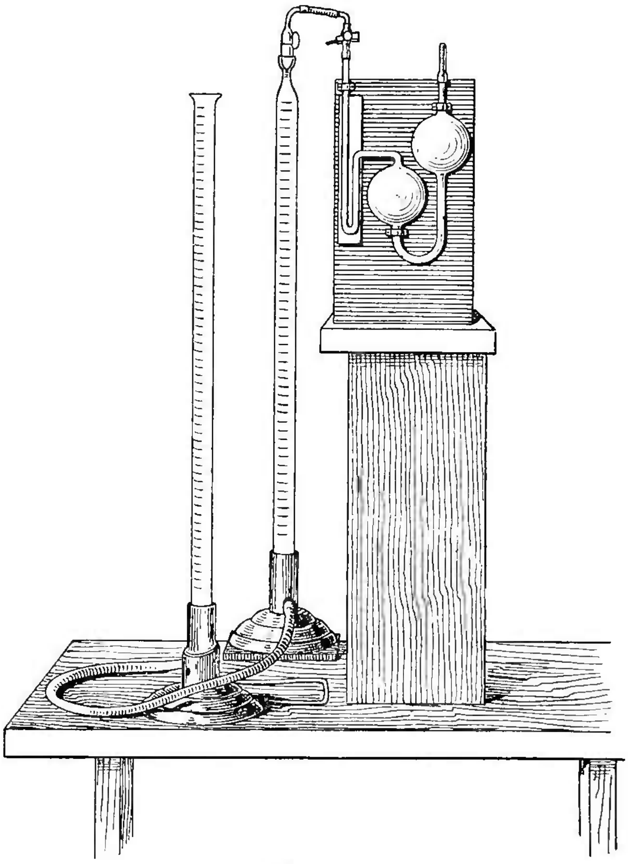


Fig. 9.

In order to use the burette, water must first be introduced, so as to rather more than half fill it. By raising the pressure-tube, the water will be caused to fill the graduated tube. By lowering the pressure-tube, a sample of air may thus be drawn into the graduated tube, which is left open at its upper end. So soon as air has been drawn into the graduated tube, a pinch-cock is made to close the upper connecting rubber tube, thereby confining the air sample in the graduated burette.

The next operation is to read off the volume of air. For this purpose it must be placed under the current barometric pressure by raising or lowering the pressure-tube until the level of the water is the same in both tubes. If the graduated tube be now read off, the volume of air in it can be expressed in c.c. Having been measured, the air sample is submitted to certain reactions in what is called an absorption pipette. By a reference to the figure, this will be seen to consist of two glass bulbs, the lower one having a larger diameter than the upper, and capable of holding at least 150 c.c. of the reagent to be employed, while the upper one should have a capacity of at least 100 c.c. By means of india-rubber connecting-tubes and bent capillary glass tubes, the gas burette is placed in communication with the absorption pipette. The india-rubber connections should be bound with thin copper wire, and the respective tubes provided with pinch-cocks; these latter need to be carefully closed before any manipulation of the connections takes place.

The particular method for estimating oxygen is based upon the well-known reaction between oxygen and nitric oxide, thus, $2NO + O_2 = 2NO_2$. The NO_2 is absorbed by water; there is, therefore, a contraction of three volumes for every one volume of oxygen. The mode of operation is to add excess of nitric oxide to the sample of air, and then to read the contraction. One-third of the contraction is the volume of the oxygen in the sample.

Some nitric oxide is prepared by the action of dilute nitric acid on copper turnings, the gas being preserved in a bell jar over water. The absorption pipette is next charged with water, and a sample of air having been drawn into and measured in the gas burette is then, after connecting the burette with the pipette, passed over into the absorption pipette and there allowed to remain while nitric oxide is introduced into the gas burette and its volume measured. This being done, the nitric oxide is passed over to the air in the absorption pipette. Immediately the well-known reaction takes place, and ruddy fumes of NO_2 make their appearance in the bulb of the absorption pipette. The absorption of these fumes by the water is very quick. The gas is passed backwards and forwards once or twice, the fumes disappear, and the final reading at once made.

Example.—Say 50 c.c. of air are drawn into the gas burette and duly passed over, after connection, into the absorption pipette containing water. Say, further, that 25 c.c. of NO_2 are drawn in, measured, and also passed over into the air in the absorption pipette. After the reaction has taken place and is completed, presume the resulting volume of air is found to be 44·2 c.c.; that is, 50 + 25 or 75 c.c. has become 44·2 c.c., being a contraction of 30·8 c.c.: one-third of this contraction, or 10·27 c.c., is the volume of oxygen present in the air sample of 50 c.c.; or in other words, 20·54 per cent.

In this, and all other processes of gas analysis, since the conditions of temperature should remain constant throughout the estimation, it is of importance that the gas burette, after it has been charged, should not be handled except by its iron stand.

Estimation of Carbon Dioxide.—The determination of this gas in air is of the greatest general importance, mainly because, as a product of both respiration and combustion, it affords an important index as to the extent to which other impurities co-exist. The procedure for its estimation in most common use is Pettenkofer's alkalimetric method.

The rationale of the process is as follows:—Clear lime-water or baryta-water, both being strongly alkaline media, will readily absorb carbon dioxide: the absorption of this weak acid will diminish the alkalinity or causticity of the original lime or baryta-water. If, therefore, the degree of alkalinity of either of these media be known both before and after exposure to the carbon dioxide, the difference will represent the amount of CO_2 which has combined with the lime or baryta.

To carry out the process it is necessary to have a clean glass vessel capable of holding about a gallon or 4·5 litres. The capacity of this jar is determined by filling it with water at 15° C. (= 59° F.), and measuring the contents by means of a litre or pint measure, one fluid ounce equalling 28·4 c.c. As already explained, the most convenient way of collecting the air sample is to fill the jar with water and empty it in the place, the air of which is to be examined, and then allowing it to drain for a while. When this has been done, 60 c.c. of clear lime or baryta-water are put in, and the mouth of the jar closed with an india-rubber cap. The vessel is agitated, so that the lime or baryta-water may run over the sides and thus become intimately exposed to the action of the air contained in the vessel. The same is then allowed to stand for half an hour or longer.

The causticity of the lime or baryta-water is next determined by titration with a solution of crystallised oxalic acid, made by dissolving 2·25 grammes of the acid in a litre of distilled water. One c.c. of this solution exactly neutralises one milligramme of lime, CaO, or 2·73 milligrammes of baryta, BaO. For the actual determination of causticity, 30 c.c. of the lime or baryta-water are taken and exactly neutralised with the oxalic acid solution, good turmeric paper, or rosolic acid or phenol-phthalein being used as indicators. If rosolic acid be used, a few drops of a solution made by dissolving 0·5 gramme of rosolic acid in 100 c.c. of 80 per cent. alcohol may be added to the lime or baryta-water. If phenol-phthalein be employed, a suitable solution is made by dissolving 5 grammes of the phenol-phthalein, with the aid of 25 c.c. spirits of wine, in 500 c.c. of distilled water. The amount of lime in the 30 c.c. taken will be then equal to the number of c.c. of the oxalic acid used; it is usually somewhere between 34 and 41 milligrammes. In the case of baryta the amount in the 30 c.c. will be 2·73 times the number of c.c. of the oxalic acid used.

In the same manner, after the lime or baryta placed in the jar has absorbed the CO_2 of the air in the vessel, 30 c.c. of it are taken out and tested for causticity with the oxalic acid, the difference between this and the previous determination showing the milligrammes of lime or baryta precipitated or combined with the carbon dioxide.

Before proceeding further with the calculation, it is necessary to estimate, subject to corrections for temperature and barometric pressure, the volume of air contained in the jar, reducing the same to normal conditions of 0° C. and 760 mm. This reduction to normal conditions of temperature and pressure is necessary, because the calculation of the volume of CO_2 from weight of CO_2, as based upon the analysis or titration of the lime or baryta-water, is expressed in these terms, and the conditions in both cases must be alike in order to compare them. Besides these necessary corrections for temperature and pressure, the volume of the 60 c.c. of lime or baryta-water put in the jar must be deducted before the nett volume of air in the vessel can be accurately stated.

The milligrammes of lime or baryta, calculated from the difference of the causticities, are next converted into terms of CO_2 by calculation of the ratio between their molecular weights, and then the CO_2 converted from milligrammes or measures of weight into cubic centimetres or measures of volume, in the ratio of as 1·9707 is to 1: because, carbon dioxide being 22 times heavier than hydrogen, and 1 litre of hydrogen at 0° C. and 760 mm. weighing 0·08958 gramme, therefore 1 litre of CO_2 at 0° C. and 760 mm. weighs $22 \times 0·08958 = 1·9707$ gramme, and 1·9707 milligramme of CO_2 under standard conditions of temperature and pressure measure 1 c.c. Having determined the exact volume of CO_2 present in the known volume of air, the proportion present is readily expressed as either a percentage or as so many parts in a thousand. The precise working of this determination will be more readily apparent after the consideration of an example.

Example.—Say, in a room with the temperature at 20° C. and barometric pressure at 720 mm., a sample of air is collected in a jar, having a capacity of 4·460 litres, and that 60 c.c. of lime-water are placed in the vessel for estimation of the contained CO_2. Whilst the jar is set aside, 30 c.c. of the lime-water are titrated with the oxalic acid solution, neutrality being obtained with 40 c.c. of this acid solution, indicating 40 mgms. of lime as being present in the lime-water. The gross capacity of the jar is recorded to be 4460 c.c., but, deducting 60 c.c. for the space occupied by the added lime-water, this gives 4400 c.c. nett as the space available for the air sample at the recorded current temperature and pressure of 20° C. and 720 mm. This, reduced to the standards of 0° C. and 760 mm., gives 3885 c.c. as the corrected volume of air operated upon, or really present, in the jar under standard conditions of temperature and pressure: thus,—

$$V = \frac{4400 \times 720}{760(1 + (0{\cdot}00366 \times 20))} = 3885 \text{ c.c.}$$

Presume, after being exposed to the action of the air in the jar, 30 c.c. of the lime-water, removed from the vessel, show a causticity equal to 34 c.c. of the oxalic acid solution, indicating the presence in that lime-water of 34 mgms. of lime. The difference between this amount of lime and that shown to be present in 30 c.c. of lime-water before exposure to the air gives 40 − 34 or 6 mgms. of lime as having combined with the CO_2 of the air sample from 30 c.c.; but as 60 c.c. of lime-water were put in, this means 12 mgms. of lime as the total loss due to the CO_2. Since lime, CaO, is to carbon dioxide, CO_2, as 56 is to 44, therefore 12 mgms. of lime equal 9·4 mgms. of CO_2. But milligrammes of CO_2 are to cubic centimetres of CO_2 as 1·9707 is to 1, therefore 9·4 mgms. CO_2 equal 4·76 c.c. of CO_2. Now the true capacity of the jar, under standard conditions, we have found to be 3885 c.c., and in this we have found 4·76 c.c. of CO_2, which is, in amount, equal to 1·22 c.c. or volumes of CO_2 in 1000 c.c. or volumes of air.

A popular method for estimating carbon dioxide in air has been suggested by Cohen and Appleyard. The method depends upon the fact that if dilute lime-water, coloured with phenol-phthalein, containing insufficient lime to combine with the carbon dioxide present, be shaken with the air sample, the rate of absorption of the gas will vary with its volume. The time required to decolourise the indicator will therefore give the quantity of CO_2 present.

The following apparatus and chemicals are required:—(1) A clear glass stoppered bottle of 22 fluid ounce capacity; (2) some phenol-phthalein solution prepared as stated above; (3) a standard lime solution prepared by diluting 10 c.c. of saturated lime-water to 1 litre.

The process is conducted as follows:—Rinse the bottle out with water, fill, and empty in the place where the air is to be examined, allowing it to drain for a minute. Add 0·25 c.c. of indicator solution and 10 c.c. of the dilute lime-water, finally stoppering and well shaking the bottle with both hands until the pink colour vanishes. The time required will indicate the condition of the atmosphere. The following determinations have been made, in which the amount of CO_2 has been ascertained by Pettenkofer's method:—

Time in mins. required to decolourise the solution.	Percentage of CO_2 by Pettenkofer's method.
$1\frac{1}{4}$	0·160
$1\frac{1}{3}$	0·138
$1\frac{1}{2}$	0·128
$3\frac{1}{4}$	0·077
$3\frac{1}{2}$	0·070
4	0·053
$4\frac{1}{4}$	0·051
5	0·046
$5\frac{1}{4}$	0·044
$6\frac{1}{4}$	0·042
$7\frac{1}{2}$	0·035

On this basis the following table may be taken to indicate roughly the condition of the air:—

Time.	Condition of Air.
Under 3 minutes,	Bad.
Above 3 and under 5 minutes,	Fair.
Above 5 minutes,	Good.

An ingenious apparatus has been designed by O. Schulz, in which a measured quantity of a standard carbonate of soda solution is placed in a long test-tube, and air drawn through it by means of an aspirator; the soda solution is coloured with phenol-phthalein, and, when the colour is discharged, it indicates that neutralisation has been effected by the CO_2 in the quantity of air drawn through. The amount of CO_2 can then be calculated according to the strength of the soda solution.

It must be understood that none of the methods hitherto used for the determination of carbon dioxide in the air give quite accurate results, but Pettenkofer's is the most convenient for ordinary use, and is sufficiently accurate for practical purposes. The results differ considerably if the quantities of air treated vary, therefore uniformity in this point is desirable.

Determination of the Organic and Oxidisable Matter.—The nitrogenous matter existing in the air may be in the form of dead or living matter of very various kinds. Its chemical determination practically resolves itself into washing the air, by agitation in distilled water, and then estimating the nitrogen, the free and albuminoid ammonia, as well as the nitrous and nitric acid as described in methods of water analysis. The mere presence of free ammonia may be determined by exposing strips of filtering paper, dipped in Nessler's solution or in ethereal solution of the alcoholic extract of logwood; the former becomes yellow, the latter purple.

Chapman, finding that water did not sufficiently absorb the nitrogenous substances in air, proposed to heat finely-powdered pumice-stone to redness, to moisten it with pure water, and then to place it over some coarse pieces of pumice-stone supported on wire in a funnel; a definite quantity of air (say 100 litres) is then drawn through the funnel. The pumice-stone is transferred to a retort containing water freed from ammonia, and distilled as in the determination of the albuminoid ammonia of water. Angus Smith took a bottle of about 2000 c.c. capacity, placed in it 30 to 50 c.c. of the purest water, drew into it the air to be examined, and then agitated the water in the bottle, and proceeded as in Wanklyn's and Chapman's water test. The most convenient way is to draw the air, by means of a measured aspirator, through a succession of wash bottles, each containing 100 c.c. of water perfectly free from ammonia, and then to determine the free and albuminoid ammonia by Wanklyn's method.

Another plan is to lead a definite quantity of air through a clean curved tube, surrounded by a freezing mixture; the water of the air condenses, and with it much of the organic matter; the tube is then washed out with pure water, the washings are put into a retort with ammonia-free water, and distilled as usual. After passing through the tube the air should be led through pure water to arrest the portion of organic matter that always escapes condensation.

The quantity of air drawn through must, of course, be accurately determined by a properly arranged aspirator, and the results then calculated in milligrammes per cubic metre.

For the estimation of the oxidisable matters in the air in terms of oxygen, a definite quantity of air is drawn through a solution of permanganate of potassium of known strength, and the amount of undecomposed permanganate is determined by oxalic acid or sodium thiosulphate. Or part of the water through which the air has been drawn for the ammonia determinations may be examined in the same way as in the case of drinking water. Carnelley and Mackie shake the air up in a bottle with a measured quantity of permanganate, and afterwards determine the amount of bleaching by comparison with a sample of distilled water to which permanganate solution is carefully added from a burette. The solution of permanganate used is of $\frac{N}{1000}$ strength, of which 1 c.c. = 0·008 milligramme of oxygen, = 0·0000056 litre of oxygen at 0° C. and 760 mm. It is usually kept at $\frac{N}{10}$ strength and diluted as required, about 50 c.c. of dilute sulphuric acid (1 in 3) being added to each litre of the weak solution.

The samples of air are collected in well-stoppered jars of from 4 to 5 litres capacity; 50 c.c. of the milli-normal permanganate solution are then run into the jar, which is at once tightly stoppered and well shaken for at least five minutes. 25 c.c. of the permanganate are then withdrawn by a pipette and then placed in a glass cylinder holding about 250 c.c. Then another 25 c.c. of the permanganate solution are placed in a similar cylinder, both diluted up to 150 c.c. with distilled water and allowed to stand for ten minutes, after which the tints of the cylinders are compared. Into the decolourised cylinder more permanganate is run in from a graduated burette, until the tints of both cylinders are of the same intensity. The amount of solution added from the burette is a measure of the bleaching effected by the known volume of air on half the permanganate. This multiplied by 2 gives the amount. The results may either be expressed in terms of the number of c.c. of the milli-normal solution bleached by 1 litre of air, or by the number of volumes of oxygen required to oxidise the organic matter in, say, a million volumes of air.

Example.—25 c.c. of solution from a 4·5 litre jar, in which 50 c.c. had been placed, required 3 c.c. of the permanganate to bring it up to the standard tint, or the whole 50 c.c. would have required 6 c.c. This represents the number of c.c. of permanganate solution bleached by 4500 − 50 = 4450 c.c. of air, consequently $\frac{6}{4·45} = 1·348$ c.c. is the bleaching effected by 1 litre of air. But 1 c.c. of $KMnO_4$ solution = 0·0000056 litre of oxygen, ∴ 1·348 c.c. $KMnO_4$ = 0·00000755 litre of oxygen is required to oxidise the organic matter in 1 litre of air, or 7·55 volumes of oxygen to oxidise the organic matter in a million volumes of air.

The method is highly ingenious and can be rapidly performed. Some difficulty may be experienced at first in matching the tints, and in some samples of very foul air no amount of permanganate solution will bring the decolourised sample up to its colour. The permanganate acts upon various matters in the air besides the putrescible organic matters, more particularly upon nitrous acid and hydrogen sulphide; this fact renders it an unsatisfactory test for organic matter, but as a test for organic matter and other impurities co-existing, it affords a useful reaction.

The presence or absence of sulphuretted hydrogen in air may be detected by either exposing strips of paper moistened with lead acetate to the air, or by drawing the air through a solution of the same salt. If there is merely a dark colour, but no precipitate, the amount may be estimated on colorimetric principles, that is, the colour may be imitated by acting upon a similar bulk of lead acetate solution by water containing known quantities of hydrogen sulphide.

Estimation of Carbonic Oxide.—There is no easy and quantitative chemical test for this dangerous gas; the best qualitative test is that of Vogel, which is based upon the spectroscopic examination of hæmoglobin, and is so delicate that it can detect 0·03 per cent. To the sample of air collected in a jar a little pure water is added, and into this a drop or two of blood from a pricked finger is made to fall. This diluted blood is next well shaken up with the air in the jar, and then a small quantity is placed in a spectroscope, for an examination of its absorption bands. As so examined, the appearance in the spectrum will be that of oxy-hæmoglobin. Oxidised hæmoglobin shows two well-marked bands in the yellow and in the green parts of the spectrum, both lying between D and E; a little ammonium sulphide is now added and the bottle well shaken; if carbonic oxide is present the spectrum will undergo no change, but if absent, the ammonium sulphide will reduce the hæmoglobin, as indicated by a single absorption band in the spectrum occupying an intermediate position with regard to the two original bands.

When carbonic oxide is suspected of existing in the air in large quantities, an estimation of this gas can be made by noting the volume of air absorbed by a solution of subchloride of copper in a Hempel apparatus. The subchloride of copper is prepared by digesting oxide of copper and copper turnings in strong hydrochloric acid. Since the presence of oxygen in the air somewhat impairs the powers of the copper solution, it is necessary, in order to successfully carry out this estimation, to first remove the oxygen, as already described, and then pour 50 c.c. of acid subchloride of copper solution into an absorption pipette, into which the air sample (now deprived of oxygen) must be repeatedly passed until a constant reading is obtained. The loss, in volume, is due to carbonic oxide.

Determination of Ozone and Watery Vapour.—The most common test for ozone is that of exposing to the atmosphere faintly reddened litmus paper, which has been moistened with potassium dioxide and then dried. If ozone be present, this becomes blue, owing to the breaking up of the potash salt and liberation of alkali. A more detailed account of ozonometry and criticism of its exact value is given in the chapter dealing with meteorology and meteorological observations.

The hygrometric condition of the air is ascertained in various ways, especially by the use of the dry and wet bulb thermometer and different kinds of hygrometer. The special facts relating to their construction and methods of use are given in the chapter upon meteorology.

Determination of Sulphurous Acid.—For this estimation are required (1) a deci-normal solution of sodium thiosulphate, made by dissolving 24·8 grammes of $Na_2S_2O_3 5H_2O$ in a litre of distilled water. One c.c. of this solution will exactly decolourise 12·65 milligrammes of iodine, forming colourless sodium tetrathionate and sodium iodide; (2) a deci-normal solution of iodine made by dissolving 12·65 grammes of iodine in a litre of water. As iodine is rarely very pure and somewhat volatile on weighing, it is usually better to prepare the solution by first dissolving 13 grammes of iodine, and then rubbing it up in a little water with 20 to 25 grammes of potassium iodide, diluting to 1 litre, and diluting still further until 10 c.c. of the preceding deci-normal sodium thiosulphate solution exactly suffice to decolourise 10 c.c. of the iodine solution, which had been coloured blue by the addition of a few drops of starch solution. The reaction being according to the formula:

$$2Na_2S_2O_3 + I_2 = Na_2S_4O_6 + 2NaI.$$

The experiment is carried out by exposing a given volume of air to say

20 c.c. of the iodine solution in an absorption pipette, when the following reaction ensues if sulphurous acid be present: $SO_2 + I_2 + 2H_2O = SO_4H_2 + 2HI$. In other words, 64 milligrammes of sulphurous acid exactly convert 253 milligrammes of iodine into hydrogen iodide, or 3·2 milligrammes exactly decolourise 1 c.c. of a deci-normal solution of iodine.

If, after exposure to a given volume of air for ten minutes in an absorption pipette, as already described under the head of oxygen determination, the iodine solution be titrated with the deci-normal solution of sodium thiosulphate, each decrease of a c.c. of the thiosulphate solution required indicates 3·2 milligrammes of sulphurous acid as present in the given volume of air.

Example.—Say, by means of a Hempel's apparatus, 180 c.c. of air have been exposed in an absorption pipette for ten minutes to 20 c.c. of deci-normal iodine solution, which previously had been found to accurately correspond with 20 c.c. of a deci-normal thiosulphate solution. After exposure to the air, on re-titration the 20 c.c. of iodine solution only required 18·6 c.c. of thiosulphate to exactly decolourise. Therefore, 20 − 18·6 or 1·4 c.c. of thiosulphate solution less, now required by the iodine solution, represents the iodine converted into hydrogen iodide by the sulphurous acid present in the 180 c.c. of air. Or, 1·4 × 3·2 = 4·48 milligrammes of SO_2 present in 180 c.c. of air or 0·024 part in 1000 of air.

Determination of Hydrogen Sulphide.—The quantitative estimation of this gas can be made in air in a similar manner. One c.c. of deci-normal iodine solution decomposes 1·7 milligramme of sulphuretted hydrogen; therefore, each c.c. of the sodium thiosulphate solution *less* used after absorption than for the titration of the same volume of the original solution of iodine, indicates the equivalent absorption of 1·7 milligramme hydrogen sulphide. The amount present, then, in 1000 volumes of the air is readily calculated.

Examination of Suspended Matter and Micro-organisms.—From time to time various methods have been suggested for the examination of the suspended matters in air. One of the earliest methods was to aspirate large volumes of air slowly through distilled water, placed in a series of small wash bottles, each holding about 100 c.c. The suspended or solid matter was allowed to settle, the supernatant fluid siphoned off and the specimens from the residue examined microscopically.

A later development was Pouchet's aëroscope and Marie-Davy's modification of it. These instruments practically consist of a closed glass vessel, perforated by two glass tubes: each tube is bent at a right angle, one being much shorter than the other. The longer tube, inside the cylinder or vessel, is drawn to a fine point and made to impinge upon a circular glass plate, which has been previously smeared with glycerin. The apparatus is connected by means of the short tube with an aspirator, which, on being worked, causes air to be sucked in by the longer tube: the air, so drawn, falls as a spray upon the glass slide, the sticky surface of which retains the suspended matters.

The simplest methods for examining the micro-organisms in air consist in exposing plates of glass or microscopic slides coated with glycerin, or a mixture of glycerin and glucose, or even coated with nutrient gelatin. Sterilised potatoes have been similarly exposed. Upon these various micro-organisms settle and subsequently develop: all these procedures are, however, crude and open to many sources of error. When specimens are only desired, and not an idea of the number for a given volume of air, Koch's method is useful. He employs a glass jar about six inches high, the neck of which is plugged with cotton-wool. In the interior is a shallow glass capsule, which can be removed by means of a brass lifter. The whole is sterilised by exposure to 150° C. for an hour. The nutrient gelatin of an ordinary stock tube is liquefied by heat and the contents emptied into the glass capsule. The jar is now exposed to the air to be examined, for a definite time, the cotton-wool plug replaced, and the whole jar set aside for the colonies to develop.

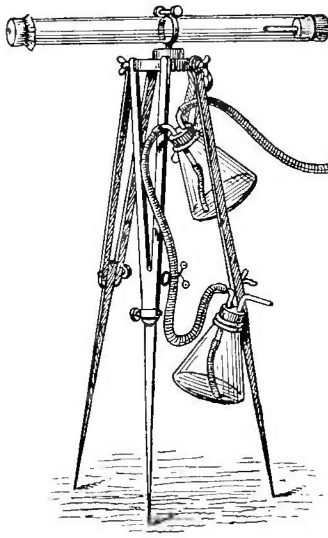


Fig. 10.

For more accurate results Hesse's apparatus may be employed (fig. 10). This consists of a glass cylinder about 18 inches long and 2 inches in diameter. At one end a piece of india-rubber sheeting is stretched and firmly bound round the end of the glass cylinder to prevent air being sucked past it. The other end of the cylinder is closed with a tight-fitting plug of india-rubber, through which a glass tube passes. From this tube passes a piece of india-rubber tubing to a litre bottle filled with water, and from this bottle to a second litre bottle another tube passes: when not in action, this tube is shut off. Along the bottom of the glass cylinder are placed 50 c.c. of nutrient jelly, solid when cooled. The cylinder rests on a tripod stand similar to those used by photographers. The nutrient jelly, india-rubber caps, tubing, cylinder, &c., are sterilised in the usual manner by steaming in a steriliser repeatedly, and the tubes with their layers of jelly are kept sufficiently long, before using, to see that there is nothing growing upon them. When it is wished to operate, the india-rubber sheeting is perforated by a heated needle or pin, making a very small hole, and the pinch-cock opened: water passes slowly from the upper to the lower bottle, and when it is empty a litre of air has been supposed to pass into the cylinder, and to deposit its contained microbes. As many litres of water as desired can be run out simply by reversing the position of the bottles. When the air is very foul, one litre will be sufficient, as the colonies otherwise would be too close and run into each other. When the operation is over, sterilised india-rubber caps or pieces of cotton-wool, also sterilised, are bound over the ends of the Hesse tube, and it is then placed in either an incubation chamber or other suitable place. After twenty-four hours or longer, the colonies may be counted. At one time the glass cylinders were used with a coating of gelatin all round the interior, but this is difficult to obtain, and in practice it is found that the microbes gravitate and settle on to the layer at the bottom of the tubes. The method of Hesse is very elegant, and has many advantages: from the length of the surface of the jelly exposed, separate colonies form, often giving pure cultivations, and their growth can be studied as on a glass plate, and inoculations can be readily made in the usual manner.

There are undoubtedly objections, some of which apply to all bacterial methods, and others which apply specially to this one in particular. The chief objection appears to be, that, although you run off a litre of water, and although the capacity of the glass cylinder is also about a litre, it does not follow that a litre of air has been drawn from the outside. The first half of the air contained in the glass cylinder may be removed, but after that, or even before it, the air from the outside and the air inside diffuse and commingle, so that a mixture of these will be aspirated out, and in consequence a litre of air will not have passed in. This defect makes the method doubtful as a quantitative test. Another objection is, that one cannot be sure that all microbes are deposited: true, we find in practice that the colonies are found in greatest abundance at the end furthest from the aspirator and gradually diminish inwards, but still one cannot be certain that some micro-organisms have not escaped. Notwithstanding these objections, the method is one of considerable practical value.

In order to obviate some of the difficulties and objections experienced with Hesse's apparatus, Percy Frankland aspirates the air through small glass tubes, 5 inches long and $\frac{1}{4}$ inch internal diameter, in which are placed two plugs of sterilised glass wool; these plugs retain the germs, and are then introduced into flasks containing nutrient gelatin, and well shaken up. The gelatin solidifies on the sides of the flask, and the colonies can be examined readily through the glass. The glass wool mixes so intimately with the gelatin that it does not interfere with the easy perception of colonies when they develop. Powdered sugar may be used instead of glass wool. The gelatin may also be poured into Petri's dishes in the ordinary way, instead of being allowed to solidify within the flasks.

A very similar plan is that of Petri, who employs calcined sand as a filter, in grains of 0·25 to 0·5 mm. in size. Two such sand filters, each 3 centimetres in length, are kept in position within small glass tubes by means of small wire caps. The whole, after sterilisation, are connected with an aspirator and air drawn through, the sand being subsequently transferred to liquefied gelatin as in Frankland's method.

It is impossible to say definitely, at present, which of these methods is the better; but a large number of observations indicate that the use of glass wool or of sand filters, with a subsequent preparation of plate cultures from them, is preferable to the growth of colonies in a long tube, such as Hesse's.

The actual varieties of micro-organisms which have been found, by one or other of these methods, in the air, are considerable, and in the majority of cases moulds are much less frequently found than bacteria. The purer air is, the more generally do the numbers of bacteria and moulds approximate. In inhabited rooms, when the air becomes vitiated, the bacteria increase, while the moulds are affected hardly at all.

The effect of stirring up dust is to increase the ratio of bacteria to moulds. On the other hand, if the air be allowed to remain quiet for any length of time, the bacteria, or rather the particles to which they are attached, settle out much more rapidly than moulds.

The ratio of bacteria to moulds in the air, on still and windy days and in dry and damp weather, is shown in the following table. Other things being equal, there are fewer bacteria in the air on damp or still days than on dry or windy days. The moulds seem to be much less affected by either wind or dryness.

	Still, damp days.	Windy, damp days.	Still, dry days.	Windy, dry days.
Bacteria,	36	63	70	106
	— or as 1 : 1	— or as 1·26 : 1	— or as 2·6 : 1	— or as 14·1 : 1
Moulds,	37	50	27	7·5

BIBLIOGRAPHY AND REFERENCES.

ADAMS, *On the presence of Arsenic in the Vapours of Bone Manure*, Lond., 1876. ALBRECHT, *Handbuch der Praktischen Gewerbehygiene*, Berlin, 1894. ALESSI, *Central. für Bakterien und Parasitenkunde*, Bd. xv. No. 7. ARLIDGE, Milroy Lectures upon *Occupations and Trades in Relation to Public Health*, Lond., 1889. ARTHUR, "Bacteriology of Sewer Air," *Sanitary Record*, Nov. 10, 1894.

BALFOUR, "Vital Statistics of Cavalry Horses," in the *Journ. Statis. Soc.*, Lond., June 1880. BALLARD, "Report upon the Middlesborough Epidemic," *Supp. to 18th Annual Report to the Local Gov. Board*, 1889. BERGEY, WEIR MITCHELL, and BILLINGS, Report upon "The Composition of Expired Air and its Effects upon Animal Life," *Proc. National Acad. of Sciences*, New York, 1895; also summarised in *Science*, vol. i. No. 18, p. 481, May 3rd, 1895. BILLINGS, *Ventilation and Heating*, New York, 1893. BLACKLEY, *Experimental Researches on the Causes and Nature of Catarrhus Æstivus*, Lond., 1873. BUCHANAN, *Report on certain Sizing Processes in the Cotton Manufactures of Todmorden*, 1872; also *9th Rep. of Med. Off. to the Privy Council*; also "Report upon an Outbreak of Enteric Fever in Caius College, Cambridge," *Supp. to 2nd Annual Report of Med. Off. to the Local Gov. Board*, 1874.

CARNELLEY, *Phil. Trans. Roy. Soc. Lond.*, vol. clxxviii., 1887; also *Proc. Roy. Soc. Lond.*, vol. xli. p. 238; also vol. xlii., June 1887. CARPENTER, A., *Trans. Internat. Med. Cong.*, Lond., 1881; also *Brit. Med. Journ.*, June 22, 1889. CHADWICK, Sir E., *Report upon Interments in Towns*, Lond., 1868. CORNET, *Zeitschr. für Hygiene*, Bd. v., 1889. CUNNINGHAM, "Microscopical Examination of Air in India," *Rep. San. Commiss. India*, Appendix, Calcutta, 1872.

DE CHAUMONT, *Lectures on State Medicine*, Lond., 1875.

FERGUSON, "On some of the Constituents of the Atmosphere,' *San. Journ. for Scotland*, Glasgow, 1876, p. 181. FODOR, *Hygienische Untersuchungen u. Luft, Boden und Wasser*, Braunschweig, 1881. FRANKLAND, *Proc. Roy. Soc. Lond.*, 1877. FRANKLAND, P., *Phil. Trans. Roy. Soc. Lond.*, 1887, p. 113.

GREENHOW, *Papers relating to the Sanitary State of the People of England*, Lond., 1858.

HALDANE, "The Physiological Effects of Air vitiated by Respiration," *Journ. Path. and Bacteriology*, vol. i., 1892, pp. 168 and 318. HERMANS, *Archiv. f. Hygiene*, Bd. i., 1883. HESSE, *Mittheil. Kaiserl. Gesundheitsampte*, 1882. HIRT, *Die Krankheiten der Arbeiter*, Erste Theil: "Staub inhalations Krankheiten," Berlin, 1871.

LEHMANN, *Methods of Pract. Hyg.*, trans. by Crookes, Lond., 1893. LEHMANN and JESSEN, *Archiv. f. Hyg.*, x. p. 367. LETHEBY, Article upon "Sanitary Science" in *Encyclopædia Britannica*. LEVY, *Annuaire de l'Observ. de Montsouris*, 1882; also *Traité d'Hygiene*, 1886. LEWES, "Gas Lighting and Ventilation," *Journal of Gas Lighting*, Lond., July 1893. LISSAUER, *Deutsche Vierteljahrschrift für öffentliche Gesundheitspflege*, 1881. LOYE, *Memoires de la Soc. de Biologie*, Paris, 1888-1891.

MARCET, "The History of the Respiration of Man," being the Croonian Lectures, 1895, *Lancet*, June 22, 29, and July 6, 1895. MERKEL, *Archiv. f. Hygiene*, 1892, xv. p. 1. MIESCHER, *Archiv. f. Anat. u. Phys.*, 1885. MILROY, *Report on Health of the Royal Navy*, Lond., 1862. MIQUEL, *Organismes vivants de l'Atmosphere*; also in *Annuaire de l'Observ. de Montsouris*, 1884, p. 533.

NÄGELI, *Die Niederen Pilze*, 1877. NASMYTH, "Report on the Air of Mines," *Brit. Med. Journ.*, 1888, vol. ii. p. 222.

OGLE, *Supp. to 45th Report of the Registrar-General*, 1885.

PARENT-DUCHÂTELET, *Hygiene Publique*, Paris, 1836. PARKES, E. A., Various Reports upon Hygiene in *A. M. D. Reports*, more particularly in 1862-3; also *Report on the Cholera in Southampton in* 1866, to the Med. Off. of the Privy Council. PARRY-LAWS, "On the Ventilation and Condition of London Sewers," *Report to London County Council*, 1894. PETTENKOFER, "Uber den Kohlensäuregehalt der Luft in der libyschen Wüste, über und unter der Bodenoberfläche," *Zeitsch. f. Biol.*, München, 1875, xi. 381-391; also in the *Handbuch der Hygiene u. Gewerbe-Krankheiten*, Berlin, 1887. Playfair, *Second Report of Health of Towns Commission*, Lond., 1887. Preece, "Sanitary Aspects of Electric Lighting," *Proc. San. Institute*, Lond., 1890, vol. xi. p. 267.

Ramazzini, *Les Maladies de l'Artizan*, Paris, 1842. Rauch, *Intra-mural Interments in Cities, their Influence upon Health and Epidemics*, Chicago, 1866. Rawlinson, *Report of Committee on Sewage*, Lond., 1864, p. 174. Robertson, "A Study of the Micro-organisms in Air, especially in Sewer Air," *Brit. Med. Journ.*, Dec. 15, 1888.

Sigerson, "Further Researches on the Atmosphere," *Brit. Med. Journ.*, June 1870, p. 638. Simon, Sir J., *Public Health Reports*, Lond., 1887. Simon, R. M., *Birmingham Med. Rev.*, May 1887. Smith, Angus, *Air and Rain*, 1862; also *Report upon Mines*, Blue Book, 1864; also "On the Air of Towns," *Quart. Journ. Chem. Soc.*, Lond., 1859, xi. 196; also "On Organic Matter in the Air," *Chem. News*, Lond., 1870, xxi. 64. Smith, Fred., *Veterinary Hygiene*, Lond., 1890. Smith and Sutherland, *Report upon Extra-mural Interments*, 1850. Soyka, "Uber die Bestimmung der organischen Substanzen in der Luft," *Amtl. Ber. deutsch. Naturf. u. Aertze*, München, 1877, i. 349. Spear, *Local Government Board Report*, 1890.

Tardieu, *Diction. d'Hygiene*, Paris, 1866. Thackrah, *Effects of Arts, Trades, and Professions upon Health*, 1832. Tidy, "On Air Analysis," *Med. Times and Gaz.*, Lond., 1873, i. 137. Tyndall, *Phil. Trans. Roy. Soc. Lond.*, 1876, Part 1; also *Floating Matter in the Air, in Relation to Putrefaction and Infection*, Lond., 1881.

Wanklyn, "On the Differences between Wholesome and Unwholesome Air," *Lancet*, 1865, i. 60. Weaver, "On the Quality of Atmospheric Air in Public and Private Buildings in Leicester," *Lancet*, July and Aug. 1872, pp. 7, 150 and 223. Wilson, *Handbook of Hygiene*, Lond., 1892.

CHAPTER III.

VENTILATION AND HEATING.

In the last chapter sufficient evidence was given to indicate the intimate connection between impaired health, whether in man or animals, and defective air supplies as to render any repetition of either facts or figures unnecessary here. It is essentially to correct any evils arising from faulty conditions of the air in houses, factories, or other enclosed spaces that the theory and practice of ventilation aims. The term ventilation, however, is not always used in the same sense, being frequently confused with aëration. In simple aëration of a room the air is changed but once or at intervals, whereas in true ventilation the air is constantly changed by the passing out of a portion of the enclosed air, and the entrance of other air to take its place. Regarded, therefore, as the continuous, and more or less systematic, renewal of air in a room or other closed space, the term ventilation may be strictly defined as the removal or dilution, by a supply of pure air, of the pulmonary and cutaneous exhalations of men or animals, and of the products of combustion from lights in ordinary dwelling-houses, to which must be added, in factories, dust from industrial processes, and in hospitals, the effluvia which proceed from the persons and discharges of the sick.

Involving, as it does, the introduction of pure external air in continuous currents, its diffusion, and the constant removal of a corresponding volume of air more or less fouled by gases, vapours, moisture and particulate matter, or which is heated above the degree which is consistent with comfort and health, the subject of ventilation is one of some complexity, and is closely connected with the facts which concern the production and distribution of heat. In studying, therefore, the allied subjects of ventilation and heating, we have to remember the chemical and physical properties of air, to bear in mind the various sources of its contamination, as well as the forces which are available for moving it in the direction best suited for our purpose, coupled with a consideration of the arrangements of flues, shafts, &c., best adapted to secure the entrance, diffusion, and exit of the amount of air required.

Notwithstanding the existence of a vast amount of literature upon these subjects, both from the purely hygienic and the purely engineering or architectural points of view, still the conditions of ventilation and heating in the greater number of dwellings and public buildings must be said to be unsatisfactory. In this country, the great majority of habitations have no systematic scheme of, or special provisions for, ventilation, and even in the greater number of churches, schools, theatres, courts of justice, and public assembly rooms, in which some openings do exist for the entrance and exit of air, it is rare to find satisfactory ventilation. The causes of this appear to be partly apathy and ignorance on the part of the people, partly an inability on the part of architects and engineers to accept a definite standard as to quantity of air required, and partly the question of cost. In respect of this last factor, it is important to remember that in most cold climates it is difficult to combine good ventilation and sufficient heating with cheapness of construction in building; possibly the question of expense might be considerably modified, were the matter of ventilation and heating duly considered in the beginning, and not taken up as after-thoughts when every detail as to construction has been decided upon. When this fact is more fully appreciated by architects and builders, doubtless considerable improvements, as to both ventilation and heating, will soon be apparent.

This subject may be conveniently considered under the following heads:—

1. The quantity of fresh air required for the purposes defined above.
2. The methods by which this quantity may be supplied.
3. The methods of heating and cooling.
4. The method of examining whether ventilation and heating are sufficient or not: or in other words, ascertaining that the air of inhabited rooms is pure, according to a certain standard.

QUANTITY OF AIR REQUIRED FOR VENTILATION.

The quantity of air required for ventilation will naturally depend upon the nature and amount of the air impurities requiring dilution and removal. These have been already considered in the preceding chapter, and, disregarding details, practically consist of impurities from respiration and from artificial lights. Of these various impurities, no matter whether from respiration or illumination, the carbon dioxide is accepted as the chief measure of air vitiation. This is so, not because the carbon dioxide exists in such amount as to much influence health, but because it appears to exist in a constant ratio with the other offensive and possibly more dangerous impurities. And as it is very readily determined with sufficient accuracy for practical purposes, it is taken as a convenient index to the amount of the other impurities in general.

Fresh Air requirements of the Healthy.—Taking the carbon dioxide as the measure of the impurity of the air vitiated by respiration and transpiration, in short, from the person in any way, we have to ask, What is to be considered the standard of purity of air in dwelling-rooms? We cannot demand that the air of an inhabited room shall be absolutely as pure as the outside air; for nothing short of breathing in the open air can insure perfect purity at every respiration. In every dwelling-room there will be some impurity of air.

The practical limit of purity will depend on the cost which men are willing to pay for it. If cost is disregarded, an immense volume of air can be supplied by mechanical contrivances, but there are comparatively few cases in which this could be allowed.

Without, however, attempting too much, it may be fairly assumed that the quantity of air supplied to every inhabited room should be sufficient to remove all sensible impurity, so that a person coming directly from the external air should perceive no trace of odour, or difference between the room and the outside air in point of freshness. This is now pretty generally admitted as the most convenient practical standard, precautions being taken that the air space be entered directly from the external air, or as nearly so as possible, for the sense of smell is rapidly dulled.

In 1875, de Chaumont showed from a large number of observations that the sense of smell, carefully employed, gives a very fair idea of the amount of impurity in an air space. In these experiments, the amount of carbon dioxide in the external air was determined at the same time, so that the respiratory impurity was accurately known. Dividing the observations into groups, the following results were obtained:—

	1. Fresh, or not differing sensibly from the outer air.	2. Rather close. Organic matter becoming perceptible.	3. Close. Organic matter disagreeable.	4. Very close. Organic matter offensive and oppressive; limit of differentiation by the senses.
Mean CO_2 per 1000 vols. reduced to 0° C. (=32° F.), due to respiratory impurity,	0·1943	0·4132	0·6708	0·9054

It will thus be seen that the smell of organic matter is, on an average, imperceptible to the sense of smell when the coincident CO_2, due to respiratory (or personal) impurity, does not exceed 0·1943 per 1000; and that when it reaches 0·9054, smell is no longer able to detect shades of difference. We may therefore take 0·2 per 1000 in round numbers as the maximum amount of respiratory impurity admissible in a properly ventilated air space.

This relation between the smell and air vitiation of an inhabited room varies greatly under certain circumstances. Thus the smell of organic contamination from respiration may not be perceptible when the CO_2 is as high as 0·5 per 1000, and yet be very decided when the CO_2 does not exceed 0·3 per 1000. These differences depend largely upon the amount of moisture present and the temperature.

In adopting any standard of air purity, as expressed by the proportion of carbon dioxide present, we must not forget that, although hitherto it has been assumed that the carbon dioxide found, in excess of that which exists in the outer air, is all due to respiration, such is not always the case. Some may be due to gas or candles. Similarly, in instances where some of the air impurity may not be readily appreciable by a chemical test, the vitiation as indicated by a greater or less amount of carbon dioxide may be wide of the mark. Subject to these considerations, we may practically accept the carbon dioxide present in any given air sample as the best and most reliable index of air pollution.

Having fixed upon a standard of respiratory impurity permissible in a properly ventilated air space, it is easy to calculate the amount of air needed to dilute the air expired by a person for a given time, so that the carbon dioxide contained in the resulting mixture shall not exceed this standard. The amount of carbon dioxide, over and above that in the inspired air, which is expired by an individual during an hour, varies with his weight and body activity.

Pettenkofer, whose experiments are still the most trustworthy, ascertained that a man of twenty-eight years of age, weighing 132 ℔ avoir., evolved per hour at night during repose 0·56 of a cubic foot of carbon dioxide, and 0·78 in the day time, using very moderate exertion; during hard work the same man evolved 1·52 per hour. These amounts give the following:—

In repose,	0·00424 cub. ft. of CO_2 per ℔ of body-weight.			
In gentle exertion,	0·00591	,,	,,	,,
In hard work,	0·01152	,,	,,	

These figures are nearly in the ratio of 2, 3, and 6, and this may serve as a guide to the proportions of fresh air required. If we now take the average weight of adult males at 150 ℔ to 160 ℔, adult females at 100 ℔ to 120 ℔, and children at 60 ℔ to 80 ℔, we should have the following amounts of carbon dioxide evolved per hour in repose:—

Adult males,	0·636 to 0·678 cubic foot.
,, females,	0·424 to 0·509 ,,
Children,	0·254 to 0·339 ,,

The estimate for children is probably too little, as tissue change is more active in their case.

For a mixed community a general average of 0·6 of a cubic foot per hour may be adopted; but for adult males, such as soldiers, it is advisable to adopt 0·7 to 0·72.

By dividing the amount of carbon dioxide exhaled in an hour by the permissible limit of respiratory impurity, de Chaumont suggested the number of cubic feet of air per hour required per person: this is now the standard most generally accepted by all sanitarians. It is conveniently expressed by the following formula:—

$$\frac{e}{\rho} = d,$$

where e = the amount of CO_2 exhaled by one individual in an hour, ρ = the limit of admissible impurity (stated per cubic foot), and d = the required delivery of fresh air in cubic feet per hour. If we take e at the general average of 0·6 of a cubic foot, then $\frac{0{\cdot}6}{0{\cdot}0002} = 3000$: or, putting e at a higher figure, say 0·7, then $\frac{0{\cdot}7}{0{\cdot}0002} = 3500$: or, putting e still higher, say 0·92, then $\frac{0{\cdot}92}{0{\cdot}0002} = 4600$.

For mixed communities, under ordinary conditions, 3000 cubic feet per hour is the accepted standard allowance per person.

This formula may also be used conversely, in order to find from the condition of the air the average amount of fresh air which has been hitherto supplied and utilised. For this purpose we simply substitute for ρ (the admissible limit) ρ_1, the observed ratio: thus, $\frac{e}{\rho_1} = d$.

Example.—Let us suppose that the total CO_2 in a room, after occupation, is found to be 1·1 per 1000, or 0·0011 per cubic foot, that in the outer air being 0·0004: therefore ρ_1, or the observed ratio of respiratory impurity, is $0{\cdot}0011 - 0{\cdot}0004$ or 0·0007; then $\frac{e}{\rho_1} = d$, or $\frac{0{\cdot}6}{0{\cdot}0007} = 857$ cubic feet of air, have been supplied during the period of occupation.

By a transposition of the last formula, we can calculate the probable condition of the atmosphere in a room into which a given quantity of air has been or is being delivered: thus, $\frac{e}{d} = \rho_1$.

Example.—If five persons occupy a room of 6000 cubic feet space for six hours, what percentage of CO_2 would be present at the end of the time, supposing 8000 cubic feet of fresh air have been supplied per hour?

Presuming that each person gives off 0·6 cubic foot of CO_2 per hour, therefore five persons in six hours exhale $0{\cdot}6 \times 5 \times 6 = 18$ cubic feet of CO_2, and this will represent e or the observed ratio of respiratory impurity : *d*, or the total amount of fresh air available, will be 54,000 cubic feet, because 6000 were originally present in the room and 48,000 are added during the six hours : then,

$$\frac{e}{d}=\rho_1 \text{ becomes } \frac{18}{54000}=\rho_1, \text{ or } 0{\cdot}00033 \text{ per cubic foot or } 0{\cdot}033 \text{ per cent.}$$

That is, the added respiratory impurity is 0·033 per cent.; but the air of the room originally may be presumed to have contained 0·04 per cent. of CO_2, therefore the total percentage of CO_2 in the air asked for = 0·033 + 0·04 or 0·073 per cent.

It must be observed that in applying these formulæ, the primary value of *e* must be changed with different conditions. For children, it averages 0·4; for adults under ordinary circumstances 0·6; for adult males, such as soldiers, 0·72 has been suggested; while for adults employed in arduous work, possibly as much as 2 cubic feet may be taken as the average hourly exhalation of carbon dioxide.

For a long time after this subject first attracted attention the amount of fresh air supposed to be necessary was put at too low a figure. Even the figures of Morin, which were a great advance at the time, are insufficient. He proposed 2118 cubic feet (60 cubic metres) for barracks at night, and Ranke adopts the same figures.

Roth and Lex adopt the maximum of total impurity at 0·6 per 1000, which includes 0·4 of initial CO_2; and as they estimate the expired CO_2 as 20 litres, or 0·706 cubic foot per hour, they give the hourly quantity of air as 100 cubic metres, or 3533 cubic feet.

It is highly desirable that some general agreement should be come to as to the amount of air necessary, even if it be admitted that the desired amount cannot always be obtained. If we adopt the following amounts of CO_2 as being evolved during repose, we shall not be far from the probable truth :—

Adult males (say 160 ℔ weight),	0·72 of a cubic foot.
,, females (,, 120 ℔ ,,),	0·6 ,,
Children (,, 80 ℔ ,,),	0·4 ,,
Average of a mixed community,	0·6 ,,

Under those conditions the amount of fresh air to be supplied in health during repose ought to be—

For adult males,	3600 cubic feet per head per hour	= 102 c.m.
,, ,, females,	3000 ,, ,, ,,	= 85 ,,
,, children, .	2000 ,, ,, ,,	= 57 ,,
,, a mixed community,	3000 ,, ,, ,,	= 85 ,,

The amount for adult males as above given is just over 100 cubic metres, or, if we state it at 3600 cubic feet, it is just one cubic foot per second. These numbers are easy to remember.

When we have to deal with places, the inmates of which are actively employed, such as workshops and the like, the amount of air supplied must be proportionately increased. We have seen that in light work the carbon dioxide evolved per hour is nearly 0·006 of a cubic foot per ℔ of body-weight, and in hard work more than double that amount,—so that for a man of 160 ℔ weight we should have—

In light work,	0·95 of a cubic foot of CO_2 evolved per hour.
In hard work,	1·84 ,, ,, ,,

This would argue a delivery of fresh air as follows :—

In light work, .	4750 cubic feet.
In hard work,	9216 ,,

Carnelley, Haldane, and Anderson, basing their opinion not only upon the average presence of carbon dioxide in the air, but also upon the organic matter and number of micro-organisms, proposed that instead of taking 0·6 cubic foot of CO_2 per 1000 as the limit, that the standard should be 1·0 for dwellings and 1·3 for schools. In the case of organic matter, that not more than two volumes of oxygen should be required for oxidation per million volumes of air, and that the micro-organisms should not exceed 560 per cubic foot of air. The above figures for carbon dioxide are inclusive of that ordinarily present in the air, and certainly give a very liberal margin, which ought not to be transgressed. If accepted, the respiratory impurity permissible in dwellings would be as high as 0·6 for dwellings and 0·9 for schools, in place of de Chaumont's general permissible respiratory impurity of 0·2. On this basis, the hourly need of fresh air in dwellings would not exceed 1000 cubic feet per head, and in schools be but 550 cubic feet. Experience, so far, has not justified the general acceptance of those low standard allowances of fresh air per hour.

In mines, experiments show that, if it is wished to keep up the greatest energies of the men, no less than 6000 cubic feet per hour must be given; if the quantity be reduced to a third or half, there is at once a serious diminution in the amount of work done by the men. This amount of fresh air includes, of course, all that wanted in the mine for horses, lights, &c.

Fresh Air requirements of the Sick.—In making differential experiments among the healthy and the sick, it has been found that among the former the smell of organic matter was still imperceptible when the air contained 0·208 per 1000 of respiratory impurity as carbon dioxide; but in hospitals containing ordinary cases it was quite distinct when the CO_2 reached 0·166. From this we may conclude that the minimum amount of fresh air for hospitals ought to exceed that required in health by at least *one-fourth*. If 3000 cubic feet per hour be admitted as a general average in health, we may demand in round numbers 4000 in sickness; and if we have to deal with adult males only, such as soldiers, 4500 per head per hour. When we have to deal with serious cases, a still greater amount must be given, reaching 5000, 6000, or even more if possible—in fact, the supply should be unlimited. These views are in accordance with the results of experimental inquiry.

In some diseases, so much organic substance is thrown off that scarcely any ventilation is sufficient to remove the odour. In some of the London hospitals de Chaumont found that there was still a close smell when 5000 cubic feet and even more were supplied, but the distribution was not perfect. Even when 3600 feet were supplied and utilised (as calculated from the CO_2), the ward was not free from smell. The great value of fresh air and of cubic space is now fully recognised in the treatment of surgical cases; and it is well known that in typhus fever, and also in small-pox and plague, the free exposure of patients to fresh air is as important a part of the treatment as the administration of suitable diet and medicines. Even temperature must be sacrificed to a considerable extent in order to obtain fresh air, if a choice requires to be made between the two.

Fresh Air required for Artificial Lights.—The same principles which govern the calculation of fresh air, needed to dilute and remove respiratory impurities, apply equally to the case of air vitiation from gas-lights, lamps, and candles. If the products of their combustion are allowed to pass into rooms, fresh air must be supplied to dilute and remove them. Although the contaminations, especially in the case of gas, are very great, it is estimated that for their proper dilution the amount of fresh air supply, in relation to the carbon dioxide evolved, need not be so great in their case as for breath impurities. It has been calculated that for every cubic foot of coal gas burnt, 500 cubic feet of fresh air must be introduced hourly to properly dilute the products of combustion; and this is not too much if we remember that a cubic foot of good coal gas produces 0·5 cubic foot of carbon dioxide, and that sulphur dioxide and other substances may be also formed. An ordinary flat flame burner will burn at least 5 cubic feet of gas per hour, and in the course of an evening of four hours, will generate at least 10 cubic feet of carbon dioxide, and, assuming that a supply of 1000 cubic feet of fresh air are needed for every cubic foot of carbon dioxide produced per hour, we shall require for this gas-burner alone some 10,000 cubic feet of air to be supplied during the evening, or about 2250 cubic feet per hour; unless, of course, the products of combustion are removed by a special channel. We have already seen that, the power of illumination being equal, gas produces less carbon dioxide than candles; but usually so much more gas is burnt that the air is much more contaminated; there is also greater heat and more watery vapour. These products should never be allowed to escape into the air of a room, for the bad effects of breathing the products of gas combustion are only too well known.

One ℔ of paraffin oil demands for complete combustion 138 cubic feet of air; and to keep the air perfectly pure, nearly as much air must be introduced for 1 ℔ of oil as for 15 cubic feet of gas. In mines, 60 cubic feet of air per hour are allowed for each light; the lights, however, are usually dim and the combustion imperfect, facts which indicate the fresh air allowance to be inadequate. Speaking generally, and under equal conditions of illuminating power, an ordinary five foot, flat flame gas-burner needs two-thirds the supply of fresh air per hour as required by an adult: the incandescent gas-lights on Auer's principle appear to need slightly less or about half the amount proposed for grown-up individuals, while ordinary paraffin lamps need quite as much fresh air as do adults. If gas is burnt in a room only in small quantities, or if only a few candles or a small oil lamp are used, it is seldom necessary to take them into account in estimating the amount of fresh air required; but where many gas-burners are used, or many candles and lamps are alight, the degree of air vitiation resulting from them needs to be considered in estimating the amount of fresh air to be supplied to inhabited rooms, in order to keep the contained atmosphere in a sufficient state of purity consistent with comfort and health. Hitherto, this point has been much neglected. The general use of incandescent electric lamps entails no extra provision of fresh air, as they do not contribute any impurity to the atmosphere.

Fresh Air required for Animals.—This is a matter which has not received much attention, though very important. Märcker gives the following:—

For *large* cattle (viz., oxen, &c.) 30 to 40 cubic metres per hour for every 1000 ℔ weight, or 1 to 1½ cubic foot for every pound of weight.

For *small* cattle (viz., sheep, &c.) 40 to 50 cubic metres per hour for every 1000 ℔ weight, or 1½ to 1¾ cubic foot for every pound of weight; the higher quantity being given on account of the more rapid tissue change in the smaller animals. These quantities seem absurdly small, and the chief reason for so limiting them seems to have been the fear of lowering the temperature too far. This is an erroneous view: animals properly fed will thrive better in a well-ventilated place at a low temperature than in a warmer place ill-ventilated. There seems no reason why the same rule should not apply to animals as to man, in which case something like 20 to 25 cubic feet per hour per pound of body-weight ought to be supplied. A horse or a cow ought, therefore, to have from 10,000 to 20,000 cubic feet per hour,—in short, it ought to be practically in the open air.

From F. Smith's experiments, and using de Chaumont's formula, $\frac{e}{\rho}=d$, where e (in a horse) equals 1·13, it is shown that the amount supplied ought to be 5650 cubic feet per hour, if the limit of respiratory impurity be assumed at 0·2 per 1000. From the experiments given in Smith's work the amount of air supplied ranged from 38,000 cubic feet per hour to 2900; in the latter case the smell is described as abominable. It is clear, therefore, that the amount of air ought to be as large as possible, and fortunately in the case of animals this can be accomplished without any great difficulty; as F. Smith considers that with proper feeding and attention the air about a horse may be changed every three minutes, or twenty times an hour, without danger, although the coat may not turn out so glossy as in a warmer stable.

Carl Dammann estimates that a horse or a cow weighing 1000 ℔ should have 50 cubic metres of air or about 1800 cubic feet per hour for ventilation. He uses the formula, $y=\frac{k}{p-q}$, in which y is the amount of air in cubic metres per hour; k is the amount of CO_2 exhaled by the animal per hour; p is the limit of impurity of CO_2 in the stable air; and q is the quantity of CO_2 in the outer or incoming air.

For small animals he estimates that the supply should be 60 cubic metres or 2100 cubic feet of air per hour for each 1000 ℔ of animal weight. The smaller animals appear to require more air in proportion to their weight than do the larger ones, while the so-called wild animals need more than the domesticated. Monkeys, in particular, require a comparatively liberal allowance of fresh air to keep them in good health.

Fresh Air required for Removal of Moisture.—In all the foregoing considerations the chief need of fresh air has been emphasised in special reference to the removal or dilution of organic and inorganic impurities in the air. It plays, however, a very important part in the removal of excessive moisture. Watery vapour, it must be remembered, is given off into the air, not only in respiration, but also largely by artificial lights, and not a little of the discomfort attending vitiated atmospheres is due to the large amount of their contained moisture. Both de Chaumont and Billings have laid special stress upon the importance of humidity in connection with ventilation. The former says that an increase of one per cent. of humidity has as much influence on the condition of an air space, when judged of by the sense of smell, as a rise of 4·18 degrees of temperature in Fahrenheit's scale, equal to 2°·32 C., or 1°·86 R. Our every-day experience confirms this. From the state of the air as regards humidity, information may sometimes be obtained which is just as valuable as the determination of so much carbon dioxide. Thus, a room at the temperature of 70° F., and with a humidity of 90 per cent., contains 7·2 grains of aqueous vapour per cubic foot: suppose the outer air to be at 50° F. with the same percentage of humidity; this would give 3·69 grains of aqueous vapour in each cubic foot of outer air. Now from 73 to 75 per cent. of humidity being the generally accepted standard of moisture usually present in the atmosphere of this country, consistent with comfort, in order to reduce the humidity of the room from 90 per cent. or discomfort to, say, 75 per cent. or comfort, or in other words, to a condition in which only 6 grains of moisture were present per cubic foot, we must add the following amount of fresh external air: $\frac{7{\cdot}2\times 6}{6\times 3{\cdot}69}=1{\cdot}95$, or nearly twice the volume of air in the room. If the occupants of the room have each 1500 cubic feet, it follows that either their supply of fresh air is short by nearly 3000 cubic feet per head per hour, or else that there are sources of excessive humidity within the room which demand immediate removal. Regarded in this manner, a sufficient supply of fresh air is just as important for lowering the atmospheric humidity in an enclosed space as it is for diluting or removing either carbon dioxide or organic effluvia. While 75 per cent., at a temperature of from 60° F. (15°·6 C.) to 70° F. (21°·1 C.), may be taken provisionally as a standard of humidity for climates like our own, in drier climates, like America, the standard or mean percentage of moisture may be as low as 30 or 40. In Germany, 50 per cent. is looked upon as an average humidity, whilst in England this would indicate an uncomfortably dry atmosphere.

METHODS BY WHICH THE NECESSARY QUANTITY OF FRESH AIR CAN BE SUPPLIED.

This subject is largely an engineering problem, and involves the consideration of certain preliminary matters, especially facts relating to cubic space and the various forces concerned in ventilation.

Cubic Space.—This is an important factor in ventilation in some cases, while in others it is of but secondary value. Sufficient has been said in the preceding pages to show that the hurtful matters in the air of an occupied room are constantly and equably produced, uniformly diffused, and fairly represented by the carbon dioxide present. It has further been explained that 0·2 of CO_2 per 1000 of air, in round numbers, may be taken as the maximum amount of impurity admissible in a properly ventilated air space. Adopting, then, this standard as the measure of the permissible maximum of impurity, the next point to be determined is the quantity of pure external air which should pass through the air of a room, vitiated by respiration, per head per hour, in order to keep the carbon dioxide at this ratio, assuming a general average of 0·6 of a cubic foot per head per hour to be given out. This question we have seen to be answered in terms of a standard of 3000 cubic feet. On this basis the following table has been constructed, showing the degree of fouling of the air in terms of carbon dioxide by respiration, and the amount of fresh air necessary, under different conditions of cubic space, to dilute to the given standard of 0·2 CO_2 per 1000 volumes of air, exclusive of the amount originally present in the air:—

Amount of cubic space (=breathing space) for one person in cubic feet.	Ratio per 1000 of CO_2 from respiration at the end of one hour, if there has been no change of air.	Amount of air necessary to dilute to standard of 0·2 during the first hour.	Amount necessary to dilute to the given standard every hour after the first.
100	6·00	2900	3000
200	3·00	2800	3000
300	2·00	2700	3000
400	1·50	2600	3000
500	1·20	2500	3000
600	1·00	2400	3000
700	0·86	2300	3000
800	0·75	2200	3000
900	0·67	2100	3000
1000	0·60	2000	3000

The above table refers to rooms occupied for several hours consecutively, such as sitting-rooms, bed-rooms, hospital wards, &c., and in each case, no matter what the breathing space per head may be, we find 3000 cubic feet of fresh air to be necessary each hour after the first to dilute to the given standard. When we come to inquire whether there is no minimum size of space through which the fresh air has to pass, we find that this will entirely depend on the rate at which air can be taken through the space without the movement being perceptible or injurious, and the size of the space is of consequence chiefly in so far as it affects this condition. The larger the air space, the less is the necessity for the frequent renewal of air, and the less the chances of draught. Thus a space of 100 cubic feet must have its air changed thirty times in an hour, if 3000 cubic feet of air are to be given, while the space of 1000 cubic feet need only have it changed three times in an hour for an equal ventilation.

When the most perfect mechanical means are employed, the air of even a small air space can be changed sufficiently often without draught. Thus, in Pettenkofer's experimental room at Munich, the air space is 424 cubic feet, and 2640 cubic feet can be drawn through by a steam-engine in an hour without perceptible movement; in other words, the change is six times per hour nearly. With the best mechanical contrivances, and with disregard of cost, we are therefore certain that a cubic space of 600 feet would be sufficient, and there is every probability that engineers could ventilate even a smaller space without perceptible movement.

But if the mechanical contrivances are of an inferior kind, and particularly if natural ventilation is used, the difficulties of ventilating a small space are considerable, and are caused not so much by the rate of movement of the greater part of the air in the room as by the rate at the openings where the fresh air comes in very quickly, and causes currents in the room. Suppose, for example, a space of 500 cubic feet occupied by one person, who has to be supplied with 3000 cubic feet in an hour; if the inlet opening be 12 square inches, the rate of movement through it would be 10 feet per second, or nearly 7 miles per hour; if 24 square inches, it would be 5 feet, or about 3·4 miles per hour. In either case, in such a small room, the air could not be properly distributed before reaching the person, and a draught would be felt. If instead of 500 cubic feet of space 1000 be given, the problem is easier, for the small current of fresh air mixing with the larger volume of air in the room is more easily broken up, and the inmate being further from the opening, the movement is less felt. The question, in fact, turns in great measure on the power of introducing the air without draught.

If the renewal of air is carried on by what is termed natural ventilation, under the ordinary conditions of this climate, a change at the rate of six times per hour, as in Pettenkofer's room, could not be attempted. Even five times per hour would be too much; for, in barracks with 600 cubic feet per head, the rooms are cold and draughty when anything approaching to 3000 cubic feet per head per hour are passing through; that is, a change of five times per hour for each 600 cubic feet of air space. A change equal to three times per hour is generally all that can be borne under the conditions of warming in this country, or that is practically attainable with natural ventilation, and if this be correct, from 1000 to 1200 cubic feet should be the minimum allowance for the initial air space.

With good warming and an equable movement, which, however, are not always easy to get, there might be larger inlets, and therefore more easy distribution and a smaller air space to begin with. If the inlets are 48 square inches, the rate through them to supply a space of 500 cubic feet with 3000 cubic feet per hour would be only 2½ feet per second; and if, as should be the case in artificial ventilation, the inlet is 72 or 80 square inches in size, the rate would only be a little over 1½ feet per second, which would be imperceptible even at the orifice. But there is an argument against a small cubic space, even with good mechanical ventilation, viz., that if anything arrests the mechanism for a time, the ratio of impurity from respiration increases much faster in a small than in a large space.

The warmth of the moving air influences the sensation of the persons exposed to it. At a temperature of 55° or 60° F., a rate of 1½ feet per second (= 1 mile per hour nearly) is not perceived; a rate of 2 to 2½ per second (1·4 and 1·7 mile per hour) is imperceptible to some persons; 3 feet per second (2 miles per hour nearly) is perceptible to most; a rate of 3½ feet is perceived by all persons; any greater speed than this will give the sensation of draught, especially if the entering air be of a different temperature, or moist. If the air be about 70° F., a rather greater velocity is not perceived, while if it be still higher (80° to 90° F.), the movement becomes again more perceptible, and this is also the case if the temperature be below 40° F. If the air could be warmed to a certain point in a cold climate, or if the climate be warm, there may be a much more rapid current, and consequently a smaller cubic space might be given. The subject of ventilation is in cold climates connected inseparably with that of warming, for it is impossible to have efficient ventilation in cold weather without warming the air.

The amount of cubic space thus assigned for healthy persons is far more than most people are able to have; in the crowded rooms of the artisan class, the average entire space would probably be more often 200 to 250 cubic feet per head than 1000. The expense of the larger rooms would, it may be feared, be fatal to the chance of such an ideal standard being generally carried out; but, after all, the question is, not what is likely to be done, but what ought to be done; and it is an encouraging fact that in most things in this world, when a right course is recognised, it is somehow or other eventually followed.

So, in the case of soldiers, the amount of authorised regulation space (600 cubic feet) is below the standard now given, but still the space is as much as can be demanded at present, as it has been found very difficult, without incurring greater expense than the country would bear, to give every man even the 600 cubic feet.

In the metropolitan lodging-houses 30 superficial and 240 cubic feet are allowed; in the section-houses of the metropolitan police 50 superficial and 450 cubic feet are given. The Local Government Board allows 300 cubic feet for every healthy person in the dormitories of poor-houses, and from 850 cubic feet and upwards, according to circumstances, as far as 1200 cubic feet for each sick person. In the Poor-law schools 360 cubic feet are given per head. In Dublin, an allowance of 300 cubic feet is required in the registered lodging-houses. While the theoretical requirements for a child in an elementary school is 400 cubic feet, and for a lad in a large public school 800 cubic feet, as minima, we find that the London School Board do not allow more than 130 cubic feet. The Education Department of the Privy Council endeavour to secure at least 80 cubic feet and 8 square feet for each unit of average attendance in the infant schools, and 10 feet of floor area with a cubic space of about 125 feet to each child in other schools. According to the model bye-laws of the Local Government Board, 300 cubic feet are allowed in common lodging-houses for each person above 10 years, and

150 cubic feet for each person younger. Other customary amounts of cubic space per head are 1000 feet in middle-class houses, 500 in good secondary schools, and 212 in ordinary one-roomed houses.

For *sick persons* the cubic space should be more than for healthy persons. We are to remember that there are other impurities besides those arising from respiration and transpiration, and that immediate dilution and as speedy removal as can be managed are essential.

Very much the same considerations apply to sick as to healthy men, except that the allowance of air in all cases of acute diseases must be greater; and, therefore, especially if natural ventilation be employed, the cubic space has to be enlarged also, to insure good distribution without draught, for surface chilling must be carefully avoided.

Admitting that, in hospitals, a minimum of 4000 cubic feet of fresh air per patient per hour should be supplied, if the change of air is to be three times per hour, as the best available rate of movement, the cubic space must be about 1300 cubic feet. A consideration of another kind may aid in determining the question as regards sick men. In hospitals a certain amount of floor space is indispensably necessary; first, for the lateral separation of patients; secondly, for convenience of attendance. For the first object, the greater floor space the better; and in respect of the second, Sir H. Acland has clearly shown that the *minimum* floor space for convenient nursing should be 72 square feet per bed. In a ward of 12 feet in height, this would give only 864 cubic feet, which is much too small.

Considering, however, the immense benefit to patients of pure air, and the practical experience of hospital physicians, it is very desirable not to fix the floor and cubic space of hospital wards at the minimum of what may suffice. The desire of most hospital physicians and surgeons is to obtain for their patients, if they can, a floor space of 100 to 120 square feet, and a cubic space of 1500 to 2000 cubic feet, and in this they are right.

It must be distinctly understood that a minimum of floor space must be insisted upon in all cases, not less than $\frac{1}{12}$ of the cubic space.

An idea prevails among many people that cubic space may take the place of change of air, so that, if a larger cubic space be given, a certain amount of change of air may be dispensed with, or less fresh air be required. This is quite erroneous: even the largest space can only provide sufficient air for a limited time, after which the same amount of fresh air must be supplied hourly, whether the space be large or small. Even in a space of 10,000 cubic feet per head, the limit of admissible impurity would be reached in a few hours, after which the same hourly supply of 3000 feet would be as necessary as in a space of 100 feet. This is shown by the table given on page 188, and may be also mathematically demonstrated by the following formula given by Donkin:—

$$x = p + \frac{P}{a} - \frac{P}{a} 2{\cdot}718^{-\frac{a\,t}{c}}, \text{ in which}$$

x is the condition of the air as to CO_2 per foot at the end of the time t; p is the CO_2 per cubic foot in the outer or fresh air introduced; P the CO_2 expired per hour per man; a the incoming air in cubic feet per hour; 2·718 is the exponential function; and c is the cubical capacity of the air space.

It will be at once seen by the above formula that when it is wished to maintain the space c at the purity of the outer air, and that x and p gradually approximate to each other, the numerical value of the last term in the equation diminishes rapidly as t increases until it becomes insensible; with it then disappears the quantity *c* or the value of the cubical capacity of the air space. It follows then that it is immaterial what the size of the air space is, for the same amount of fresh air will be needed to keep it sweet, be it large or small.

Example.—Suppose, in a room containing 1000 cubic feet of space, a man giving off 0·6 cubic foot of CO_2 remains for *t* hours, and 3000 cubic feet of fresh air are introduced hourly. Applying Donkin's formula, we get, $x = 0{\cdot}0004 + \frac{0{\cdot}6}{3000} - \frac{0{\cdot}6}{3000} 2{\cdot}718^{-\frac{3000t}{1000}}$. This being worked out, according to the varying values of *t*, we find that the units of carbon dioxide per cubic foot of air are, 0·0004 at first, 0·00059 after one hour, 0·0005995 after two hours, and 0·00059997 after three hours; so that even after two hours the air of the room will have sensibly reached the final or permissible condition of 0·0006 CO_2 per cubic foot. If the room contained 10,000 cubic feet, the approximation to the final state would be less rapid, but equally certain as time elapsed.

The question really resolves itself into, what is the ratio of *a* to *c*, or in other words, what is the least amount of *c* through which *a* can be passed without causing inconvenience from draughts? Under ordinary circumstances, and without artificial methods of warming the incoming air, the answer has been given as an original air space of close upon 1000 cubic feet. These considerations as to the imperfect value of cubic space alone have suggested the rule that, in computing cubic space for purposes of ventilation, the heights of rooms above 12 feet should be largely disregarded.

The cubic space required *for animals* has not been very carefully examined. Certain animals, notably pigs, sheep, horses, and cattle generally, emit large quantities of marsh gas from the intestines. Our chief knowledge as to the oxygen consumed, the carbon dioxide and marsh gas given off by animals, is derived from Reiset's observations. The following is an abstract of his work:—

	Weight of Animal in Kilos.	Oxygen consumed in Grammes per hour.	Oxygen consumed per Kilo. of body-weight.	Carbon Dioxide exhaled in Grammes.	Nitrogen exhaled in Grammes.	Marsh Gas exhaled in Litres.
Sheep,	67·7	33·51	0·495	42·63	0·246	1·4
Calves,	97·3	45·87	0·480	54·54	0·280	1·3
Pigs,	105·6	49·30	0·477	60·50	0·025	0·1
Oxen,	230·0	110·50	0·480	128·80	0·293	3·07
Horses,	250·0	117·42	0·470	131·62	0·295	3·66

An average-sized sheep spoils 112 litres or 3·9 cubic feet of air per hour; calves spoil 154 litres or 5·4 cubic feet; moderate-sized pigs spoil 166 litres or, say, 6 cubic feet of fresh air hourly; rabbits about 10 litres or 0·35 cubic foot; fowls 1 litre or 0·035 cubic foot; a dog of medium size, 23·5 litres or 0·83 cubic foot; a cat weighing 10 lb spoils 17·8 litres or 0·6 cubic foot of fresh air per hour.

On the basis of respiratory impurity alone, we may reckon that calves and pigs vitiate the air rather more than a man does; about 10 sheep foul the air in the same degree as 8 men; while 14 rabbits or 140 chickens are equal to a man in this respect. As a matter of fact, these animals contaminate the air more than the above, because they are always associated with their own excreta. If we followed the rule for men, and gave one-third the quantity of air supplied per hour, this would give for horses and cattle from 3000 to 7000 cubic feet. This, however, is probably not necessary, because change of air can be carried on more freely than in human habitations, and animals cannot close ventilators as men will often do. A floor space of 100 to 120 square feet would probably be sufficient, giving a space of 1200 to 1800 cubic feet, according to the height of the building. If this could be secured, there is every probability that the results would be excellent. We might put the estimate roughly at 2 cubic feet of space for every pound avoirdupois the animal weighs, the floor space being not less than $\frac{1}{12}$ of the cubic capacity. Another rule might be to give 600 times the amount of air spoilt, which is practically the rule employed in the case of adult men: an adult man renders, we know, 5 cubic feet of air absolutely irrespirable every hour, and 600 times this or 3000 cubic feet per hour of fresh air is the generally recognised amount required to keep the air of a room in the highest degree of practicable purity. On the same principle, if we multiply the cubic feet of air which the different animals render irrespirable by 600, we get the following theoretical quantities of air which should be supplied per hour to animals:—

	Cubic feet per head per hour.	Cubic feet of space.
Fowls,	22	4
Rabbits,	222	44
Cats,	360	72
Dogs,	474	95
Calves,	3120	604
Pigs,	3510	702
Oxen,	7920	1584
Horses,	7920	1584

Formerly, in the cavalry stables of the British army each horse had 1605 cubic feet and 100 square feet of floor space. At present the superficial area of army stables has been fixed as follows:—for the stall alone, 52 feet; for the stall and share of passage, 91 feet. F. Smith considers that the stall alone should be 70 feet, and the stall and share of passage, 100. In the Army Horse Infirmaries the superficial area is to be 137 square feet, or 200 with share of passage; loose boxes 204, and the cubic space 1900 feet per horse.

In the stables of cattle there is often excessive overcrowding, and it is well known that there is a vast amount of disease among them, which, however, is seldom allowed to go far, as they are sent to the butcher. Ballard, who paid great attention to the cattle plague in Islington, recommended that at least 1000 cubic feet should be allowed per animal.

Source and Distribution of Air Supplied.—In order that the object of ventilation shall not be defeated, it is necessary that the air entering a room shall be pure. The air must be the pure external air, and not be derived from places where it has stagnated and taken up impurities; if it is drawn along passages or tubes, and through louvres or basements, these should be capable of inspection and cleansing. All delivering air-shafts should, if possible, be short and easily cleaned. This is an important rule, and should lead to the rejection of all plans in which the air-shafts are long and inaccessible. Several instances have occurred of air being distributed by costly appliances, but drawn from an impure source, or allowed to be contaminated on its passage. Instead of perforated bricks, there should be sliding panels, or hinged flaps, so that the tube may be easily reached. In towns it may be necessary to filter the air, which is often loaded with the products of combustion and other impurities.

The air may require to be warmed to 60° or 65° F., or cooled according to the season or locality. The warming in cold and temperate climates is a matter of necessity, as, if discomfort is caused by cold draughts, ventilation openings are certain to be closed. When the external temperature is low, the air supplied will often require to be moistened as well as warmed. This can be done by either injecting clean steam or water spray, or simply by exposing a water surface to the air. For these islands, a humidity of 75 per cent. is the most general requirement.

The distribution in the rooms should be perfect, that is, there should be uniform diffusion of the fresh air through the rooms. The best way of ascertaining this is to compare the amount of air utilised, as calculated from the observed carbon dioxide, with the actual movement of air, as measured with the air-meter. If the distribution is good, the two quantities ought not to differ materially. Much difficulty is found in properly managing uniform diffusion, and it requires careful arrangement of the various openings. The distributing plans should, if possible, prevent the chance of breathed air being rebreathed, especially in hospitals. As the ascent of respired air is rapid, on account not only of its temperature, but from the force with which it is propelled upwards, the point of discharge for patients in bed should be above.

By some it has been argued that it is better that the foul air should pass off below the level of the person, so that the products of respiration may be immediately drawn down below the mouth, and be replaced by descending pure air. But the resistance to be overcome in drawing down the hot air of respiration is so great that there is a considerable waste of power, and the obstacle to the discharge is sometimes sufficient, if the extracting force be at all lessened, to reverse the movement, and the fresh air forces its way in through the pipes intended for discharge. This plan, in fact, must be considered a mistake. In the case of vapours or gases the proper place of discharge is above; but heavy powders, arising in certain arts or trades, which from their weight rapidly fall, are best drawn out from below. Finally, in determining the plan of ventilation of a room, the whole building must be treated as one system, and the plan of air circulation drawn out for the whole. It is useless having a system which is only workable in a room so long as all the doors are shut, if one of the conditions of the room being used is that the doors be frequently open. This is particularly necessary in ordinary dwelling-houses, and it practically amounts to saying that every outlet for air should be supplied with an adequate air inlet, so that there shall be no head between different rooms.

Forces concerned in Ventilation.—All ventilation methods are based either upon forces continually acting in nature, which produce what has been called natural ventilation; or upon forces set in action by man, which produce the so-called artificial ventilation. This division is convenient, but not strictly logical, as the forces which act in natural do so also in artificial ventilation to a certain extent. These forces are practically three, namely, diffusion, winds, and the difference in weight of masses of air of unequal temperature.

Diffusion.—As every gas diffuses at a certain rate, viz., inversely as the square root of its density, there is a constant escape of any foreign gas into the atmosphere at large. From every room that is not air-tight Pettenkofer and Roscoe have shown that diffusion occurs through brick and stone, and it is probable that one of the evils of a newly built and damp house is that diffusion cannot occur through its walls. But ordinary plastered and papered walls reduce diffusion to a most insignificant amount. Through chinks and openings produced by imperfect carpentry the air diffuses fast, and Roscoe found that when he evolved carbon dioxide in a room the amount had decreased one-half from that cause in 90 minutes.

The amount of purification produced by diffusion under ordinary circumstances is shown by observation to be insufficient; and, in addition, organic substances, which are not gaseous, but molecular, are not affected by it. As a general ventilating power, it is therefore inadequate.

Winds.—The action of wind is a powerful ventilating agent in various ways. If it can pass freely through a room, with open doors and windows, the effect it produces is immense. For example, air moving only at the rate of 2 miles an hour (which is almost imperceptible), and allowed to pass freely through a room 20 feet broad, will change the air of the room 528 times in one hour. No such powerful action as this can be obtained in any other way.

The wind will pass through walls of wood (single-cased), and even of porous bricks or stone; and perhaps this will account for the fact that such houses, though cold, are healthy habitations. By covering a brick with wax, or enclosing a portion of a brick wall in an air-tight box, Pettenkofer has shown that the force of the breath will drive air through the brick, and will blow out a candle on the other side if the current of air be collected in a small channel. The force required to drive the air through is, however, really considerable, as the air in the brick must be brought into a state of tension.

Märcker has given the following as the amount of air passing in one hour through a square metre of wall space, when the difference of temperature is 1° C.:—Sandstone, 1·69; limestone, 2·32; brick, 2·83; tufaceous limestone, 3·64; and loamy brick, 5·12 cubic metres of air. The little porosity of sandstone depends on the amount of moisture it holds. The moisture, in fact, greatly influences the transit. Plaster, however, appears to arrest wind, if it be true, as stated, that in the interior of some thick walls, after many years, lime has been found still caustic; and Märcker also notices the obstructive effects of mortar.

There are two objections to winds as ventilating agents by perflation.

(1) The air may be stagnant. In this country, and, indeed, in most countries, even comparative quiescence of the air for more than a few hours is scarcely known. Air is called "still" when it is really moving 1 or 1½ mile an hour. The average annual movement of the air in this country is from 6 to 12 miles per hour; but it varies, of course, greatly from day to day, and in different places.

(2) A much more serious evil is the uncertainty of the movement, and the difficulty of regulation. When the velocity reaches 5 or 6 feet per second, unless the air be warm, no one will bear it. The wind is therefore excluded, or, if allowed to enter directly through small openings, is badly distributed. Passing in with a great velocity, it forces its way like a foreign body through the air in the room, causing draughts, and escaping, it may be, by some opening without proper mixing. A current entering in this way may be measured for many feet.

But the wind acts in another way. A moving body of air sets in motion all air in its vicinity. It drives air before it, and, at the same time, causes a partial vacuum on either side of its own path, towards which all the air in the vicinity flows at angles more or less approaching right angles. In this way a small current moving at a high velocity will set in motion a large body of air.

The wind, therefore, blowing over the tops of chimneys, causes a current at right angles to itself up the chimney, and the unequal draught in furnaces is owing, in part, to the variation in the velocity of the wind. Advantage, therefore, can be taken of this aspirating power of the wind to cause a movement of air up a tube. The wind, however, may impede ventilation by obstructing the exit of air from any particular opening, or by blowing down a chimney or tube. This is, in fact, one reason of the failure of so many systems of ventilation; they may work well in a still atmosphere, but the immense resistance of the wind has not been taken into account. At 3 miles an hour, the pressure of the wind is $\frac{3}{4}$ of an ounce on each square foot; it is 1 ounce at $3\frac{1}{2}$ miles; 2 ounces at 5 miles; 4 ounces at 7 miles; $\frac{1}{2}$ pound at 10 miles; and 1 pound at 14 miles.

In some systems of ventilation the perflating power of the wind has been used as the chief motive agent. In Egypt the wind is allowed to blow in at the top of the house through large funnels. This plan has been in use from time immemorial. This was the case in Sylvester's plan, which was used at Derby and Leicester fifty or sixty years ago. A large cowl, turning towards the wind, was placed in a convenient spot near the building to be ventilated—a little above the ground if in the country, or at some height if in a town. The wind blowing down the cowl, passed through an underground channel to the basement of the house, and entered a chamber in which was a so-called cockle-stove or calorifère of metal plates or water or steam pipes, by which the air was warmed. It then ascended through tubes into the rooms above, and passed out by a tube or tubes in the roof, which were covered by cowls turning from the wind. So that the aspiratory power of the air was also used. This plan is extremely economical, but the movement of the air is unequal, and it is difficult to regulate it. It has been proposed to place a fan in the tunnel to move the air in periods of calm, and the plan then becomes identical in principle, and almost in detail, with the method of Van Hecke.

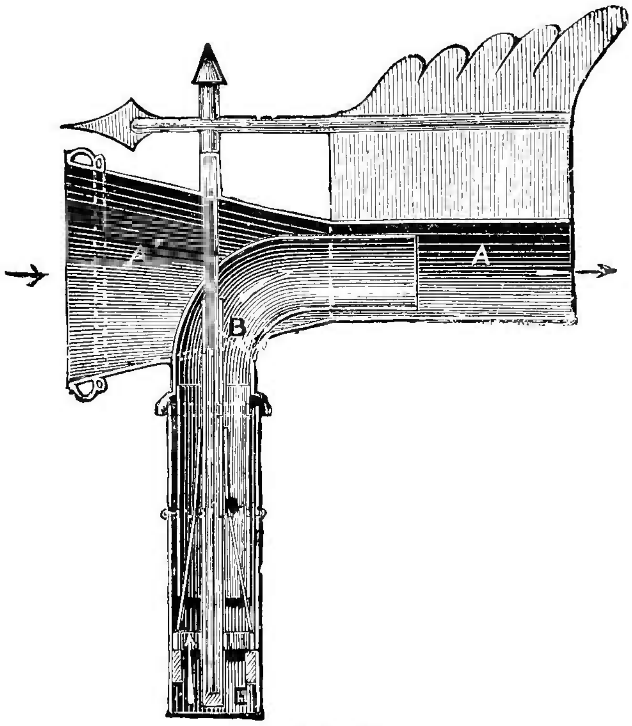


Fig. 11.

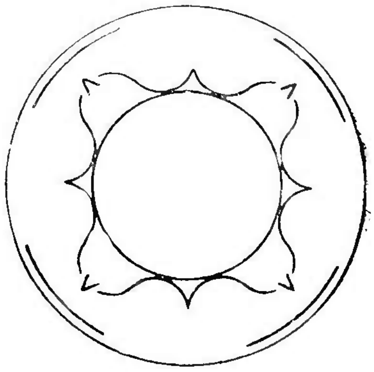


Fig. 12.

In the ventilation of ships the wind is constantly used: and by wind sails, or by tubes with cowls turning towards the wind, air is driven between the decks and into the hold. In using the wind in this way, the difficulty is to distribute the air so that it shall not cause draught. This is best done by bending the tubes at right angles two or three times, so as to lessen velocity, or by enlarging the channel towards the opening in the interior of the vessel, and by placing valves to partially close the tubes, if necessary, and by screens of wire gauze. If perforated plates or wire gauze are used, care must be taken to see that they are constantly kept clean, as they very soon get clogged with dirt. It should also be understood that the delay by friction through fine wire gauze is exceedingly great.

In all cases in which the air of a room, as in a basement story, or in the hold of a ship, perhaps, is likely to be *colder* than the external air, and when artificial means of ventilation cannot be employed, the wind should be taken advantage of as a motive agent.

The aspiratory power of the wind and the production of a head for ventilation, by the motion of air over the mouth of a tube, can be secured by covering air-shafts with cowls, which both aid up-currents and prevent down-draughts. This is practically the idea with which all the varieties of up-cast ventilators are constructed, however varied may be their external appearance. Cowls are uncertain in their action when fixed to buildings, owing to the variability of the wind-currents, due to the effects of the surfaces of the buildings themselves. Although many forms of cowl have been designed to render them serviceable, no matter from which direction the wind blows, there are practically only two types: namely, those with rotating cowls and those with fixed vanes. Of the former type, Banner's cowl (fig. 11) may be regarded as a specimen: it sets itself by means of a wind vane so that the opening always faces away from the wind. The latter type is represented by Boyle's ventilator: in it the vanes are fixed, as shown in fig. 12, so that from whatever direction the wind blows, the motion of the air is always tangential to the shaft opening. In all forms of cowl the air-current is both variable and small, and very liable to be overweighted by the head from some other opening, so that what was primarily intended to be an up-cast often becomes a down-draught shaft.

Effects of Unequal Weights of Air.—Though constituting one of the causes of wind itself, it is necessary, in discussing ventilation, to look upon it as if it were an independent force. If the air in a room be heated by fire, or by the presence of men and animals, or be made moister, it endeavours to expand: and if there be any means for it to escape, a portion of it will do so, and that which remains will be lighter than an equal bulk of the colder air outside. The outer air will then rush into the room by every orifice, until the equality of weight outside and inside is re-established. But as the fresh air which comes in is in its turn heated, the movement is kept up in a constant stream, cold air entering by one set of openings, and hot air escaping by another.

We have now to inquire how the rate of this constant stream of air may be calculated. The mode most generally used is based on two well-known laws: first, that the velocity in feet per second of falling bodies is equal to nearly eight times the square root of the height through which they have fallen; and second, that fluids pass through an orifice in a partition with a velocity equal to that which a body would attain in falling through a height equal to the difference in depth of the fluid on the two sides of the partition. This is frequently called the rule of Montgolfier. The formula is $v = \sqrt{2g\mathrm{H}}$: in which g is the acceleration of velocity in each second of time, viz., 32·18 feet, and H is the height of the descent. When simplified out, this formula becomes $v = 8\sqrt{\mathrm{H}}$. The pressure of the air upon any surface may be represented by the weight of a column of air of uniform density of a certain height. Thus the pressure of the atmosphere at the surface of the earth is nearly 15 ℔ on the square inch, and this would be the weight of a column of air of about 5 miles in height. Air, therefore, rushes into a vacuum with a velocity equal to that which a heavy body would acquire in falling from a height of 5 miles, viz., 1300 feet per second. But if, instead of rushing into a vacuum, it rush into a chamber in which the air has less pressure than outside, its velocity will be that due to a height which represents the difference of pressure outside and inside. In ordinary cases this difference of pressure cannot be obtained by direct observation, but must be inferred from the difference of temperature of the outer and inner air. We have already learnt that air is dilated one part in 491 of its volume (0·00203) for every degree Fahrenheit, or one part in 273 (0·00366) for every degree Centigrade that its temperature is raised; consequently, the difference of pressure outside and inside will be as follows:—

The height from the aperture at which air enters to that from which it escapes, multiplied by the difference of temperature between outside and inside and by the co-efficient of expansion.

Example.—Say the height of a column of air in a chimney, between its throat and aperture of exit, be 20 feet, and that, owing to a fire in the grate below, its temperature be 15° F. above that of the outside air. Then the height to produce velocity of an inflowing and colder current will be $20 \times 15 \times 0{\cdot}00203 = 0{\cdot}609$ foot, and the velocity will be $8\sqrt{0{\cdot}609} = 8 \times 0{\cdot}781 = 6{\cdot}248$ feet. This, however, is the theoretical velocity. In practice, an allowance must be made for friction of $\frac{1}{4}$, $\frac{1}{3}$, or even $\frac{1}{2}$, according to circumstances. The deduction of $\frac{1}{4}$ would leave 4·686 linear feet per second as the actual velocity. If this be multiplied by the area of the opening, in feet or decimals of a foot, the amount of air is expressed in cubic feet per second, and multiplying further by 60 gives the amount per minute. If in this particular case the area of the chimney throat be a square foot, the amount of air escaping by the chimney under the above circumstances, and of course replaced by a similar volume of fresh and colder air, will be 281 cubic feet per minute.

A table is given on page 242, in which this calculation has been made for all probable temperatures and heights; but it must be remembered that the movement is greatly influenced by wind.

This cause of movement is, of course, constantly acting when the temperature of the air changes. It will alone suffice to ventilate all rooms in which the air is hotter than the external air, but will not answer when the air to be changed is equal in temperature to, or colder than, the external air.

As its action is equable, imperceptible, and continuous, it is the most useful agency in natural ventilation in cold climates, in inhabited and warm rooms; and in all habitations arrangements should be made to allow it to act. As the action increases with the difference of temperature, it is most powerful in winter, when rooms are artificially warmed, and is least so, or is quite arrested in summer, or in hot climates, when the internal and external temperatures are identical.

Influence of Friction upon Air-currents.—The amount of loss produced by friction from various causes is often overlooked, and its neglect is apt to lead to failure and disappointment. The chief causes of loss are the following:—

1. *Length of Tube or Shaft.*—Here with equal sectional areas the loss is directly as the length, so that if we take a shaft of 30 feet as a standard, a shaft of 40 feet long would have an increased friction of one-third.

2. *Size of Opening.*—For similar sections the friction is inversely as the diameter. Thus for two openings, respectively 1 and 2 feet in diameter, the friction at the smaller opening will be twice that of the larger. In this way dividing up an opening into a number of smaller openings, the aggre-

gate of which is equal to the original opening, produces a loss by friction in the direct ratio of the diameters. An opening of 1 square foot divided into four openings of $\frac{1}{4}$ of a square foot loses in the ratio of $1 : \frac{1}{2}$, being respectively the diameters of the openings. When the shapes of the openings are not similar, the ratio may be stated as that of the square roots of the areas. Thus 1 square foot divided into nine openings, each equal to $\frac{1}{9}$ of a square foot, will lose in the ratio of $1 : \frac{1}{3}$, the square roots of the respective areas.

3. *Shape of Opening.*—A circular opening may be taken as the standard, that being the figure which includes the greatest area within the smallest periphery. The loss sustained from any other shape being used will be proportionate to its difference from a circle enclosing a similar area. Thus, if we have two openings, each of 1 square foot area, the one being a circle and the other a square, the length of periphery of the latter will be 4 square feet, of the former $3\frac{1}{2}$; therefore the velocity of the current through the square opening will be $\frac{3\frac{1}{2}}{4}$ or $\frac{7}{8}$ of that through the circular opening.

4. *Angles in the Tube or Shaft.*—This is a most serious cause of loss. The exact formula has not been distinctly determined, but it may be accepted, as in accordance with experiment, that every right angle diminishes the current by one-half, so that two right angles in a tube would reduce it to $\frac{1}{4}$, and so on. Yet it is no uncommon thing to find tubes and shafts bent recklessly at numerous angles to fit a cornice or architrave, to save expense and appearance.

In smooth channels the co-efficient of friction is represented by $\frac{1}{1+\sin^2\theta}$, θ being the angle at any bend of the shaft or tube. For more general application, $\frac{1+\cos\theta}{2}$ is probably better: in either case, an angle of 90° shows a loss from friction of one-half. At 60° the friction is $\frac{4}{7}$, at 45° it is $\frac{2}{3}$, and at 30° it is $\frac{4}{5}$.

5. The presence of dust, soot, or dirt of any kind seriously interferes with the current, but this may of course be obviated with a moderate amount of care and attention.

It is obvious that attention to the above points is necessary to obtain success in any scheme of ventilation.

Example.—Let us suppose a straight shaft 30 feet long, sectional area circular, of 1 square foot,—the current through this giving a sufficient amount of air for the purpose required. Let it be necessary to produce a similar amount of ventilation in another place, but to use smaller shafts, square in section, area of each $\frac{1}{4}$ of a square foot,—each shaft being 40 feet long, and having one right angle in its course; what would be the relative amounts of air available, other things being equal? Taking the circular shaft, we have length of shaft 30, length of periphery $3\frac{1}{2}$, total $33\frac{1}{2}$ = friction. In the four smaller shafts we have length 40, length of periphery of each 2, which multiplied by $4 = 8$, total 48: the right angle doubles the friction, so that $48 \times 2 = 96$ as compared to $33\frac{1}{2}$. Thus the result would be nearly as 3 to 1 in favour of the single shaft. It would be obviously necessary to treble either the number of the smaller shafts or the size of each of them.

It is advisable generally to widen slightly the openings of shafts, especially if they are of small diameter, as the current tends to be contracted and obstructed at that point. At every change of direction the same thing takes place. Hence the desirability of rounding off angles as much as possible, where they cannot be altogether avoided.

It is generally best to have the sections of shafts circular or elliptical instead of rectangular, for not only is there less loss by friction originally, but there is less chance of lodgment of dust, &c., and they can be more easily and thoroughly cleaned.

It must not be overlooked that the specific gravity of vitiated air, as compared with pure air, is often as important as friction in hindering ventilation action. Usually the specific gravity of foul air is greater than that of fresh air; for instance, taking pure air as unity, the gravity of air containing 0·8 part of carbon dioxide per 1000 would be 1·0016, while that of air fouled by organic vapours would be greater still. This explains why contaminated air tends to cling or hang about particular parts of rooms, or, if there are no air currents, smells are so often apt to flow down towards basements of houses from the upper stories. It is obvious that in such cases calculations based upon the movements of absolutely pure air may be considerably in error.

Natural Ventilation.—Of all the methods of natural ventilation, the simplest and most obvious is that of more or less open doors and windows; but this arrangement, except in the warmest summer weather, causes draughts, and is unpleasant. To secure adequate perflation, all windows should, if possible, be placed on opposite sides of a room, while, too, each of such windows should be made to open at the top. Owing to air flowing against the body, at or even slightly above the temperature of a room, causing a sensation of cold or draught, it is necessary for comfort that air should be introduced into and removed from inhabited rooms at those parts where it will not give rise to sensible draughts. In the large majority of houses, even in these days, ventilation arrangements are either of the most crude and haphazard kind, or else absolutely wanting. The greater number of living-rooms depend for their supply of fresh air upon just so much as can find its way in through doors, windows, or through cracks and crevices around and under doors and windows, or even through the floor; and for the escape of foul air, upon what goes up the chimney, if a fire be alight, or what can get out through doors and windows; the general result being that either the chamber is so cold and draughty that no one can live comfortably in it, or so hot, close, and stuffy that health is affected. All ventilation methods aim at avoiding these results, by providing, in the first place, *inlets* or means of entrance for the fresh air, and *outlets* or means of escape for the impure air.

Total size of all the special openings, whether intended for Inlets or Outlets.—As the movement of air increases with temperature, the precise size of the ventilating apertures can only be fixed for a certain given temperature; and as the efflux of hot air increases with the height of the column, supposing the temperature is equal throughout, a different size has also to be fixed for different heights. This causes a difficulty in fixing the proper size for ventilating openings in the case of natural ventilation, because the conditions are so variable.

The theoretical size for any required change of air, supposing the conditions are constant, can be obtained by the use of the following formula, suggested by de Chaumont:—

$$\frac{D}{200f(\surd h(t-t^1)\times 0\cdot 002)} = \text{I or O.}$$

Where D = delivery per hour in cubic feet; 200 is a constant; f is the coefficient of friction; h is the height of the heated column of air; t its temperature; t^1 that of the outer air; 0·002 the ratio of expansion of air for each degree F.; I indicates inlet, O indicates outlet, both in square inches; while I and O combined are often written as ϕ. A converse formula to the foregoing is useful to find the delivery per hour, under conditions h, t, and t^1, and when the area of the inlet or outlet is known: it reads thus,

$$200f(\sqrt{h(t-t^1)\times 0{\cdot}002})O = D.$$

The different expressions for time and space require a factor 200 or 100, which is thus obtained: $\frac{\text{Seconds in an hour}}{\text{Square inches in a square foot}} = \frac{3600}{144} = 25$, which multiplied into $\sqrt{2g}$ or 8, where $g = 32{\cdot}18$, gives a constant 200 for inlets or outlets only, and consequently 100 for inlets and outlets combined.

Example.—Suppose that the heated column be 20 feet, its mean temperature 65° F., and that of the outer air 45° F., and the required delivery be 3000 cubic feet hourly. Let friction be $\frac{3}{4}$: required the size of inlet. Applying the formula, we get,

$$\frac{3000}{200\times 0{\cdot}75(\sqrt{20\times 20\times 0{\cdot}002})} = 22{\cdot}2 \text{ square inches for inlet,}$$

and consequently also an outlet of equal size.

To take another example: let us say the heated column is 15 feet, the difference of temperature 10° F., and the required supply 3000 cubic feet, with friction $\frac{3}{4}$. What should be the size of inlet and outlet? Worked out in the same way, we find that there must be 36·5 square inches of inlet and the same of outlet.

But if in the above conditions only 2000 cubic feet hourly were wanted, the opening need only be 24·3 square inches for each.

These examples show how impossible it is to fix any size which shall meet all conditions, even if the influence of wind could be completely excluded, which is impossible. The only way is to adopt a size which will meet most cases, and supply means of altering the size according to circumstances. In this country, a size of 24 square inches per head for inlet, and the same for outlet, seems calculated to meet common conditions; but arrangements should be made for enabling this to be lessened or closed in very cold weather, or if the influence of strong winds is too much felt. Moreover, the size must be in part dependent on the size of the room, because in a small room with many people it is impossible to have the size so great as it would be if each person's area of ventilation opening were 48 square inches, unless some portion of the air were warmed.

Relative size of the Inlets and Outlets.—It is commonly stated that, as the heated air expands, the outlets should be larger than the inlets, and the great disproportions of 5 to 4 and 10 to 9 have been given. As, however, the average difference of temperature is only about 10° to 15° F. in this country, this disproportion is much too great, as a cubic foot of air only expands to 1·020366 cubic foot with an increase of 10° Even if the difference is 30° F., a cubic foot of air only becomes 1·061 cubic foot, which is equal to an increase of about $\frac{1}{17}$th. The difference is so slight that it may be neglected, and the inlets and outlets can be made of the same size.

It is desirable to make each individual inlet opening not larger than 48 to 60 square inches in area, or enough for two or three persons; and to make the outlet not more than 1 square foot, or enough for six persons. Distribution is more certain with these small openings.

Position and Varieties of Inlets.—As a rule, the inlet tubes should be short, and so made as to be easily cleaned, otherwise dirt lodges, and the air becomes impure. Inlets should not be large and single, but rather numerous and small (from 48 to 60 inches superficial), so that the air may be properly distributed. They should be conical or trumpet-shaped where they enter the room, as the entering air, after perhaps a slight contraction, spreads out fan-like, and a slight back current from the room down the sides of the funnel facilitates the mixing of the entering air with that of the room. To lessen the risk of immediate down-draught they should turn upwards, if they are placed above the heads of the persons. Externally the inlets should be partly protected from the wind; otherwise the wind blows through them too rapidly, and, if the current be strong, draughts are felt; an overhanging shelf or hood outside will answer pretty well. Valves must be provided to partially close the openings if the wind blow in too strongly, or if the change of air is too rapid in cold weather. If covered with wire gauze, this must be frequently cleaned.

Sometimes an inlet tube must be carried some distance to an inner room, or to the opposite side of a large room which is unprovided with cross-ventilation. In this case the heat of the room so warms the tube that the wind may be permitted to blow through it.

The position of the inlets is a matter of some difficulty. If there are several, they should be, of course, equally distributed through the room, so as to insure proper mixing of the air. They should not, however, be placed too near an outlet, or the fresh air may at once escape; theoretically, their proper place of entrance is at the bottom of the room, but if so, the air must in this climate be warmed; no person can bear the cold air flowing to and chilling the feet. The air can be warmed easily in various ways, viz.:—

(*a*) The air may pass through boxes containing coils of hot-water pipes, or (in factories) of steam pipes. This is one of the best modes of warming. The coils may be close to the outside wall, or in the centre, or, in hospitals, in boxes under the beds communicating with the exterior air, and opening into the ward.

(*b*) The air may pass into air-chambers behind or round grates and stoves, and be there warmed, as in the stove contrived by Sir D. Galton, or as in the Meissner and Bohm stoves of Germany. Similarly, the air may be warmed in a tube passing through a stove, as in George's Calorigen, or by the method of Bond's Euthermic stove.

If the air cannot be warmed, it must not be admitted at the bottom of the room; it must be let in above, about 9 or 10 feet from the floor, and be directed towards the ceiling, so that it may pass up and then fall and mix gradually with the air of the room. The Barrack Commissioners have adopted this plan with half the fresh air brought into a barrack-room. The other half is warmed.

In towns or manufacturing districts the air is so loaded with particles of coal, or, it may be, other powders, that it must be filtered. Nothing answers better for this than muslin or thin porous flannel, or paperhangers canvas, spread over the opening, which then should be made larger. This covering can be moistened if the incoming air be too dry.

The use of air-washing screens at the intakes has been very generally employed of late years in the ventilation of hospitals and public buildings, more particularly in the Victoria Infirmary, Glasgow, and the New General Hospital, Birmingham. The practical application of these air-filters constitutes a material advance in ventilation methods.

Among the many devices for inlets of fresh air, the simplest plan is that of Hinckes Bird. The lower sash of a window is raised by means of an accurately fitting block of wood, whereby a corresponding space is left between the upper and lower sashes in the middle of the window, through which the external air passes, and, being directed upwards, curves gently into the room without perceptible draught. With the same idea, others have proposed double panes of glass, an open space being left at the bottom of the outer and at the top of the inner one.

Perforated sashes are made by boring holes into the lower part of the upper sash; the air enters vertically, but being divided up into small streams, no draught is perceptible. This plan considerably weakens the window frame.

What is known as Currall's window ventilator is merely an opening made into the lower sash bar, and then a metal plate fixed inside in a direction parallel to the window frame, so as to direct the current of air upwards. In principle it is very similar to Hinckes Bird's plan.

Double windows constitute an excellent method for the admission of air. By opening the outer one at the bottom and the inner one at the top, a very efficient air-shaft is formed. Swinging windows are often employed as inlets, particularly in hospitals and board schools. They may be so arranged that the whole window swings on a centre pivot, thus offering a very large inlet; or only the upper part of a window opens inwards like a valve, and thus directs the current up towards the ceiling.

Louvres or ventilators constructed on the principle of venetian blinds are a very common form of inlet. The louvres or strips of glass are connected together on to a frame, which, by a mechanical arrangement, can be opened or shut at will. Glass being most easily cleaned, and also transparent, constitutes the best, though not the only, material for louvres. The proper place for these appliances is the lowest pane of the upper sash, and not the upper part of the highest panes where they are so often seen to be placed.

Cooper's ventilator is merely a circular disc of glass, perforated with holes, and attached by means of a pivot to a pane of glass similarly perforated. By rotating the disc, the holes in the pane and disc can be made to correspond or not as required.

Perforated or air bricks, such as those of Ellison, consist of bricks which are pierced with conical holes, about $\frac{2}{10}$ of an inch in diameter externally and $1\frac{1}{4}$ inch internally, depth $4\frac{1}{2}$ inches. A usual size is 9 by 3 inches, and the united area of all the several openings in one brick is about $11\frac{1}{2}$ square inches. Another common size is 10 by 6 inches, with an open area of about 24 square inches. The air blown in from the narrow to the wide end of the openings is so distributed as to be imperceptible as a draught in a room. These bricks are best placed just behind, and concealed by, the skirting board. Jennings' air-brick (fig. 13) is another form of these inlets. These are more usually placed in the walls near the ceiling, and differ from Ellison's bricks in that the air is first led into a small chamber, where the dust can deposit. From this "dust trap" the air passes through louvres into the room.

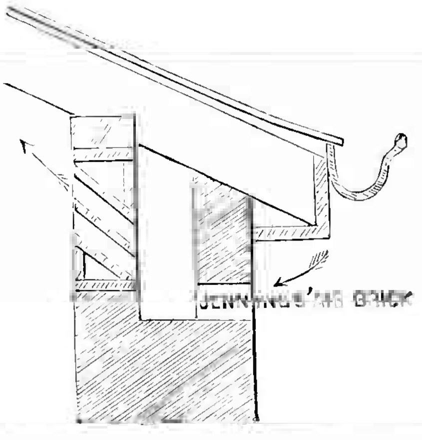


Fig. 13.

Steven's drawer ventilator is very like a drawer, with its back or end most remote from the handle absent. This drawer is made to fit into a hole in the wall; when it is shut there is, of course, no air-current, but when pulled open, the air enters freely, and impinging against the front, is given an upward direction.

The Sheringham valve is a great improvement on this: the air passes through a perforated brick or iron box inserted in the wall close to the ceiling of the room. The current of inflowing air is then directed upwards by a valve opening, which can be closed, if necessary, by a balanced weight (fig. 14). The size of the internal opening is, in the usual-sized valve, 9 inches by 3, and the area is 27 inches. This is somewhat larger than the outside area, and the velocity of the entering air is accordingly lessened. The wind blows through them, and the movement is therefore variable. They are often outlets; it will, in fact, depend upon circumstances whether they are inlets or outlets. Very little draught is, however, caused by them, unless with a high wind; on the whole, they are the best inlets of this kind.

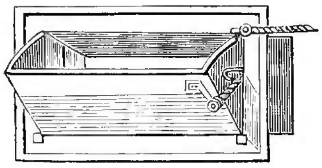


Fig. 14.

An open iron frame of the size of a brick, covered with perforated zinc, and with a valve to close it if necessary, is a still simpler plan, and the air is pretty well distributed. The gauze should be cleaned frequently. Boyle used a round plate working on a screw, which can be brought nearer or farther from a corresponding opening in the wall; the air entering strikes on the plate, and then spreads circularly over the wall, and is then drawn gently into the room.

The tubes proposed by Tobin (fig. 15) provide for the introduction of air from the outside at the floor level and then up a vertical tube, about 6 feet in height; this gives a vertical direction to the current, which is retained for several feet further before it begins to spread and descend. The action of such a tube is, of course, much affected by the direction of the wind, and in some instances it is reversed altogether. The method is, however, useful in most cases, particularly for introducing air into places which could only be reached with difficulty by other means. In some forms (as made by the Sanitary Engineering Company) there is an arrangement for washing the air and arresting impurities. An ingenious contrivance for warming the air for the upright tube by means of a gas jet has been suggested by Lawson Tait; it also provides an outlet for foul air.

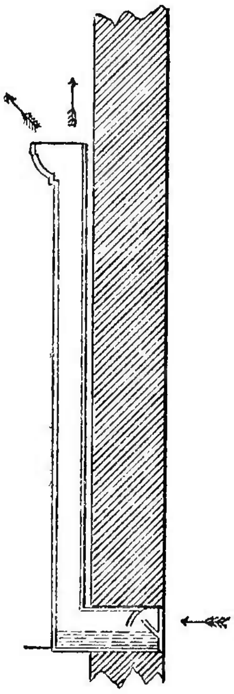


Fig. 15.

The Tobin tubes are not very suitable for ordinary houses and dwelling-rooms, as they are difficult to keep clean, and often become clogged up with cobwebs, dirt, and dust. They, moreover, do not readily become or act as outlets when occasion requires, which, being a conspicuous feature of the Sheringham valve, renders that form of ventilating agent practically the most convenient for every-day application.

Position and Varieties of Outlets.—The place for the outlets is a most important consideration, as it will determine in great measure the position of the inlets. If there are no means of heating the air passing through them, they should be at the top of the room; if there are means of heating them, they may be at any point. If not artificially warmed, the highest outlet tube is usually the point of greatest discharge, and sometimes the only one. In the absence of artificial heat, they should be placed at the highest point of the room; should be enclosed as far as possible within walls, so as to prevent the air being cooled; should be straight and with perfectly smooth internal surfaces, so that friction may be reduced to a minimum. In shape they may be round or square, and they may be covered above with some apparatus which may aid the aspirating power of the wind and prevent the passage of rain into the shaft.

The causes of down-draught in outlet tubes are these: the wind forces down the air, rain gets in, and by evaporation so cools the air that it becomes heavier than the air in the room; or the air becomes too much cooled by passage through an exposed tube, so that it cannot overcome the weight of the superincumbent atmosphere; or another outlet shaft with greater discharge reverses the current.

Arrangements should be made to distribute the down-draught, if it occurs; flanges placed at some little distance below, so as to throw the air upwards again before it mixes with the air of the room, or simple contrivances of a similar kind, may be used. Valves should be also fixed to lessen the area of the outlet when necessary. If there are several outlet tubes in a room, all should commence at the same distance from the floor, be of the same height (or the discharge will be unequal), and have the same exposure to sun and wind.

Simple ridge openings may be used in one-storied buildings with slanting roofs; they ventilate most thoroughly, but snow sometimes drifts in. Rain may be prevented entering by carrying down the sides of the overhanging ridge for some little distance. A flange placed some little distance below will throw any down-draught towards the walls.

With artificial warmth, the discharge of outlets is much more certain and constant. The ordinary chimney with an open fire is an excellent outlet: in fact it is so good that, in dwelling-houses, provided there are proper inlets, no other outlet need be made, except, however, when gas is used. When rooms are large, and more crowded, other outlets are necessary; the heat of the fire may be further utilised by shafts round the chimney, opening at the top of the room, or, in other words, by surrounding the smoke-flue with foul-air shafts.

Gas, if used, may be made to warm an outlet tube, both to carry off the products of combustion and to utilise its heat. Probably a better arrangement would be to make the ventilation independent of the lighting, and to enclose the gas-lights, as is done on the Wenham gas-light system and other regenerative gas-burners, so that only so much air is supplied to the gas as is required for the combustion: this may be drawn either from the room or separately from the outside.

In various other ways the heat of fire and lights may be taken advantage of.

There will seldom be any difficulty in arranging the inlets and outlets, and in obtaining a satisfactory result, if these principles are borne in mind, viz., to have the fresh air pure, to distribute it properly, and to adopt every means of securing the outlets from cold, or artificially warming them, and of distributing the air, which, in spite of all precautions, will occasionally pass down them.

In hot climates, when outlet shafts are run up above the general level of the building, it would be of advantage to make them of brick-work, and to colour them black, so that they may absorb and retain heat.

Frequently so-called ventilating gas-lights are used as outlets, in which the products of combustion, after being collected by means of a cover or bell glass, are carried off by a tube which is itself often contained in a larger one. Owing to the heating of the inner tube, the space surrounding it and between it and the outer one, acts as an extracting shaft for foul air. In theatres and other public buildings advantage is taken of this method by using the sunlight gas-burners, which, in addition to lighting the building, act as extraction shafts for removing the polluted air. To guard against possible down-draught, the shaft or tube should be surmounted by either a Sugg's cowl or be provided with a horizontal plate of talc, which, threaded on a central pin only, and resting on a seat, is lifted up by any upward pressure, but closes the channel under the slightest pressure from above.

Another arrangement, known as Arnott's valve, is designed to act as an outlet for foul air. It is usually placed in the wall of a room near the ceiling, so as to open into the chimney. The valve is so arranged as to swing towards the chimney, when the pressure or draught of the air is from the room to the chimney; but when the pressure is greater from the chimney into the room, the valve closes, and thus prevents the escape of smoke or air from the chimney. These valves are sometimes objectionable, owing to the noise they make. Boyle's exit ventilator is merely a modification of this, but instead of metal, there are a number of light talc flaps. These are both good forms of outlet.

A single tube has been sometimes used for inlet and outlet, a double current being established. This is, however, a crude plan, as there are no means of distributing the air, and as the intermingling of the current and the friction of the meeting air is sometimes so great as to impede, or even for a time stop, the movement. To avoid these inconveniences, Watson proposed to place a partition in the tube (fig. 16), and Mure suggested the use of a double partition running from corner to corner, so as to make four tubes. He covered his divided tube with a louvre, so as to make use in some degree of the aspiratory power of the wind on one side.

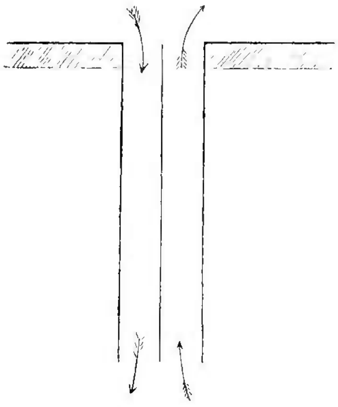


Fig. 16.

In these tubes, accidental circumstances, such as the sun's rays on one side, the wind, the fire in the room, &c., will determine which is outlet and which is inlet. They are so far better than the single tube, that the partition divides the currents and prevents friction, but there is the same irregular action and changing of currents from accidental circumstances, so that the direction of the currents and their rate are variable. The distribution of the entering air is also not good.

Much better than these plans is M'Kinnell's circular tube. It consists of two cylinders, one encircling the other, the area of the inner tube and encircling ring being equal. The inner one is the outlet tube; it is so because the casing of the other tube maintains the temperature of the air in it; and it is also always made rather higher than the other; above it is protected by a hood, but if it had a cowl it would be better. The outer cylinder or ring is the inlet tube; the air is taken at a lower level than the top of the outlet tube; when it enters the room it is thrown up towards the ceiling, and then to the walls by a flange placed on the bottom of the inner tube; the air then passes from the walls along the floor towards the centre of the room, and upwards to the outlet shaft (figs. 17 and 18). Both tubes can be closed by valves. If there is a fire in the room, both tubes may become inlets; to prevent this the outlet tube should be closed; if doors and windows are open, both tubes become outlets.

The movement of air by this plan is imperceptible, or almost so; it is an admirable mode for square or round rooms, or small churches, but for very long rooms it is less adapted.

It would be advisable to make the outer ring of these tubes larger, as the friction to be overcome is about double that of the inner tube.

On much the same principle, ventilating cornices are made, which consist of a double channel of perforated metal: by the lower channel cold fresh air is brought into a room, while by the upper one the fouled air is carried to the chimney or other outlet. Analogous to this plan is that of carrying along a cornice of a room, on three sides, a perforated inlet tube, while on the fourth side is a similarly perforated outlet tube. In other cases, a fairly good cross ventilation can be secured by means of a series of transverse ventilating boxes or tubes placed at regular intervals and close to the ceiling. These, running across the room from wall to wall, open into the outer air at each end by an air-brick. The sides of these tubes are made of perforated zinc, and to prevent the wind blowing right through, they are stopped or blocked in the centre by a partition. According as to whether the wind blows from one side or the other, so one half becomes an inlet for fresh air, which diffuses gently into the room through the perforations, while the other half acts as an outlet for the fouled air.

Artificial Ventilation.—The chief agencies by which ventilation is artificially secured are heat, steam-jets, pumps and fans or wheels: according as to whether these various means act by drawing the air out of a building or room, or whether the air is driven in so as to force out that which is already in the room, so is any given scheme of mechanical ventilation spoken of as being one by extraction methods or one by propulsion.

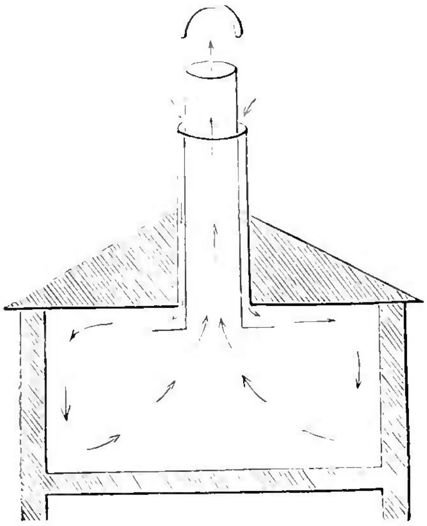


Fig. 17.

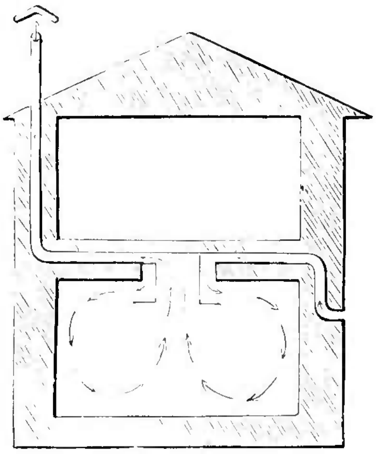


Fig. 18.

Extraction by Heat.—The common chimney is a well-known example of this. There is a constant current up the chimney, when the fire is burning, in proportion to the size of the fire and of the chimney. The usual current up a common sitting-room chimney, with a fair fire, is, as measured by an anemometer, from 3 to 6 feet per second. A very large fire will bring it up to 8 or 9 feet. The movement caused by a kitchen or furnace fire is, of course, greater than this.

With an ordinary fire, a chimney gives a discharge sufficient for four or five adults: if more than this number habitually occupy a room, another outlet must be provided.

When the air enters equably, and is well distributed, the movement of air is from the inlets gently towards the fireplace; there is also said to be a movement, from above the fireplace, along the ceiling and down the walls, and then along the floor to the chimney.

As the current up the chimney is so great when the fire is lighted, all other openings in a room, if not too many, become inlets; and, in this way, down-draughts of air may occur from tubes intended as outlets. There is no remedy for this; and if too much enters, the outlets must be more or less closed.

If the room be without openings, so that no air can reach the fire, air is drawn down the chimney, and a double current is established, by which the fire is fed. The down-current coming in puffs is one cause of smoky chimneys, and may be at once cured by making an inlet.

The chimney and fire is a type of a number of other similar modes of ventilation by extraction.

The ventilation of mines is often carried on by lighting a fire at the bottom of a shaft (the upcast or return shaft), or half a shaft, if there be only one. The air is drawn down the other or downcast or intake shaft, or half the shaft, and is then made to traverse the galleries of the mine, being directed this way or that by partitions. Double doors are used, so that there is no back or side rush of the air. The current passes through the upcast shaft at the rate of from 8 to 10 feet per second ; it flows through the main galleries at the rate of from 4 to 6 feet per second, or even more, and from 1000 to 2000 cubic feet per head per hour are supplied in good mines. In fire-damp mines much more than this is given, even as much as 6000 cubic feet per man per hour.

If a furnace be used to ventilate a fiery mine, it is usual to bring special air to support combustion through a separate channel from the outer air, in order to prevent the mine air coming in contact with the furnace flames.

Though this system of ventilating by furnaces is still used in some collieries, it cannot compete, except at great depths, with mechanical methods. Speaking roughly, the useful effect from furnaces rarely exceeds 5 per cent. of the actual energy given out by the fuel consumed; the maximum power being the discharge of about 1000 cubic feet per minute per foot area of the upcast shaft.

The velocity of the artificial draught up an extraction shaft may be found by the formula, $V = 36{\cdot}5\ \sqrt{H(t - T)}$, in which V is the velocity in feet per second, H is the height of shaft in feet, t is the temperature of air at top of shaft, and T is the temperature of the air supplying it. The same velocity may also be determined by the following formula, $V = \dfrac{W \times Vo \times (t + 461)}{A \times 493}$, where W is the weight of coal burnt in pounds per second, Vo is the volume at 32° F. of the air supplied per pound of coal (usually this is 300 cubic feet, since each pound of coal requires practically 24 ℔ of air for its complete combustion, and at 32° F. each pound of air = 12·5 cubic feet), t is as in the foregoing, and A is the sectional area of the shaft in feet. The velocity determined by either of these equations, when multiplied by the sectional area of the shaft, naturally gives the cubical discharge.

In large buildings the same plan is often used ; a chimney is heated by a fire at the bottom, and into the bottom of this shaft, close to the fire, run a number of tubes coming from the different rooms. Several French and English hospitals, and many other buildings, are ventilated in this way. Reid for some years ventilated the Houses of Parliament in the same manner, and so powerful was his up-draught that he could change the entire air in the building in a few minutes.

In dwelling-houses it has been proposed to have a central chimney, into which the chimneys of all the fires shall open, and to surround this with air-shafts connected with the tops of the rooms. It is supposed that, if other inlets exist, there will be a current both up the chimney and up the shaft running beside it.

In all these cases it is necessary that the workmanship shall be very exact, so that air shall not reach the extracting shaft except through the tubes.

On the same principle some men-of-war are now being ventilated. The funnel and upper part of the boiler, and, as far as possible, all the steam apparatus, are enclosed in an iron casing, so that a space is left of some 3 or 4 feet between the casing and the funnel. When the fires are lighted, there is, of course, a strong current up this space; to supply this the air is drawn down through all the hatchways towards the furnace doors. The temperature of the stokehole is reduced from 130° or 140° F. to 60° and 70°, and the draught to the fires is so much more perfect that more steam is obtained from the same amount of fuel.

Sometimes, instead of a fire at the bottom of the chimney, it is placed at the top; but this is a mistake, as there is a great loss of heat from the immediate escape of the heated air; the proper plan is to heat, as much as possible, the whole column of air in the chimney, which can only be done by placing the fire below. Sometimes, as in Jebb's method for prison cells, the shaft is too short for the work it has to do.

Frequently, instead of a furnace, heat is obtained for extraction shafts by means of accelerating coils containing either steam or hot water, or even hot oil. When so employed, it is often of material importance to know what shall be the heating surface offered by the steam or hot-water coils. Billings gives the following formula: $S = \frac{W \times t}{H(T - t)} \times 1500$, in which $S =$ the number of square feet in the outer surface of the accelerating coil, $W =$ weight in pounds of the air which is discharged in one second, $t =$ the absolute temperature of the external air, or the thermometric reading $+ 459^{\circ}{\cdot}4$, or $(t + 459{\cdot}4)$, $H =$ the height of shaft, and T is the absolute temperature of the steam in the coil, or $(T + 459{\cdot}4)$. The constant 1500 is deduced from other constants, particularly force of gravity, specific heat of air, rate of transfer of heat to air from coils, and the ratio between theoretical and actual velocities as influenced by friction.

Example.—Suppose a room containing 18,000 cubic feet of air, at average temperature of 60° F. and 75 per cent. of humidity, is required to have its air discharged four times an hour up a shaft 50 feet high, the temperature of the outer air being 50° F. It is required to know what should be the heating surface of a coil containing steam at a pressure of 5 ℔. In this case, each cubic foot of air will weigh 0·059 of a pound, and W will be $\frac{18000 \times 4 \times 0{\cdot}059}{60 \times 60}$ or 1·18 ℔, t will be $50^{\circ} + 459{\cdot}4 = 509{\cdot}4$, H is 50, and T will be $228^{\circ} + 459{\cdot}4 = 687{\cdot}4$: that is,

$$S = \frac{1{\cdot}18 \times 509{\cdot}4}{50 \times (687{\cdot}4 - 509{\cdot}4)} \times 1500 = 101{\cdot}29 \text{ square feet.}$$

Very frequently, instead of a fire or hot-water coils, lighted gas is used to cause a current, and if the gas can be applied to other uses, the plan is an economical one. In theatres, the chandeliers have long been made use of for this purpose. It is calculated that each cubic foot of gas burnt is capable of extracting 3000 cubic feet of air; thus twenty burners, each consuming 5 feet of gas hourly, will withdraw 300,000 cubic feet of air, corresponding to the complete renewal six times in the hour of the air of a hall 100 feet × 25 feet × 20 feet. Though the extracting power of gas under suitable tubes is undoubtedly large, its practical value as a ventilating agent may be overrated, as generally its special flue is in a position most unfavourable for general ventilation. This is particularly the case when the gas is intended to be both an illuminant and a means of ventilation, as in public halls, where the air must be very impure before a central chandelier is effective in removing impurity.

Extraction by the Steam-Jet.—The moving agent here is the force of the steam-jet, which is allowed to pass into a chimney. The cone of steam sets in motion a body of air equal to 217 times its own bulk. Tubes passing from different rooms enter the chimney below the steam-jet, and the air is extracted from them by the strong upward current. This plan is best adapted for factories with spare steam. It was employed for some time in the ventilation of the House of Lords, but was finally abandoned.

In some collieries the steam-jet has been tried with great success, as at Lower Moor near Oldham, where the "apparatus consists of 72 vertical pipes 5 feet long and 7 inches in diameter, fitted to a frame on the top of the upcast shaft; into each is inserted a steam pipe having a nozzle $\frac{3}{16}$ inch in diameter, supplied with steam at a pressure of 38 ℔. Rough as it is, this apparatus exhausts 16,000 cubic feet per minute." The principle of action of a steam-jet is similar to the production of a head by the passage of wind over an aperture, that is, by a lowering of pressure in the vicinity of the aperture. Steam-jets appear unsuited for exhausting large quantities of air at low pressures.

Extraction by Pumps.—This method is employed at some collieries, and was also used at the St Gothard Tunnel works. One of the best known in England of this class of mechanical ventilators is that of Struvé of Swansea. It consists of a gasometer-like piston, working in a large brick chamber filled with water. The air is admitted and expelled by flap valves. Those at Cwm Avon are 18 feet in diameter, and have a stroke of 7 feet working eight strokes a minute. With a water-gauge of 3 inches, this machine exhausts 50,000 cubic feet a minute. The air-pumps in the St Gothard works were cylinders hung at each end of a rocking beam, which alternately dipped into water-tanks. The tops of the cylinders were fitted with outlet valves, while the space to be ventilated was connected by pipes and inlet valves with the cylinders. Each time the cylinder rose, it filled with air from the tunnel, which was expelled through the valves in the top when it fell. They worked efficiently with a water-gauge of 6 inches.

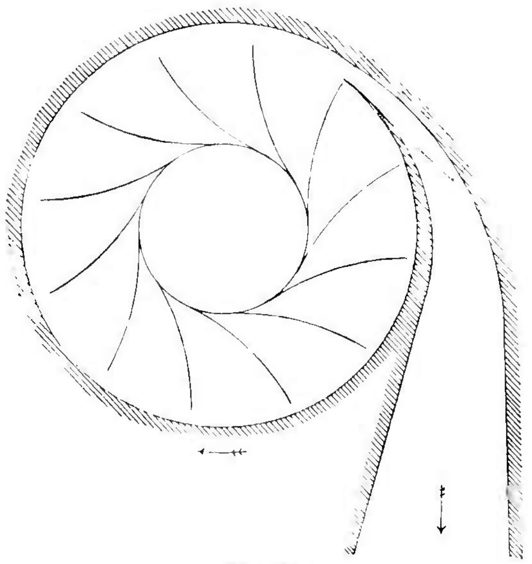


Fig. 19.

Lemielle's Extractor is a huge drum with movable vanes, placed excentrically in a casing so that they lie close against the drum on one side, but expand as they pass on the other, and thus sweep out, as it were, a certain amount of air at each revolution. Except in a few collieries, these ventilators are not much used: their effective power appears to be under 40 per cent. of the gross boiler power.

Extraction and Propulsion by Fans.—These are very largely used in tunnels and collieries. A fan ventilator is nothing but a wheel formed by a number of vanes attached to an axle. When the wheel is rapidly rotated, air is carried along by the vanes, finally leaving the tips of the vanes tangentially with a velocity practically equal to that of the vane tips. As the wheel rotates, the air tends to move from the axis to the circumference, causing thereby a lessening of pressure at the axis.

One of the best of these fans is Guibal's (fig. 19), which is enclosed in a circular cover, with openings at the axle and an opening at the periphery which leads into a tube along which the air is discharged. By placing the axis of the wheel excentrically with regard to the circle of the enclosing case, an appreciable space is formed, between the periphery of the revolving vanes and the cover, gradually increasing up to the discharging tube. This arrangement materially saves the kinetic energy of the wheel by saving loss of power in the production of eddies. When working, air is drawn through the apertures near the axle, and driven into and along the tube. In the best forms of these fans the size of the delivery aperture can be altered by means of a sliding door, the aperture itself is trumpet-shaped, and the vanes are so shaped that, though tangential to the aperture at the axle, they are at right angles to the periphery at the tip; this enables the air to slide on to the vanes without loss of energy in eddies.

One of these fans is working at Thirslington colliery, being 36 feet in diameter and 12 feet wide, and revolving at eighty, discharges 80,000 cubic feet of air per minute under a water-gauge of 6·2 inches.

For ventilating tunnels, the best agents are undoubtedly fans. This is well seen in the case of the Lime Street Tunnel, Liverpool, and the success attending the working of the pneumatic tube between Euston and the General Post Office, London. This tube is tunnel-shaped, 4 feet wide and 4·5 feet high: it is worked by a fan in Holborn, 22 feet in diameter, and revolving 160 times a minute. It discharges 20,000 cubic feet of air per minute, and enables the carriage to travel at a speed of 15 miles an hour; the water-gauge shows 10 inches of pressure. The best fans appear to utilise only 15 per cent. less than the indicated power of the engine which drives them.

The Blackman Air-Propeller is a kind of fan (fig. 20) much used in ventilation. It is claimed for this agent that the larger sizes will give 12,000 cubic feet and the smaller ones 6000 cubic feet of air per minute for each horse power expended in driving them. This estimate is based upon there being no resistance against the air except that from the machine itself. In actual practice, considerable resistance results from the ducts of the ventilation system as well as from the machine.

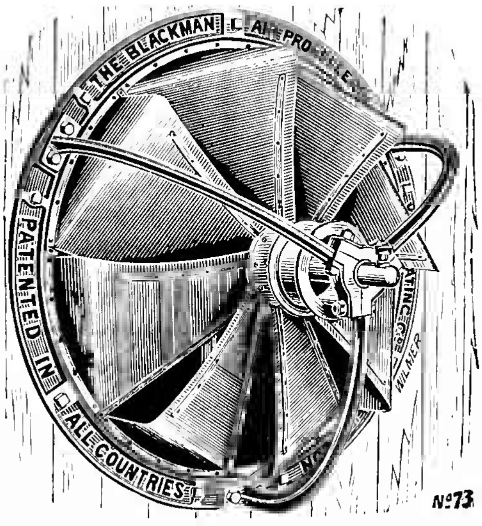


Fig. 20.

In the ventilation of mines, the resistance to the movement of the air due to friction from the gallery surfaces, abrupt turns, expansions and contractions of ducts, and from eddies is often very great, so much so that a large part of the power employed to produce air-currents is needed to overcome this resistance. The friction increases in direct proportion to the area of the surface, and as the square of the velocity of the current. According to Atkinson, for every 1000 feet per minute velocity, the average co-efficient of friction in mines is 0·0217 ℔ per square foot of surface.

In artificial and other ventilation problems, especially in mines and tunnels, the weight in pounds of air per square foot required to give a velocity to a column of air is usually called the "head," just as in the case of furnaces it is calculated as the difference in height of two columns of air of equal weight, but of different temperatures. The total resistance to the flow of air due to friction, &c., in any given system of air-circulation may be represented as the resistance which would be given by an orifice of a certain size in a thin plate, for a certain head of air, which may be called the resistance of the mine or tunnel. If the head be stated as so many foot-pounds of force required to drive a pound of air through a given orifice, and the flow of air be expressed in cubic feet per second, then the ratio of the head to the square of the flow is a constant, which is inversely proportional to the square of the area of the orifice. This constant is practically the resistance of the orifice, and the head equals $R.V^2$., when R is the resistance and V is the flow.

Now the pressure of 1 foot of air at 60° F. is 0·0765 ℔ per square foot, and the pressure of 1 inch of water is 5·2 ℔ per square foot; and as it is often convenient to state this force in terms of either pounds of air per square foot or of inches of water, in order to reduce the result in pound-feet of air to its equivalent in inches of water, we must multiply it by $\frac{0·0765}{5·2}$ or divide by 68. Further, knowing the head required, in terms either of feet of air or inches of water, to maintain a definite circulation of air, it is easy to calculate the horse power, H.P., necessary to generate that head, by multiplying the head, H, by the weight, W, in pounds of the cubical delivery per second, and dividing by the value of a horse power in foot-pounds per second. Taking this latter to be 550 foot-pounds, we get $\text{H.P.} = \frac{H \times W}{550}$

For most practical purposes of mine or tunnel ventilation, the following formula, by Morrison, is suitable : $H = \frac{KV^2PL}{A}$, where H is the head in feet of air, K is the co-efficient of friction or 0·03, V is the velocity in thousands of feet per minute, P is the perimeter of the cross section in feet, L is the length of the passage in feet, and A is the area of the same in square feet.

For circular passages, taking D for the diameter, the formula becomes $H = KV^2 \times \frac{4L}{D}$; if the passage is very short in proportion to the diameter, the formula for circular passages becomes $H = KV^2 \times \frac{4(L+50D)}{D}$, and that for irregular shapes, $H = KV^2 \times \frac{PL+200A}{A}$

Example I.—What is the head required to ensure a current of air at the rate of 5 miles an hour through a tunnel 5 miles long, and whose sectional area is 200 square feet, with a perimeter of 40 feet? Also, what horse power is needed to maintain this head? In this case, $H = \frac{0·03 \times 0·440^2 \times 40 \times 26400}{200} = 30·66$ feet of air or 0·45 inch of water; and the $\text{H.P.} = \frac{30·66 \times 1460 \times 0·0765}{550} = 6·22$ horse power.

Example II.—Calculate the horse power required to deliver 300,000 cubic feet of air an hour, assuming the head for the circulation is equivalent to one-tenth inch of water pressure. In this case, $H = 0{\cdot}1$ inch of water and $W = 5{\cdot}2 \times 83{\cdot}3$; therefore $\text{H.P.} = \frac{0{\cdot}1 \times 5{\cdot}2 \times 83{\cdot}3}{550} = 0{\cdot}0787$ horse power.

Example III.—What is the head required to impart a current of 5 miles an hour through a short circular passage 25 yards long and 5 feet in diameter? In this case, $H = 0{\cdot}03 \times 0{\cdot}440^2 \times \frac{4(75 + 250)}{5} = 1{\cdot}51$ foot of air, or $0{\cdot}022$ inch of water.

Example IV.—What is the head required to impart a current at the rate of 5 miles an hour through a short tunnel of irregular shape, 1000 yards long, and whose sectional area is 200 square feet, with a perimeter of 40 feet? Here $H = 0{\cdot}03 \times 0{\cdot}440^2 \times \frac{40 \times 3000 + 40000}{200}$ $= 4{\cdot}64$ feet of air or $0{\cdot}068$ inch of water.

The use of blowing machines for ventilation has been known since 1734, when Desaguliers invented a fan or wheel enclosed in a box. The fan, if small, is worked by hand as in the machine largely used in India, under the name of the Thermantidote. Larger fans are worked either by horses or by steam engines.

The amount of air delivered can be told by timing the speed of revolution of the extremities of the fan per second, or per minute; the effective velocity is equal to $\frac{3}{4}$ths of this, and this is the rate of movement of the air. If the section area of the conduit be known, the number of cubic feet discharged per second, minute, or hour can be at once calculated.

The power of this plan is very considerable. With a fan of 10 feet diameter, revolving sixty times per minute, the effective velocity is 1414 feet per minute. The rate of movement in the main channel should not be more than 4 feet per second; the conduits must gradually enlarge in calibre; and the movement, when the air is delivered into the rooms, should not be more than $1\frac{1}{2}$ foot per second.

This plan is very well adapted for those cases in which a large amount of air has to be suddenly supplied, as in crowded music halls and assembly rooms. St George's Hall at Liverpool is ventilated in this way, which, after thirty years' experience, is still considered satisfactory. The air is taken from the basement; is washed by being drawn through a thin film of water thrown up by a fountain; is passed into calorifères (in the winter), where it can be moistened by a steam-jet, if the difference of the dry and wet bulb be more than four to six degrees, and is then propelled along the channels which distribute it to the hall. In summer, it is cooled in the conduits by the evaporation of water.

In the present day, Root's blower (fig. 21) or a machine worked by rotating pistons is largely used. In principle it is a revolving pump, in which two pistons, each shaped like a figure of 8, are worked on parallel axles inside a box with two openings. As the pistons rotate, the air is drawn in at one opening and driven out at the other. In all machines of this type it is evident that a definite volume of air is transmitted at each stroke, and knowing this volume from measurements of the machine, the actual delivery per second is readily worked out from the speed of revolution, and whatever head is needed to drive that volume will be supplied from the source of power which drives the fan.

It will be readily understood that any given scheme of ventilation need not, necessarily, be limited to either extraction or propulsion, but may be carried out by a combination of both methods, as in the present Houses of Parliament.

Air is admitted into the chamber of the House of Commons through openings in the floor, having been previously warmed, moistened, or cooled according to the requirements of the season. The vitiated air is extracted through the perforated ceiling, and is conducted through a shaft to the base of the Clock Tower, where a large fire is maintained at the bottom of an upcast shaft.

At the Hôpital Necker in Paris, and in many other places, the plan of Van Hecke is in use. A fan, worked by an engine, drives the air into small chambers in the basement, where it is warmed by cockle stoves, and then ascends into the rooms above and passes out by outlet shafts constructed in the walls. The system is effective and economical, though it is only just to say that, the use of the fan excepted, it is precisely similar in principle to Sylvester's.

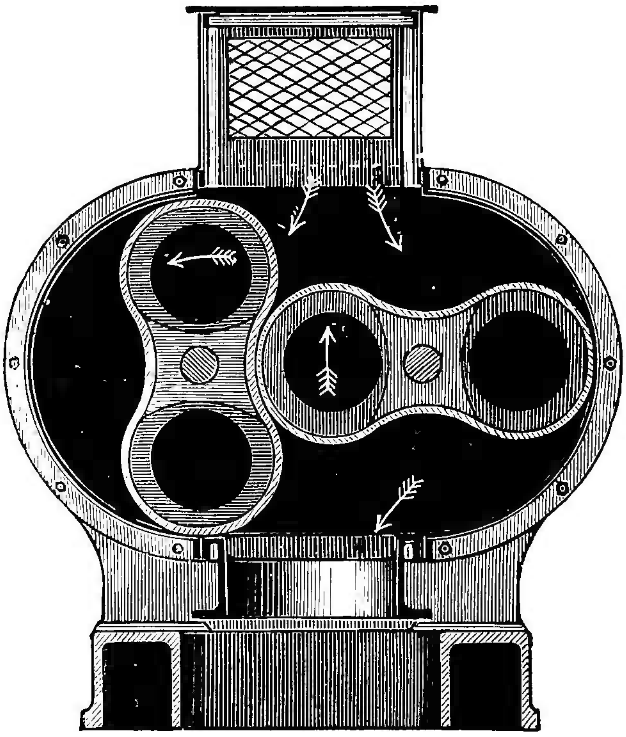


Fig. 21.

Comparative Value of Ventilation Methods.—In endeavouring to compare extraction methods with those of propulsion in attempts to ventilate mechanically, we find that there are some objections to both. When extraction of air is produced by fire and hot-air shafts, there is often inequality of draught due to the impossibility of keeping the fire at a constant height.

Another difficulty arises from the inequality of the movement from different rooms. From rooms nearest the shaft, and with the straightest connecting tubes, there may be a strong current, while from distant rooms the friction in the conduits is so great that little air may pass. The greatest care is therefore necessary in calculating the resistance, and in apportioning the area of the tubes to the resistance. This plan is, indeed, best adapted for compact buildings. Occasionally, if the friction be great, from too small size or the angular arrangement of the conduits leading to the hot-shaft, there may be no movement at all in the conduits, but a down-current to feed the fire is established in the shaft itself—a state of things which was discovered by Sanderson to exist formerly in the ventilation of St Mary's Hospital in London.

The possibility of reflux of smoke, and perhaps of air, from the shaft to the rooms, is another objection of some weight, to which must be added the impossibility of properly controlling the places where fresh air enters. It will flow in from all sides, and possibly from places where it is impure, as from closets, &c.; air is so mobile that with every care it is difficult to bring it under complete control—it will always press in and out at the point of least resistance.

The advantages of ventilation by propulsion are its certainty, and the ease with which the amount thrown in can be altered. The stream of air can be taken from any point, and can, if necessary, be washed by passing through a thin film of water, or through a thin screen of moistened cotton, and can be warmed or cooled at pleasure to any degree. In fact, the engineer can introduce into this operation the precision of modern science.

The disadvantages are the great cost, the chances of the engine breaking down, and some difficulties in distribution. If the air enter through small openings at a high velocity, it will make its way to the outlets without mixing. The method requires, therefore, great attention in detail.

As to the relative value of natural and artificial ventilation, we find circumstances differ so widely that it is impossible to select one system in preference to all others. In temperate climates, in most cases, especially for dwelling-houses, barracks, and hospitals, natural ventilation, with such powers of extraction as can be got by utilising the sources of warming and lighting, is the best. Incessant movement of the air is a law of nature. We have only to allow the air in our cities and dwellings to take share in this constant change, and ventilation will go on uninterruptedly without our care.

In some circumstances, however, as in the tropics, with a stagnant and warm air; and in temperate climates, in certain buildings where there are a great number of small rooms, or where sudden assemblages of people take place, mechanical ventilation must be used. So much may be said both for the system of extraction and propulsion under certain circumstances, that it is impossible to give an abstract preference to one over the other. In fact, it is evident that the special conditions of the case must determine the choice, and we must look more to the amount of air, and the method of distribution, than to the actual source of the moving power. But in either case the greatest engineering skill is necessary in the arrangement of tubes, the supply of fresh air, &c. The danger of contamination of air as it passes through long tubes, and the immense friction it meets with, must not be overlooked. The cost of the various plans will depend entirely on circumstances, the nature of the building, the price of materials, coal, &c. On the whole, the plans of ventilating and warming by hot-water pipes, and Van Hecke's plan, are cheaper than the method by propulsion by means of a large fan; but the latter gives us a method which is more under engineering control, and is better adapted for hot climates when it is desired to cool the air. By means of damp canvas air-screens or filters placed at both inlets and outlets, cleansed, tempered, and humidified air may be propelled through narrow wedge-shaped openings in the ceilings, and then, by means of a simple form of spreader, be evenly distributed through buildings. This arrangement has already been successfully applied to several hospitals by Messrs Key and Henman, and certainly seems the proper plan, as it not only ensures the delivery of clean air, but also purifies that emitted from the building.

Comparing two sets of schools in Dundee, Carnelley, Haldane, and Anderson have shown that mechanical ventilation has the advantage. In naturally ventilated schools, the average amount of CO_2 was 1·86 per 1000 vols., the organic matter 16·2 (vols. oxygen required per million vols. of air), and the micro-organisms 152 per litre; while in mechanically ventilated schools, the CO_2 was 1·23, the organic matter 10·1, and the micro-organisms 16·6: and notwithstanding this greater purity of the air, the temperature was considerably higher in the latter. The incoming air is warmed by being driven by means of fans over hot pipes, and then delivered into the rooms, about 5 feet from the floor, through shallow broad openings; the outgoing air is drawn up from apertures about 2 feet from the floor into a chamber in the roof, and thence out through valved louvres. The mean delivery of air (calculated from the CO_2) in the mechanically ventilated rooms was 670 cubic feet per head per hour,—in those naturally ventilated, only 400; the range in the former being from 375 to 1680, and in the latter from 175 to 1370. In neither case, however, was the ventilation very good.

METHODS OF HEATING AND COOLING.

Just as, in discussing the problems of ventilation, we were largely concerned in considering the various natural and mechanical processes involved in air movement, so now, in dealing with the problems relating to the heating of buildings, we have to discuss the laws governing the production and distribution of heat. In actual practice, the problems of ventilation are very closely associated with the problems of heating, because heat is one of the most important agents in ventilation, and the distribution of heat is commonly dependent upon the distribution of heated air or water.

Production and Measurement of Heat.—The production of heat for the purposes of heating and ventilating buildings is commonly effected by the combustion of fuel. The chief constituents of fuels are carbon and hydrogen, with various chemical combinations of these two elements; while the principal products of their combustion are carbon dioxide and water.

For measuring and comparing quantities of heat, a unit of measure is required, and that which is most commonly used in this country is the amount of heat required to raise a pound of water 1° F., say from 32° F. to 33° F. This is sometimes spoken of as the British thermal unit. In the metrical system, the unit of heat is the calorie, or the amount of heat required to raise a kilogramme of water from 0° C. to 1° C. It is sometimes convenient, in ventilation and heating problems, to express the amount of heat in terms of force. When so expressed, the British thermal unit is equivalent to 772 foot-pounds of force, and the calorie is equal to 423·985 kilogramme-metres, each kilogramme-metre being equal to 7·2 foot-pounds, or one calorie is equal to 3·968 ℔ Fahrenheit units.

The quantity of heat produced by the combustion of a fuel is approximately the sum of the quantities of heat which the hydrogen and carbon contained in it would produce separately by their combustion. When hydrogen and oxygen exist in a compound in the proper proportion to form water, these constituents have no effect on the total heat of combustion, and it is only the surplus of hydrogen above that which is required by the oxygen that is to be taken into account. The heat of combustion of one pound of pure carbon is 14,500 British thermal units, and that of one pound of pure hydrogen is 62,032: from these principles and data is deduced the following general formula for the total heat of combustion of any compound, of which the principal constituents, carbon, hydrogen and oxygen, are known:—

$$h = 14{,}500 \left\{ C + 4{\cdot}28 \left(H - \frac{O}{8} \right) \right\}$$

in which h is the total heat of one pound of the compound in British thermal units, C, H, and O are the fractions of one pound of the compound consisting respectively of carbon, hydrogen and oxygen, while 4·28 is a constant deduced from the ratio of 14,500 to 62,032.

On the basis of this formula, the following table of the total heat from combustion of one pound of each of the fuels has been prepared.

Fuel. One pound.	Carbon. lb.	Hydrogen. lb.	Oxygen. lb.	Yields British thermal heat units.
Charcoal,	0·930	...	...	13,585
Coke,	0·940	...	...	13,630
Coal—Anthracite,	0·915	0·035	0·026	15,225
,, Bituminous,	0·900	0·040	0·020	15,370
,, Cannel,	0·880	0·052	0·054	15,837
,, ,,	0·810	0·052	0·040	14,645
,, Lignite,	0·700	0·050	0·020	11,745
Peat,	0·580	0·060	0·310	9,660
Wood—dry,	0·500	...	...	7,245
Petroleum,	0·840	0·160	...	21,930

Specific Heat.—As we have chiefly to do with questions involving the amount of heat in different quantities of air, water and watery vapour, the exact amounts of heat which can be stored in equal weights of these different substances, by raising their temperatures through the same range, becomes of material importance. The heat capable of being stored or retained in this way is called the *specific heat*, and is usually described as being so many units required to raise the temperature of 1 lb of the substance through 1° F. From the following table of specific heats, it will be easy to compare the efficiency of different substances for the storage of heat.

Water	requires	1·0000	British thermal	unit to raise	the temperature	of 1 lb	through 1° F.
Ice	,,	0·5040	,,	,,	,,	,,	
Steam	,,	0·4800	,,	,,	,,	,,	,,
Copper	,,	0·0951	,,	,,	,,	,,	,,
Iron	,,	0·1140	,,	,,			
Brass	,,	0·0939	,,	,,	,,	,,	,,
Firebrick Wood	requires	0·2000	,,	,,	,,		,,
Air (expanding)	,,	0·2380	,,	,,	,,	,,	,,
,, (volume constant)		0·1690	,,	,,	,,	,,	,,

From this table it is evident that, weight for weight, water will absorb more heat for the same rise of temperature than any other substance, hence the comparative economy secured by using water as a carrier of heat, instead of air. In the case of the former it is unity, while for the latter it varies from 0·169 to 0·238, according as to whether the volume of the air mass is constant or expanding.

Assuming that the volume of air is constant, the following table from Billings shows the number of thermal units required to heat a given volume of dry air a certain number of degrees Fahrenheit, commencing at 32° F.

Cubic Feet.	Heated.								
	1°	2°.	3°.	4°.	5°.	6°.	7°	8°.	9°.
100	1·92	3·84	5·76	7·68	9·60	11·52	13·44	15·36	17·28
200	3·84	7·68	11·52	15·36	19·20	23·04	26·88	30·72	34·56
300	5·76	11·52	17·28	23·04	28·80	34·56	40·32	46·08	51·84
400	7·68	15·36	23·04	30·72	38·40	46·08	53·76	61·44	69·12
500	9·60	19·20	28·80	38·40	48·00	57·60	67·20	76·80	86·40
600	11·52	23·00	34·56	46·08	57·60	69·12	80·64	92·16	103·68
700	13·44	26·88	40·32	53·76	67·20	80·64	94·08	107·52	120·96
800	15·36	30·72	46·08	61·44	76·80	92·16	107·52	122·88	138·24
900	17·28	34·56	51·84	69·12	86·40	103·68	120·96	138·24	155·52

From this table it is easy to calculate the amount of heat required to raise the temperature of any given volume of air through any number of degrees of temperature.

Example.—It is required to know how many thermal units are necessary to heat 14,000 cubic feet of air from 32° F. to 60° F. or 28° F.

Then 7000 cubic feet heated 28° = 3763 thermal units.
7000 ,, ,, ,, = 3763 ,, ,,
7526 ,, ,,

Distribution of Heat.—In order to thoroughly understand the principles of applying heat, it is necessary to remember that the heat evolved from fuel is disseminated to surrounding bodies by conduction or immediate contact, by radiation, and by convection. *Conducted* heat passes from one particle of matter to another when they touch, that is, are separated by insensible distances. Heat is conducted through all solids, but to a very limited degree only by liquids and gases. Bodies which are good conductors rapidly give off their heat to the surrounding air or to anything in contact with them: in like manner, if colder, they withdraw heat from other bodies. A table of conductivities or conducting powers is given below; while the amount of heat, H, flowing per hour through an area, A, in square feet of l inches thickness of a substance whose conducting power is K, when the difference of temperature is t° F., may be calculated by the formula, $H = K\frac{At}{l}$.

Substance.	Conducting power in lb Fah. units (K).	Substance.	Conducting power in lb Fah. units (K).
Copper,	3225·0	Water,	5·82
Iron,	477·4	Air,	0·16
Lead,	113·0 ?	Wool,	0·32
Slate,	16·0 ?	Fossil meal,	?
Brick,	4·3	Glass, .	6·60
Fire-brick,	5·1	Eider-down,	0·31
Asphalte,	3·79	Slag-wool,	0·314
Oak (across fibres),	1·70	Asbestos,	?

Radiation is not only the most common, but probably the most wasteful of the ways by which heat is distributed. Radiated heat is propagated in straight lines in all directions with equal intensity, the effect lessening according to the square of the distance: thus, if the heat at one foot distance from a fire be 1, then at ten feet it will be one hundred times less. If radiant heat fall on a solid body, it is reflected in the same way as light, but some of the heat is absorbed, the amount reflected and absorbed being in inverse proportion to one another, and largely dependent upon the surface, colour and nature of the body, as well as upon the difference of temperature between the receiving and radiating bodies. Speaking generally, we may say that good radiators are good absorbers: good reflectors are bad radiators: transparent bodies are bad radiators.

Different transparent substances often exhibit remarkable variability as to radiation. Dry air is very transparent, but, if moist, is often more or less opaque, and becomes heated itself when heat is radiated through it. Similarly, a glass plate, 0·37 inch thick, will absorb half the energy of radiation which falls upon it, but transmitting the other half; hence thick glass is often effective in screening off heat from the sun or fire, while at the same time transmitting the light.

The *convection* of heat is that mode in which heat is propagated in liquids and gases, and is dependent upon that characteristic of those bodies which allows the portions of them which have been heated to expand and rise, their place being taken at once by colder parts. A sort of circulation of the water or air is set up, and the whole mass soon warmed. Every person in a room causes convection currents by the heat conducted to the air in contact with his skin or clothes; while the air of a room, with a fire in it on a cold day, is in a highly complex state of movement, from a similar cause. The convection currents produced by fires and by the human body in an atmosphere colder than itself not only carry off some heat but incidentally provide the body with a supply of fresh air. When the temperature of the surrounding air is nearly that of the body, this natural replacement of air does not take place, necessitating an artificial movement of the air either by means of fans or by punkahs as in the East.

Disregarding any particular variations in the source of heat, that is, whether from coal, coke, wood, gas or oil, we can say that the principal methods of warming and heating houses or rooms may be classed as either open fires, closed fires or stoves, and pipes containing either heated air, hot water, or steam.

Open Fireplaces.—Long-established custom and prejudice have caused open fires to be the means of heating nine-tenths of the houses in England, notwithstanding the fact that they are really the most costly and imperfect means of heating, as evidenced by the fact that they only render available 13 per cent. of the total heat capable of being yielded by coal or coke, and only 6 per cent. of that by wood, the rest being lost in the air, or escaping as unconsumed carbon up the chimney. The actual heating effect of open grates is most unequal in different parts of a room, but on account of the cheerful light which they emit, and the ventilation which they ensure, open fires will always be preferred as the pleasantest and healthiest mode of heating. Following Teale, the chief practical points to be aimed at in making open fireplaces may be summarised as follows:—(1) Use as little iron, but as much fire-brick, as possible. (2) The back and sides should be made of fire-brick. (3) The back of the fireplace should lean or hang over the fire, while the throat of the chimney should be contracted. (4) The bottom of the fire should be deep, from before back. (5) All slits in the bottom of the fire should be as narrow as possible. (6) The bars in front should be narrow. (7) The space beneath the fire should be closed in front by a close-fitting iron shield or "economiser." The object of this latter point is to secure as complete combustion as possible of the fuel at the bottom of the fire by the exclusion of cold air. In the use of an ordinary open fireplace, about one-eighth of the heat given off by the fuel consumed is utilised on the air of the room. All open grates should be made so as to have the fuel slowly and completely consumed, while the draught up the chimney should not be in excess of ventilation requirements.

To calculate the quantity of air required for the combustion of any given fuel we may use the formula, $12C+36\left(H-\frac{O}{8}\right)$, which is based on the fact that 72 parts by weight of air represent 16 of oxygen: the weight of air theoretically necessary is therefore 12 times that of the carbon + 36 times that of the hydrogen, less $\frac{0}{2}$ that of any oxygen that may be present in the fuel itself. If the unit employed be 1 ℔, we may obtain the volume of air at 32° F. by multiplying the weight of air, obtained by the formula, by 12·844, this figure being the volume which 1 ℔ of air occupies in cubic feet at that temperature. In actual practice, from half as much again to twice this theoretical quantity of air is found necessary. Thus, 1 ℔ of coal requires 300 cubic feet of air, and 1 ℔ of dry wood needs 160.

Most English grates consume 8 ℔ of coal in an hour: this means 2400 cubic feet hourly, but in actual practice something like 20,000, or even 40,000, cubic feet of air pass up the chimney; in which case, supposing the room contains 4000 cubic feet of space, the air in it gets changed from 5 to 10 times in the hour according to the strength of the fire. If the incoming air were warm, this liberal ventilation would be excellent, but, unfortunately, it rarely is so, but is in the main quite cold, finding entrance through the floor, or by chinks round the windows or beneath the door.

If the whole of the heat generated in the combustion of coal were utilised, 1 ℔ would suffice to raise a room, 20 feet square by 12 feet high, 10° F. above the temperature of the outer air, that is, making no allowance for loss by ventilation and conduction. To save some of the large margin of 87 per cent. of practically wasted fuel has been the object of many "improved fireplaces."

One of the first improvements in fireplaces was the securing of increased radiation from the burning fuel. This is best attained by either regulating the shape of the stove so that its coverings are inclined at an angle of 135° to the back of the grate, or by making the fireplace as much as possible of material which, while having a high radiation power, is but a poor conductor of heat. Reference to page 219 will indicate that fireplaces on this account should be made as far as possible of fire-brick, and the amount of metal about them reduced to a minimum. Several grates improved in this direction are now in the market, more particularly some made by Doulton, which are constructed almost entirely of fire-clay or pottery.

Fireplaces have further been improved by surrounding the stove by an air-space with two openings which communicate, one with the external air, and the other with the room. The air entering this chamber behind the grate becomes warmed by passing over the heated back portion of the fireplace, and then ascends by a separate shaft or by an iron pipe placed in the chimney to enter the room near the ceiling. The ventilating fireplace of Sir D. Galton (fig. 22), largely used in military barracks, is a very good form of this class of fire-grate. Boyd's Hygiastic grate is another constructed on the same principle, but delivers the heated air through an opening just above the fire under the mantel-shelf. Both these grates reduce the wasted heat by about one-fourth. It is, however, important that the air which enters by these ventilating fireplaces should not pass over any iron surface which is heated to a red heat, as, owing to the direct action of the oxygen of the air upon the carbon of the cast iron, and the frequent decomposition of the atmospheric carbon dioxide by the red-hot metal, free carbon monoxide may be generated. To these reasons may be

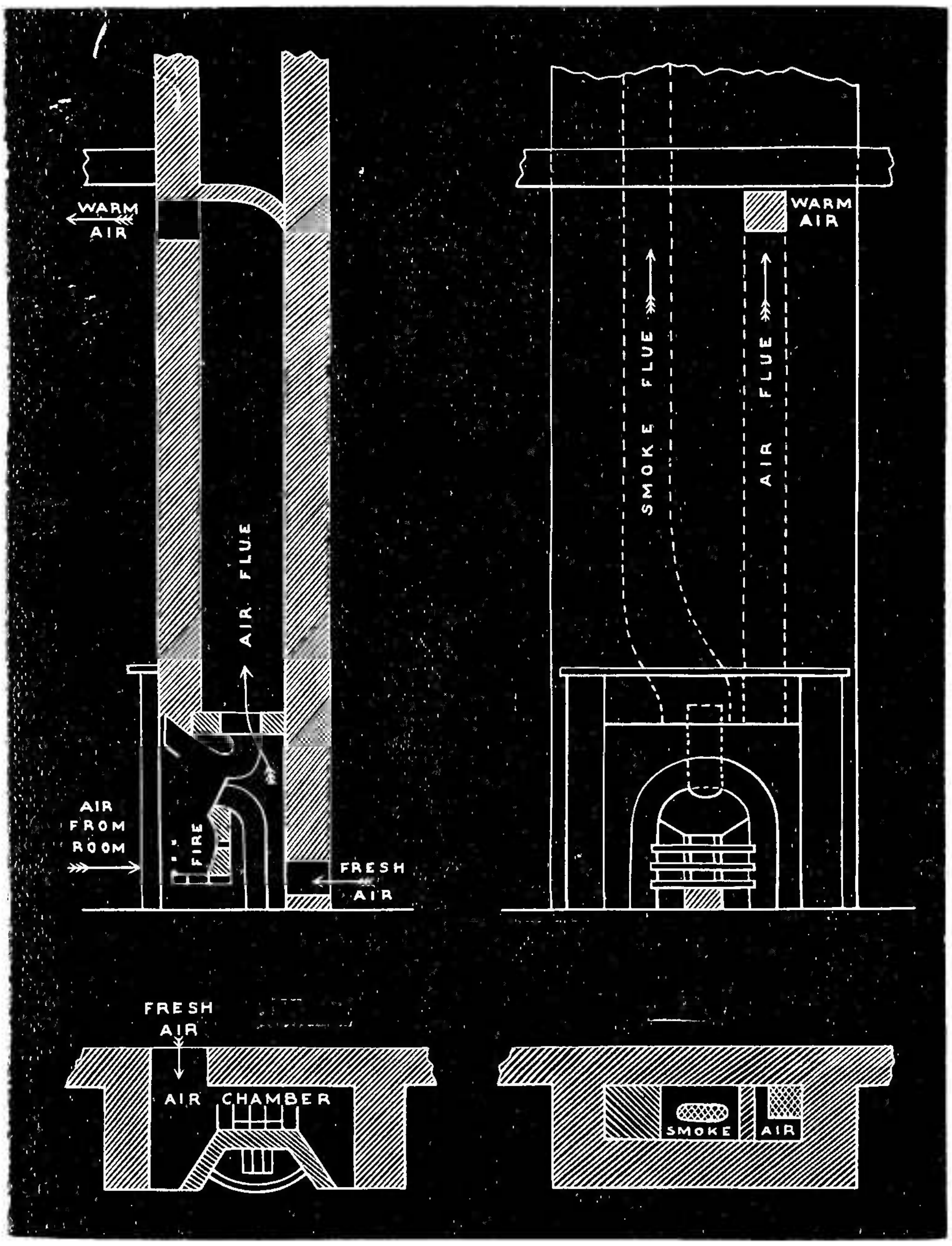


Fig. 22.

added the fact that, if any carbonic oxide is formed in the fire, some of it will pass out through the red-hot metal to the external air. "Slow-combustion grates," having solid floors, are now much used. The fuel, which is piled up against the back, burns away mostly at the upper part, where the current of air strikes the top of the fuel on its way to the chimney. The fuel is brought well forward, so that the heat may be radiated freely, and the flanks of the fireplace are splayed for the same reason. The fire is lighted at the top, and gradually burns downwards.

In some other grates, economy of loss of heat is gained by limiting the amount of air carried up the chimney without having taken part in the combustion. This loss of heat can usually be restricted by narrowing the chimney and its orifices, but care needs to be taken that the proper proportions of the chimney and its openings are maintained, so that the efficiency of the fireplace, as a ventilating and warming apparatus combined, is not interfered with. To secure this, Morin recommends that the temperature of the air in the chimney should be at least 45° F. or 25° C. above that of the outer air, and that the smoke should not issue from a chimney at a greater velocity than 10 feet per second, and that the top orifice of the chimney should be one-half of that of the chimney itself. The following table, by Morin, gives the dimensions of the chimney flues needed for rooms of different sizes, when an ordinary open fireplace is used.

Capacity of room in cubic feet.	Volume of air to be removed by the chimney each hour in cubic feet.	Sectional area of the rectangular chimney in square feet.	Diameter of cylindrical chimney in feet.
3,500	17,500	0·99	0·88
4,200	21,000	1·19	0·98
5,300	26,500	1·48	1·08
6,350	31,750	1·78	1·21
7,750	38,750	2·17	1·31
9,200	46,000	2·57	1·44
10,600	53,000	2·97	1·54

For ventilating grates, Morin recommends the following proportions:—

Capacity of room in cubic feet.	Volume of air to be supplied per hour in cubic feet.	Sectional area of chimney flue in square feet.	Sectional area of flue for fresh air in square feet.
3,500	17,500	0·54	1·5
4,200	21,000	0·66	1·8
5,300	26,500	0·81	2·3
6,350	31,750	0·97	2·7
7,750	38,750	1·20	3·3
9,200	46,000	1·40	3·9
10,600	53,000	1·60	4·6

In Sylvester's grates, which have been adopted with advantage in both public offices and private houses, the fuel is placed upon a grate, the bars of which are on a level with the floor, and air is supplied to the ash-pit below by a series of passages which pass under a hearth composed either of separate bars of iron, arranged in front of the grate, or of ornamental tiles. The heat from the fire is made to warm the hearth and the air passing beneath it, while the low position of the fire, and the angle of inclination given to the sides and back of the grate, tend to disperse the heat more effectually than in the ordinary open fireplaces. The sides and top of these stoves are made of double casings of iron, and in the sides a series of vertical plates is enclosed, which collect a great portion of the heat generated by the fire. The extent of these plates is so proportioned to the fuel consumed that the air can never rise above 212° F. or 100° C. under any circumstances. This arrangement converts the sides and top of the stove into an air-chamber, into which, by an opening at the bottom, fresh air is allowed to enter. The air traverses in its ascent the various compartments formed by the parallel plates, is warmed, and escapes at the top by an opening into the room. In order to prevent the heated air being too dry, a vessel containing water is introduced into the top of these grates, where it evaporates, and yields moisture to the air. Figs. 23 and 24 represent these stoves, one being intended to fit into an ordinary chimney recess, while the other stands forward into the room. At the back of the grate is a series of louvres, by opening or closing which, a greater or less draught can be created, according to the amount of combustion required.

Closed Fires or Stoves.—The simplest definition of a stove is that of a chamber constructed to disseminate heat by the direct contact of air with the heated surface, which is obtained by burning fuel on a grate, closely surrounded on all sides, except below the bars, by a good conducting or absorbing material. If the fire is not required to materially assist in ventilation as well as in heating, the enclosing of the fire in a chamber affords a considerable economy in the consumption of fuel, as the air supplied is entirely limited to that taking part in the combustion, and only the products of that combustion escaping by the chimney or smoke flue. The materials used for the construction of stoves are cast iron, sheet iron, bricks or tiles; and much of the success of stoves depends upon the facility with which the materials of which they are constructed communicate the heat they receive.

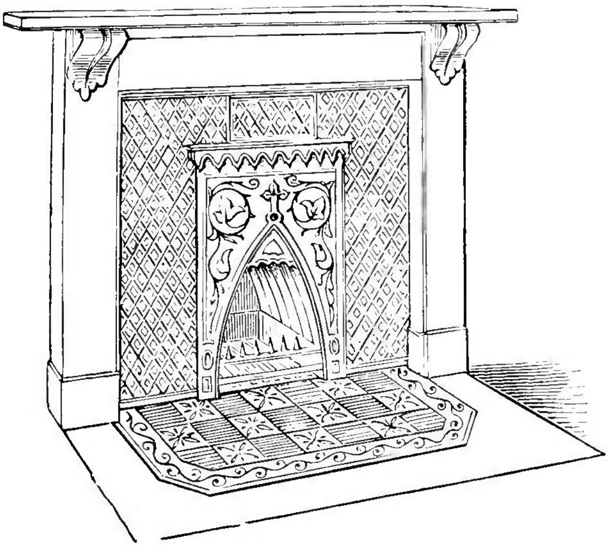


Fig. 23.

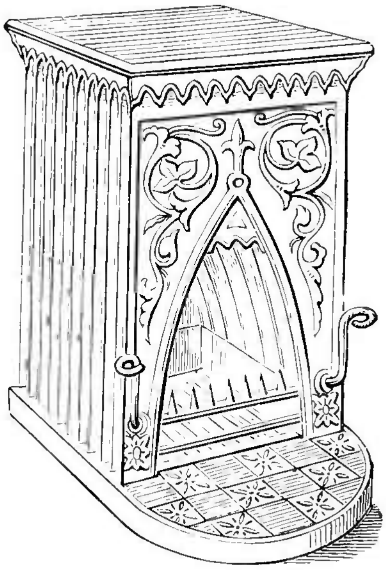


Fig. 24.

When the fuel is rapidly burnt in a stove, so as to evolve at once the entire amount of heat it is capable of affording, the temperature produced is often greater than is required. Iron, therefore, which conducts and radiates heat almost as rapidly as it is received, is not an appropriate material for communicating a uniform temperature, say of about 68° F. Clay, in the form of bricks or tiles, is decidedly preferable, as no matter with what degree of rapidity its temperature is raised, it evolves its heat slowly and gradually. From the given quantity of air (=A) which the stove must heat hourly (to t°) to make up for the loss by cooling and ventilation, the corresponding amount of clay surface may easily be calculated. The mean weight of a cubic foot of fire-clay is 62 ℔: a cubic foot of air at 68° F. weighs 0·037 ℔, therefore, 1680 times less than an equal bulk of clay; the same amount of heat produces the same rise of temperature in equal masses of both, the specific heat of each being about one fourth that of water. The heat, therefore, required to raise 1680 cubic feet of air to the desired temperature or $t°$ above the outer air, will be sufficient to produce the same effect in 1 cubic foot of clay. The latter, however, becomes hotter from the fire and warms the air in contact with it, by cooling gradually from a maximum temperature, or T°, to a temperature $t'°$, which is sensibly higher than $t°$. The heat evolved during cooling will warm a greater body of air to $t°$ in the ratio of as $t°$ is to $(T° - t'°)$, whence we obtain the formula, $x = \frac{At°}{1680(T° - t'°)}$ as giving the volume of fire-clay corresponding with the body of air to be heated.

Iron stoves are often objectionable, because they occasion an unpleasant smell, and produce headaches. The smell is commonly caused when, by want of attention, some part of the stove is allowed to become red-hot, and the dust particles in the air, coming in contact with it, are charred; often a slight smell comes from the iron itself. Another objection exists in the fact that iron, when red-hot, permits the passage of carbon monoxide and other gases through it. If water is not placed on a stove, the air becomes heated without acquiring an amount of moisture commensurate with its increased temperature, and is proportionately unpleasant.

In stoves of the simplest construction, the fire is surrounded directly by the surface to be heated, which, being placed unprotected in the room, radiates heat and warms the air by direct contact, the smoke passing away into the chimney. The relative heating surface needed for any given space may be approximately calculated from the facts established by Péclet, that a square foot of sheet iron, freely exposed to the air, will yield about 200 heat units per hour; a square foot of cast iron 500; and bricks or tiles, $\frac{2}{5}$ths of an inch in thickness, 180 units, supposing the fuel to be consumed in such a manner as to yield in each case 0·8 of its heating power.

The Meidingen stove is a slow-combustion stove much used in Germany: it consists of an inner cylinder with fluted rings enclosed in a double casing, through which the outer air can be passed and warmed before entering the room. A door fixed in the grate regulates the draught and the rapidity of combustion.

Saxon Snell's stove has a small boiler placed behind the grate, which communicates with a series of iron pipes: these are filled with water, and air admitted to the room between them. The products of combustion are carried off by a flue.

What are called American stoves, are stoves specially constructed for burning anthracite coal, which does not burn freely in any open grate, in consequence of the cooling action exerted by the large quantity of air necessarily admitted to the fuel. So liable is anthracite coal to be extinguished by sudden cooling, that it is found more advisable to feed the fire from above than from the side by a fire door, as in ordinary stoves; hence these American stoves are of peculiar construction. In Nott's stoves, the grate bars are curved, so as to form together three parts of a cylinder, and firmly attached to side plates, so that the whole grate can be moved by a handle outside the stove, round an axis to which the side plates are fixed. One-third of the convex side of the grate cylinder is required as a support for the fuel; by means of the handle, the other two-thirds can be alternately brought to occupy its position, and by this rotating motion the ashes are caused to fall through the bars. In Spoor's stove, also much used in America, the hot gases are made to traverse the sides of the stove in an upward and downward direction before escaping into the chimney. Olney's stove is very similar to Nott's, except that the escape for the gases is confined to one aperture, whilst in Nott's there are two, at different elevations.

In some stoves, the heating surface is surrounded by an outer casing open at the top and bottom, through which the air of the chamber or air from the outside is caused to circulate and become warmed in its ascent. These arrangements are often called cockle stoves: large stoves on this plan used on the Continent are known as *calorifères*.

The stove introduced by the late Mr Napier (fig. 25) is designed to economise solid fuel, and has arrangements by which the hot gases are made to descend before entering the chimney. This principle of conducting the gases downwards before they are allowed to escape is scientifically correct, because the heavier or cooler gases escape first, the hotter gases being kept longer in contact with the radiating surfaces of the stove: better diffusion of the hot gases is also obtained in this way. Experiments made with this stove show that one having 24 square feet of heating surface, in a room of 5000 cubic feet, by burning 1 ℔ of coke hourly for ten hours a day, kept the room as fresh as, and hotter than 30 ℔ of the same coke burned in either an American stove, or 40 ℔ of good coal burning hourly in an ordinary open fireplace.

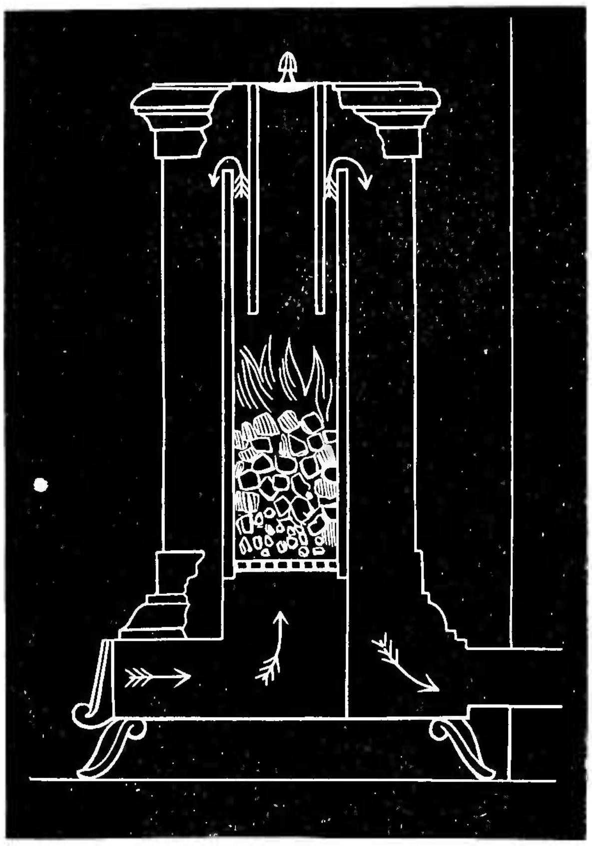


Fig. 25.

Gas Stoves.—The use of appliances for using illuminating gas as fuel in heating and cooking has largely increased of late years, several exhibitions of such appliances having greatly stimulated the introduction of improved forms. Gas stoves without chimneys, that is, those from which the products of combustion are allowed to escape into the air of the room which is being heated, are obviously fundamentally wrong, and are only used where health is sacrificed to economy of gas. Under certain circumstances, gas is a more economical fuel than coal: where heat is required quickly and only for a short time, the waste which necessarily accompanies the lighting of a coal fire is far more than equivalent to the higher cost of the gas. In reference to this aspect of the question, the following experiments are of interest, particularly as they indicate that a gallon of water may be more economically brought to the boiling point by a gas stove than by a recently lighted coal fire.

	Coal used.	Wood used.	Time employed.	Total cost.
With fire,	$4\frac{1}{4}$ lb.	$\frac{1}{4}$d. worth.	56 minutes.	$\frac{51}{100}$ of 1d.
With gas,	4·5 cubic feet of gas at 3s. 2d. per 1000.		21 minutes.	$\frac{17}{100}$ of 1d.

There is, therefore, according to this estimate, an economy in cost of just 33 per cent., and a saving in time of nearly two-thirds, besides great cleanliness and comfort, in the use of gas.

Speaking generally, there may be said to be four common forms of gas stove in general use: these are (1) coke and asbestos or hollow ball refractory fuel stoves, (2) reflector stoves, (3) condensing stoves, (4) calorigen stoves.

Stoves fitted with coke, asbestos fibre, common peroxide of manganese, pumice stone, and fire-brick, and lighted by Bunsen burners, are relatively popular, owing to the fact that the fuel is rendered incandescent, with a close resemblance to the glow of an ordinary coal fire. These stoves yield radiant heat only as a rule, though a few are made with attached hot chambers to give off heated currents of air. They are, in the main, good stoves, but somewhat extravagant as gas consumers, and always needing a flue to carry off the products of combustion, and which as well takes much of the heat which they produce as so much waste. Gas fires of this kind for an ordinary room consume on an average 15 cubic feet of gas per hour; that amounts to about $\frac{1}{2}$d. per hour, taking gas at 3s. per 1000 cubic feet. Fletcher of Warrington says that gas fires cost from 1d. to 4d. per hour, but quotes no experiments to show this: much will obviously depend upon the local cost of gas.

Reflector stoves have usually a naked gas flame, backed by a glass or metal reflector. They are bright and cheerful looking, but give out little heat, and unless provided with a flue—which more often than not is not provided—very considerably add to the vitiation of the air.

Condensing stoves are those so constructed that the water vapour, which is one of the products of gas combustion, is condensed by passing through upright tubes, and then caught in a tray beneath. This condensed vapour naturally carries down with it some if not all the sulphur products, but fails to remove any of the carbon dioxide which, notwithstanding all statements to the contrary, really escapes into the room. For this reason, these stoves always require a flue; unfortunately, their heating powers are small.

The essential defects of all the three preceding forms of gas stoves are a disproportionately low amount of heat gained as compared with the high expenditure of gas, due mainly to a failure to rob the products of combustion of their heat before they escape out of the stove in as large a degree as is consistent with ensuring their escape from it. It is at once obvious that this can be most effectively secured by bringing the heated combustion products into contact with a large metallic area, so arranged that the heat which it absorbs shall be given off either by direct radiation, or by the conducting influence of air-currents flowing over it. Of stoves which provide luminous flames, or a source of radiant heat as well as a supply of fresh heated air, those of Adams and Fletcher may be taken as examples: while of the numerous stoves which merely supply heated air, those of George and Bond will serve as specimens.

In Adams' stove (fig. 26) a mixture of gas and air is burned in a series of fire-clay burners. These are arranged upon a tray, which is drawn forward for lighting: in a short time the burners become red hot, and a small supply of gas then suffices. The heated products of combustion are passed over a large surface formed by sheet-iron partitions, the other side of which is traversed by the air which is being heated: a certain amount of radiation also takes place from the red-hot brick burners. The waste hot gases escape by a chimney at about 240° F., while a supply of fresh air is drawn in and rapidly heated to 180° F. at a rate of about 200 cubic feet per cubic foot of gas burned per hour.

In Fletcher's gas stove use is made of simple illuminating flames from ordinary burners for the supply of radiant heat; the hot combustion products ascend in contact with vertical tubes, which are thus heated, and induce a current of air through them, the air being delivered heated at the top (fig. 27).

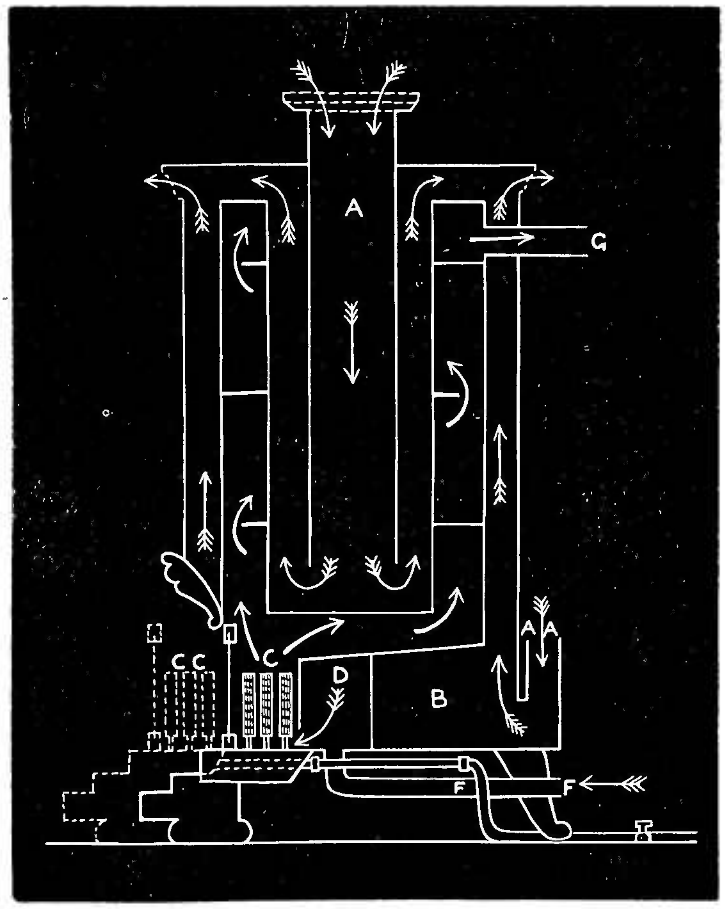


Fig. 26.

In George's Calorigen stove the body is made of rolled iron, and contains a coil of wrought iron tubing open at the top. This at its lower end is carried through the outer wall either above or below the floor to a point from which an appropriate supply of fresh air can be obtained. The cylindrical metal body of the stove has connected with it two pipes, one an upper one for carrying away the products of combustion into the outer air, while the lower one brings in fresh air to support combustion. The action of the stove is simple: the heated combustion products not only heat the outer metal case, and through it the air in contact with it, but also heat the current of air constantly passing up through the coiled tube into the room.

Bond's Euthermic stove (fig. 28) consists of a corrugated metal cylinder which, as in George's Calorigen, constitutes the stove body: above this, it discharges into a flue for the escape of the combustion products, while below it is open for the location of a gas jet and a supply of air. Inside this metal cylinder is a metal drum, having an inlet tube, E, below, for bringing fresh air, and open at its upper end, to allow of air which is heated in its passage through the stove to escape into the room. The corrugation of the cylinder secures not only an increased superficial surface for the heated products of combustion to yield their heat into the room direct from the outer surface of the corrugation, but also from the inner surface of the contained drum to the air within it.

Of these stoves, the Euthermic is perhaps the best, mainly on account of its open bottom rendering it a true ventilating agent, inasmuch as the air needed for the gas combustion has to be drawn from the room itself, and by that means favours a continuous change of air through it. This is not well secured in the others, all movement of air through the tubes being largely dependent upon the conditions which exist in the room for allowing air into and out of them, and is but slightly influenced by the pure and simple action of the stoves themselves.

For supplying the gas which is now usually supplied to gas stoves, use is made of so-called atmospheric burners constructed on the same principle as Bunsen burners. From the supply pipe the gas passes by a nozzle into a small chamber provided with perforations, behind the nozzle, through which air passes. The air and gas mix, and, escaping by the jets, on ignition burn with a non-luminous, faintly blue, smokeless, but extremely hot flame. If the supply of gas be too small, it burns at the nozzle, producing an easily recognised odour of half-burnt gas. This "burning down" always occurs if the gas is turned too low, or when the gas is exposed to a sudden draught. It constitutes a serious drawback to the use of gas fires. If by chance burning back occurs, the gas should be turned off completely and re-lighted at the proper opening. Many atmospheric burners are now made with devices for preventing the lighting back, one of the best being to cover the openings at which the gas burns with fine wire gauze.

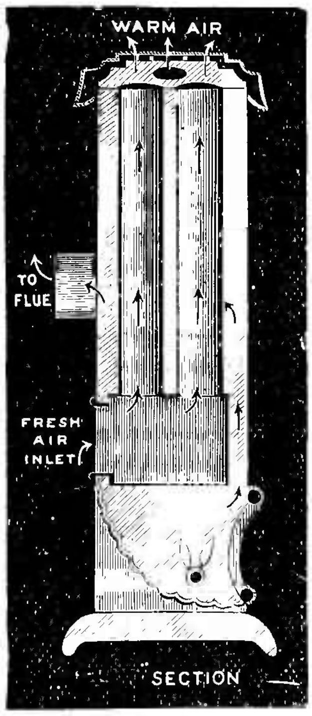


Fig. 27.

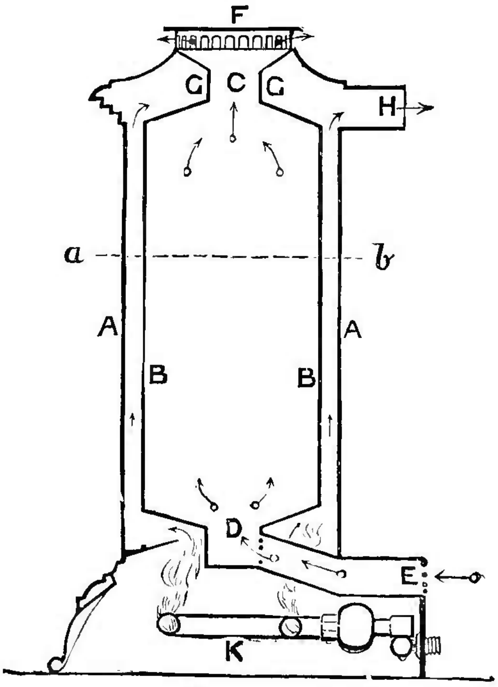


Fig. 28.

Oil Stoves.—Under some circumstances the use of oil stoves, such as those made by Rippingille, affords a convenient means of heating apartments. This is a matter of great practical importance often in country places, and where no chimneys are available to carry off the products of combustion. The problem how to make a stove that shall not require a flue is one that has occupied the minds of many inventors, and although it is easy to say that so long as carbon dioxide is one of the products of combustion the thing is impossible, there is a good deal of experience to show that a considerable degree of heat may be safely obtained from the combustion of hydrocarbons, without any other flue or outlet than is required for the removal of the products of respiration of those who dwell in the room. We do not think that the experience has yet been accumulated which would enable us to speak positively of the innocuousness of a considerable admixture of carbonic acid with the air we breathe, but the knowledge that in hundreds of cases oil stoves are used for heating living-rooms and even bed-rooms without apparent injury to the occupants, makes one feel fairly confident that the products of the complete combustion of hydrocarbons are not injurious when mixed with such an amount of air as is sufficient to dilute to a proper degree the respiratory products.

It has elsewhere been explained that anything over 0·6 of CO_2 per 1000 of air may be taken as indicating concomitant and hurtful organic impurity of the atmosphere of dwelling-rooms, but that is so mainly on the assumption that the carbon dioxide is the product of animal respiration. It is probable that this permissible limit of carbon dioxide does not apply with the same force to cases in which it is formed by lamps and stoves. At present we have no very complete data as to the exact proportion of carbon dioxide which it is safe to breathe for long periods, but the probabilities are that danger does not arise until a far larger ratio is reached than would be produced by an oil stove warming a room in which there is sufficient ventilation to keep it sweet, even if no stove were present.

Experiments show that, provided the combustion of the oil is complete, and that the ventilation is sufficient for the ordinary effects of respiration, the use of oil stoves for heating purposes may be advantageously employed in both ordinary day and sleeping rooms. The efficiency of oil stoves is increased by placing over them a diffuser or radiator, so as to prevent the heated products ascending direct to the ceiling: care needs also to be taken that only the better kinds of mineral oil are used; if inferior qualities of oil are burnt, perfect combustion is more difficult to obtain.

Heating by Means of Hot Air.—When want of space or other considerations render it desirable to remove stoves or fires away from the rooms to be heated, the necessary quantity of air can be warmed in another part of the building, and conducted by air flues into the different rooms or passages. This arrangement is eminently suitable for large public buildings. When the supply of heated air is abundant, and is transmitted to the apartments with some force by means of fans, no extra outlet for the vitiated air is necessary, sufficient ventilation being afforded, in small rooms and not overcrowded with inmates, by the unavoidable cracks and crevices around doors and windows. If, however, the rooms are at all crowded, special means of ventilation must be provided. With a view to economise the heat of the air, which has already circulated once through the apartments, two methods have been proposed: one consists in reconducting the air to the heating surface of the stove, and again transmitting it to the spaces to be warmed; the other conducts the used air to the ash-pit of the stove to supply oxygen for combustion, when the higher temperature, as compared with the external atmosphere, which it still retains, will more than compensate for the lesser proportion of oxygen which it affords.

Supposing that proper ventilation can be kept up in the rooms by means of doors and windows, the first method is obviously advantageous, as the warm air streaming in will force out that already in the room, and thus produce a condition of affairs in which the natural tendency of the outer air to force its way through crevices will cease with all its attendant disadvantages. The methods of heating by hot air are not desirable for buildings in which the number of rooms heated varies, because the proper relation between the dimensions of the heat generating stoves and the supply of hot air cannot be easily apportioned to meet a fluctuating demand. On the other hand, this manner of heating is economical, as only one stove is required and its fuel more completely consumed than if the same quantity were distributed in separate stoves, while there is the further advantage of a uniform and equable heat proceeding from the floor level.

The actual generating hot-air stoves are constructed according to either of two systems. In one, the smoke and hot gases from a fire are caused to circulate in an extensive series of stoneware or metallic flues, and the air to be warmed, supplied from the outside of the building, is conducted around these flues, where it absorbs heat. In the other, the air to be heated is conducted through metallic or stoneware pipes, round which the flame and smoke of a fire are allowed to play. In both systems, about 10 square feet of heating surface per pound of coal consumed is found practically to work well.

The forms of apparatus constructed by different inventors for heating air are numerous, but they all conform in principle to one or other of the foregoing systems. Perhaps one of the most successful is the "Convoluted Stove" of Messrs Constantine & Son of Manchester, and applied to the heating of the Manchester Royal Exchange, Pantechnicon, Concert Hall, Theatre Royal, and to the Arlington Street Turkish Baths in Glasgow. In fig. 29 is shown a horizontal section of the stove with its brick-work casing which forms the air-circulating space. The stove is on the model of a "gill" stove, but with the gills made hollow. In order to diffuse the hot gases and flame into the grooves of the gills and to prevent the too rapid escape of heat by the chimney, fire-brick slabs are placed across the fire space and form a roof to the combustion chamber, or baffle plate to the flames. Security against overheating is obtained by having the proportion of heating to grate surface as large as 100 to 1. In the Manchester Royal Exchange, where the space is 1,500,000 cubic feet, a uniform temperature of 50° to 56° F. is maintained by two of these stoves with an expenditure of only 2½ cwts. of coke in the twenty-four hours. The arrangement is very simple: fresh air is drawn from the top of the building down a shaft, 6 feet square, through a cold chamber at the bottom, in which it is filtered, and is then passed through the warming chamber to two flues which run the full length of the hall, with branch flues into the plinths of the columns, from which the warm air is delivered.

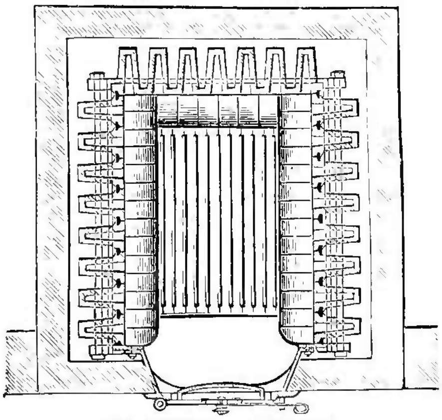


Fig. 29.

In the Arlington Baths, Glasgow, and the Llandudno Hydropathic Establishment the use of these stoves for supplying hot air has been equally satisfactory: in the former place "the cubic capacity of the hot and hottest rooms is 17,700 feet, giving a proportion of 1 square foot of cast-iron heating surface in the stoves to about 23·8 cubic feet of contained space. The heating and ventilation of these rooms is obtained by a consumption of from 48 to 60 cwts. of gas coke per week of fifty-five hours."

Heating by Water and Steam.—Both water and steam are often used as means of carrying heat, in consequence of the high specific heat of the former, and the large quantity of latent heat in the latter. The quantities of heat contained in equal weights of water and air at the same temperature are in the ratio of 421 to 100 : or the heat which is set free when water cools down one hundred degrees is sufficient to raise the temperature of 4·21 times as much air to the same amount. Therefore, the heat destined for a given quantity of air can be retained in a much less quantity of water. Further, a greater effect is produced when water, in the form of steam, is made the carrier of heat, because 1 ℔ of water vapour at 100° C. (212° F.) will, in condensing to form boiling water, give off sufficient heat to raise the temperature of 5·36 ℔ of water, or 4·21 × 5·36 = 22·5 ℔ of air raised to 100° C. or 212° F.

Heating by hot-water pipes is either conducted on the so-called low-pressure system, or on Perkins' high-pressure principle. In a low-pressure water system, the pipes are about 4 inches in diameter, and arranged in a double row to allow of the water circulating. The boiler in connection with it is commonly placed in the basement of the building, and from its upper part runs a main pipe, ending in branches, which extend to the furthest end of the building : these then return underneath the others, unite into another single pipe, and then re-enter the boiler at its bottom. The circulation of the water is dependent upon the water, after being heated, being lighter than when cold, and as such tending to rise to a higher level : this, having given up its heat to the various rooms, returns cooled by the lower pipe. The heat of the pipes is controlled by a valve which can be opened and closed at will. A feed pipe from a supply cistern enters the return pipe near the boiler, while an escape of air is provided at the highest point of the system.

The circulation being open to the air at one point, the highest temperature possible at or near the top, where this opening is, does not exceed 100° C. or 212° F. : at the deeper portions it may be higher, but the average temperature in a low-pressure circulation rarely exceeds 212° F. The calculation of the flow of water in the circulation is very similar to that of air ; the head being due to difference of densities between hot and cold water. To find the head for any circulation, this latter may be conveniently divided into foot sections by horizontal parallel planes, one foot apart. By measuring the temperature of the flow and return pipes in each section, the head of the whole circulation will be the sum of the differences of temperature of corresponding sections, multiplied by the co-efficient of expansion of water. The average temperature in the flow and return pipes will be between 92° F. and 212° F., and for this range the mean co-efficient of expansion of water is 0·000318, hence the head for each foot section = 0·000318 $(t - t')$. If the total sum of the differences of temperature is negative, it is evident that the circulation is in the opposite direction. However small the head may be, there will be a flow of some sort, provided there is a continuous channel filled with water from the boiler and back again. The precise velocity of flow of water in the circulation depends not only on the head but upon the resistance of the whole channel. Its computation is subject to the same laws as those governing resistance in air-channels, but as the calculation for a hot-water system would be very intricate, most hot-water engineers work empirically from known successful arrangements to any new one required.

In Perkins' high-pressure system the water is completely enclosed in wrought-iron pipes, whose internal diameter is $\frac{7}{8}$ inch, external $1\frac{5}{16}$ inch, and sufficiently strong to withstand the pressure corresponding to very high temperatures. Thus, the pressure of steam, or the pressure required to prevent steam forming at 212° F., is $14\frac{3}{4}$ lb per square inch, at 300° F. it is 67 lb, and at 400° F. it is 250 lb per square inch. The narrow iron pipes are so arranged as to form a complete circuit, part of it being coiled within and exposed to the heat of a fire. At the top of the circuit there is a series of larger pipes called expansion tubes: these contain half air and half water, and therefore allowing for the expansion of the latter. When the pipes have been filled with water, they are closed with screw plugs, making the whole circuit practically a closed vessel full of water except at the top, where there is a little air. The temperature is regulated by fixing the proportion of pipe within the fire to that outside as 1 is to 10. Once started, the circulation of water within these high-pressure pipes is very rapid, while the temperature usually reaches 300° F. This system has faults due to the irregularity of temperature at different parts of the same coil, and the rapidity with which the heat diminishes on lowering the fire. High-pressure water pipes are also very liable to overheat the air, a fact which renders them objectionable for heating houses: on the other hand, they are very useful for heating disinfecting chambers and drying closets, where a small space is required to be quickly raised to a high temperature. Wherever there is a high-pressure water circulation, it must not be forgotten that, although the whole is closed up, the water in it wastes to a small extent, necessitating the periodical opening of the plugs and the addition of a little fresh water.

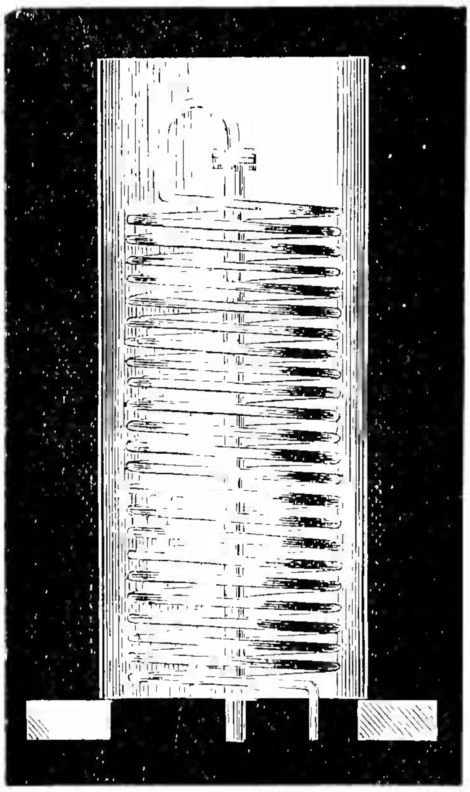


Fig. 30.

It has already been explained that steam heats much more effectively than water, and that 1 lb of steam at 100° C. will, in condensing to form boiling water, yield sufficient heat to raise 22·5 lb of air to 100° C. (212° F.). Methods of heating by steam are based upon this fact that, if steam be conducted to suitable condensing pipes or tubes, they then will impart the generated heat to the surrounding air. The pipes destined to carry the steam to the place of condensation are chosen of narrow bore (about 1·5 inch) and, to avoid all condensation in transit, are surrounded with a thick covering of felt: the condensing pipes are of copper or cast iron, and at least four times as wide, and must be so arranged that the air can escape when the steam is first admitted. Whatever form is given to the apparatus, ample means must be afforded for the removal of the condensed water, and a special set of pipes, conducting it back to the boiler, is generally employed for this purpose. One of the best modes of employing steam is shown in fig. 30. There is only one pipe through which the steam ascends from the boiler and also one extensive coil of pipe by which the condensed water returns. A cock should be shown in the drawing at the top of the pipe, to allow air to escape. When placed in the place to be heated, this apparatus practically becomes a steam stove. If at a distance and surrounded with a case, through the bottom of which air enters, the warmed air may be transmitted to a higher position. If the diameter of the pipes is small, the length must be increased in proportion to afford a sufficient heating surface.

A question of very practical importance is how much hot-water piping of given external diameter is necessary for the heating of a given room or series of rooms. The answer to this question depends upon a large number of conditions, more especially the loss of heat by conduction through the walls and windows, as well as that carried away by the air in the process of ventilation. Much of our information on this matter is due to Hood, who says, "The quantity of air to be warmed per minute in habitable rooms and in public buildings must be from 3·5 to 5 cubic feet for each person the room contains, and 1·25 cubic foot for each square foot of glass." According to the same authority, an iron pipe, 4 inches in external diameter, loses 0·851 of a degree of heat (Fahr.) per minute (or 1° F. in seventy seconds) when the excess of its temperature is 125° F. above that of the surrounding air. Hood estimates also that 1 foot of a 4-inch pipe will heat 222 cubic feet of air 1° F. per minute when the difference of temperature of pipe and temperature of air is 125° F.

Putting it in another way, we can say that one British thermal unit will heat 50 cubic feet of air 1° F., and that the amount of heat given off from iron pipes containing steam or hot water is 1·75 thermal unit per hour per square foot of radiating surface for each Fahrenheit degree of difference between the temperature of the pipe and that of the surrounding air. Hence, to find the number of square feet of radiating surface required to heat a given supply of air to a given temperature, multiply the number of cubic feet of air per hour by the difference between the temperature of the cold air supply and that to which it is to be heated, and divide it by 50: this will give the number of thermal units required; then, dividing these by the difference between the temperature of the radiating surface and that of the surrounding air multiplied by 1·75, the number of square feet of surface required will be found.

Example.—A room receiving 6000 cubic feet of air per hour is required to have its temperature raised from 32° F. to 70° F. by a radiating surface whose temperature is 210° F. How many square feet of radiating surface are needed to do this work? Then, $\frac{6000 \times 38}{50} = 4560$ thermal units, and $\frac{4560}{140 \times 1{\cdot}75} = 18{\cdot}6$ square feet.

This calculation does not allow for the loss from windows and walls.

To obtain the amount of radiating surface required for a given room, and to compensate for heat lost by radiation from windows, doors and walls, Baldwin and J. H. Mills give the following rules:—Take the difference in temperature in degrees Fahrenheit between the lowest outside temperature to be provided for and the temperature at which the room is to be kept, and divide it by the difference in degrees Fahrenheit between the temperature of the pipes and the temperature at which the room is to be kept. Multiply the quotient thus obtained by the number of square feet of glass *plus* the number of square yards of external wall surface in the room, and the product will be the number of square feet of radiating surface required.

Example.—Suppose we have a room, containing 2000 cubic feet, with 36 square feet of window glass and 20 square feet of external wall surface, which has to be kept at 70° F. when the outside air is 10° below zero, the temperature of the radiating surface being 210° F. Then, $\frac{80}{140} \times 56 = 32$ square feet of radiating surface required.

This calculation does not provide for any leakage of air through crevices, or for any change of air by ventilation. To make allowance for this, we must make the additional calculation of multiplying the number of cubic feet of air per hour by the number of degrees Fahrenheit which they are to be heated and divide the product by 12,500. The quotient is the number of square feet of radiating surface required.

Example.—Let us suppose the same room as above, only that the air is to be changed three times an hour to provide for its constant occupancy by two persons, or 6000 cubic feet of air must be delivered hourly. Then, $\frac{6000 \times 80}{12,500} = 38{\cdot}4$, which, added to 32, gives in round numbers 70 square feet of radiating surface required.

The following table, from Hood, shows the length of 4-inch pipe at 200° F. necessary to warm 1000 cubic feet of air at varying internal and external temperatures. If the diameter of the pipe is increased in any ratio, the length required will be reduced in the same ratio: thus, 100 feet of 4-inch pipe can be replaced by $\frac{4}{3}$ of 100 feet = 133 feet of 3-inch pipe, and so on.

Temperature of External Air.	Temperature, in degrees Fahrenheit, at which the room is required to be kept.									
	45°.	50°.	55°.	60°.	65°.	70°.	75°.	80°.	85°.	90°.
10° Fahr.	126	150	174	200	229	259	292	328	367	409
12° ,,	119	142	166	192	220	251	283	318	357	399
14° ,,	112	135	159	184	212	242	274	309	347	388
16° ,,	105	127	151	176	204	233	265	300	337	378
18° ,,	98	120	143	168	195	225	256	290	328	368
20° ,,	91	112	135	160	187	216	247	281	318	358
22° ,,	83	105	128	152	179	207	238	271	308	347
24° ,,	76	97	120	144	170	199	229	262	298	337
26° ,,	69	90	112	136	162	190	220	253	288	327
28° ,,	61	82	104	128	154	181	211	243	279	317
30° ,,	54	75	97	120	145	173	202	234	269	307
32° ,,	47	67	89	112	137	164	193	225	259	296
34° ,,	40	60	81	104	129	155	184	215	249	286
36° ,,	32	52	73	96	120	147	175	206	239	276
38° ,,	25	45	66	88	112	138	166	196	230	266
40° ,,	18	37	58	80	104	129	157	187	220	255
42° ,,	10	30	50	72	95	121	148	178	210	245
44° ,,	3	22	42	64	87	112	139	168	200	235
46° ,,	...	15	34	56	79	103	130	159	190	225
48° ,,	...	7	27	48	70	95	121	150	181	214
50° ,,	...	...	19	40	62	86	112	140	171	204
52° ,,	...	...	11	32	54	77	103	131	161	194

To use the table, find in the first column the temperature of the outer air, and at the top of one of the other columns find the temperature at which the room is to be maintained: then in this latter column, and on the line which corresponds with the external temperature, the required number of feet of 4-inch pipe at 200° F. will be found which will heat 1000 cubic feet of air per minute.

If the high-pressure system is employed, the necessary area of pipe surface is very much reduced in consequence of the higher temperature which is reached. The length of pipe required can be usually found from the formula, $\frac{2{\cdot}252d(t' - t)}{\mathrm{D}(\mathrm{T} - t')} = \mathrm{L}$, in which d is the cubic feet of air to be warmed per minute, t' is the temperature to be obtained in the room, t is the temperature of the outer air, D is the external diameter of the pipe, and T the temperature of the pipes: L being the length of pipe required.

Artificial Cooling of Air.—Any consideration of the subject of ventilation would necessarily be incomplete, if reference were not made to methods for cooling the air, for although, in this country, the general problem of maintaining the air of an inhabited room at a temperature most suitable for its occupants involves the consideration of how to heat the air rather than to cool it, still there are countries and circumstances in which the question of reducing the air temperature is one of paramount importance.

The simplest method to adopt for preventing direct radiation of the sun from entering rooms is to shut doors and windows, and covering them with either blinds or louvre shutters. In countries, like India, where the outside air is often excessively dry, it can be cooled by being made to pass over wet surfaces of linen or *tatties* made of khus-khus grass. Some years ago, it was suggested by Jeffreys to supply cooled air to the hospital and barracks at Cawnpore by passing the air, before delivery into the rooms, through underground channels. This, though ingenious, is not a desirable method, as the air is likely to be fouled in its passage beneath the earth, unless very special precautions are taken to keep the channels dry and clean.

Owing to the development of a demand for artificial ice, and the supply of cold air in ships employed for the carriage of meat, a considerable impetus has been given of late years to the invention of machines and methods for artificial cooling. Practically, cold can be produced in one of three ways: namely (1) by the expansion of air; (2) by the expenditure of mechanical work in the evaporation of a liquid; (3) by the evaporation of a volatile liquid in one vessel, the vapour so formed being absorbed by water or some other liquid in another vessel connected with the first.

1. The remarkable changes of temperature produced by the rarefaction and condensation of air was pointed out in 1845 by Joule. The following table shows the effect of the dynamical cooling of air by reduction of pressure to 30 inches, from the pressure as stated in the first column, without allowing any heat to be communicated to it during expansion, the original temperature at 30 inches of pressure being 60° F. (Shaw).

Initial pressure of the air in inches of mercury.	Temperature after expansion.	Initial pressure of the air in inches of mercury.	Temperature after expansion.
31	55°·1 Fahr.	60	− 33°·9 Fahr.
32	50°·4 ,,	70	− 52°·4 ,,
33	45°·9 ,,	80	− 67°·7 ,,
34	41°·6 ,,	90	− 80°·8 ,,
35	37°·5 ,,	100	− 92°·1 ,,
40	18°·7 ,,	200	− 158°·5 ,,
50	− 11°·0 ,,	300	− 191°·6 ,,

Thus it will be seen that if a jet of air at 60° F. were blown into a room by a pressure behind it of 10 inches of mercury above the ordinary barometric pressure, so that the air would find itself in the room suddenly under the ordinary pressure of 30 inches, the temperature of that air would be 13°·3 F. below freezing, presuming that there is no gain of heat from friction at the nozzle. On this principle it is possible, by means of suitable arrangements of expansion cylinders, to furnish a supply of air cooled by expansion to a temperature considerably below that of the surrounding bodies. If the air were compressed instead of being rarefied, a corresponding rise of temperature would be produced. This principle of dynamical cooling has now been applied to the refrigeration chambers of ships conveying meat from the colonies, where, by first compressing the air in a suitable engine, it is then passed cooled to an expansion engine, which finally delivers the air cooled to an extent depending on the difference of its pressure in the compressed and uncompressed states. It is not improbable that in the near future, with a supply of compressed air at ordinary temperatures and by an expansion engine, every householder may not only get ice-cold air, but so produce ice if wanted. Its applicability to Indian life is obvious, where the use of refrigerating engines, as now employed on board ships for the meat refrigerating chambers, will probably gradually replace the crude and cumbrous thermantidote of the present day.

2. We know that water evaporates at all temperatures, and that the amount of evaporation really depends upon the pressure to which the surface is exposed. If, therefore, two vessels, each containing a volatile liquid, be in communication through an air-pump, and the pump be worked, any air or vapour in the one vessel will be gradually pumped out and delivered to the other. In other words, continuous evaporation will take place in one vessel, and continuous condensation in the other. As a result of evaporation, there is an absorption of heat from the one vessel, and, as a result of condensation, a development of heat in the other. If an arrangement be made for transferring the condensed liquid back to the evaporating vessel, the process may go on continuously. If heat is wanted, the cold vessel should be surrounded with an ample supply of water to keep up its temperature : if cooling be desired, the heat produced by the condensation may be allowed to pass into the outside air or a tank of water. The production of cold on this principle by the evaporation of methylic ether is now one of the methods of cooling ships employed in the carriage of meat. By the cooling apparatus, the meat is kept in a current of dry air very near the freezing point, and thus kept fresh during long voyages.

3. In Carré's ammonia machine for the production of ice, a solution of ammonia gas in water is placed in a vessel connected with a condenser. If the vessel is heated and the condenser be immersed in a cold-water tank, the ammonia is driven off from its solution, and, condensing to a liquid in the condenser, gives out heat in so doing to the surrounding water in the tank. If the vessel be now immersed in cold water, and the condenser be surrounded by the water it is required to freeze, the cooled water in the vessel reabsorbs the ammonia vapour and reduces the pressure in the condenser, accompanied by a large reduction of temperature in the liquid in it and in the water surrounding it. By a continuous repetition of the process, successive quantities of heat are removed from the water surrounding the condensed ammonia, until it actually freezes. By this method, ice can be made at a cost of only twopence per hundredweight.

As to the advantages and disadvantages of the various systems of heating and ventilating, no better summary can be given than that by the late Prof. Carnelley in his Report on the Cost and Efficiency of the Heating and Ventilation of Schools, made to the School Board of Dundee in 1889. The Report is a complete arrangement of the results of an investigation of 323 schools, and extracts from it are best quoted in their original form.

OPEN FIRES.

Advantages—

1. More cheerful.
2. First cost much less than hot-pipe systems.
3. Keeps air fresher than hot pipes, owing to draught up chimney.
4. So far as the Dundee schools are concerned, the temperature in the open-fire schools was higher than in those heated by hot pipes.
5. The rooms of these schools will probably need painting less frequently than those heated by other systems.

Disadvantages—

1. Greater labour in service.
2. Slightly greater annual cost than stoves, or steam-pipes, or large hot-water pipes.
3. Unequal distribution of heat.
4. Air more highly charged with micro-organisms.

STOVES.

Advantages—

1. Smallest first cost.
2. Least annual cost.
3. Probably more effective heaters than open fires.

Disadvantages—

1. Greater labour in service.
2. Require more attention than open fires.
3. More liable to smoke than open fires.
4. More liable to get out of repair than open fires.
5. Not so cheerful as open fires.

HOT PIPES.

Advantages—

1. Less labour in service than either open fires or stoves.
2. The class is not disturbed as in the case of the mending open fires and stoves.
3. More equal distribution of heat.
4. Air less charged with micro-organisms than when open fires are used.
5. On the whole the annual cost is probably slightly less than with open fires, but more than with stoves.

Disadvantages—

1. Not so cheerful as open fires.
2. First cost much more than in the case of open fires or stoves.
3. Air not so fresh as with open fires.

Of Hot-pipe Schools—

1. Small high-pressure pipes are cheaper in first cost than large low-pressure pipes.
2. In those schools examined, the air was better in rooms heated by small high-pressure pipes than in those heated by large low-pressure pipes.
3. It takes longer to get up heat with large than with small pipes.
4. Small pipes are less obtrusive in the rooms.

MECHANICAL VENTILATION.

Advantages—

1. Much greater purity of air as regards all the constituents.
2. Efficiency of ventilation much more independent of the weather; whereas with other systems the ventilation is worst when most needed.
3. The schools are warmer.
4. More equal distribution of heat and of fresh air.
5. Very effective in diminishing the number of micro-organisms, not only at the time the mechanical ventilation is in operation, but also for a long time after it has been stopped.
6. Reduces draughts to a minimum.

In fact, the mechanical system heats and ventilates far better in every respect than any other system, and is, therefore, far more conducive to health and comfort and to success in teaching and learning.

Disadvantages—

1. Greater first cost.
2. Greater annual cost (except in the case of very large schools).
3. Though in towns where several schools were heated and ventilated mechanically, there would not need to be more than an ordinary caretaker in each of such schools, yet *one* of these should be a man who had some knowledge of gas-engines, &c., so that he could attend to any repairs which might be necessary. Such a man would require a somewhat higher wage than an ordinary caretaker. This, however, would amount to very little if distributed over a number of schools.

In the same Report, as regards efficiency, the following summary is given :—

(*a*) *Radiation* v. *Conduction*.—With those systems in which the rooms are heated by radiation rather than by conduction, the air is much more highly charged with micro-organisms than with those systems in which the rooms are heated more by conduction than by radiation.

(*b*) *Manchester Grates* v. *Ordinary Grates*.—As regards open fires, "Manchester grates" are much more effective in keeping the air of the rooms pure than ordinary grates.

(*c*) *Mechanical* v. *the Ordinary Systems*.—Mechanical ventilation and heating is undoubtedly far more effective in maintaining the purity and temperature of the air in schools than any of the ordinary methods usually adopted, and is hence more conducive to health and comfort.

(*d*) *Gas-engines* v. *Water-engines*.—Gas-engines are much cheaper and more effective than water-engines for driving the fans.

(*e*) *Power of Gas-engine required*.—A 2 H.P. gas-engine is amply sufficient for driving 4-ft. Blackman fan ; while a 1 H.P. is sufficient for six of Cunningham's fans.

(*f*) *Blowing in* v. *Exhausting the Air*.—The former is preferable.

(*g*) *Inlet Shafts*.—One large fresh-air inlet shaft is much better than several small ones, and the entrance to the shaft should be as free as possible.

(*h*) *Air Filters*.—These are best employed, made of coarse jute cloth, to remove soot and dirt.

(*i*) *Blackman's* v. *Cunningham's Fans*.—When *properly arranged*, a 4-ft. Blackman fan appears to be more effective, and costs less, both in first and annual cost, than the five or six Cunningham's fans usually employed to do the same work. Cunningham's fans are, however, more independent of the weather than are Blackman's or Aland's fans.

(*j*) *Blackman's* v. *Aland's Fans*.—The former are the better and more suitable.

(*k*) *Otto* v. *Stockport Gas-engines*.—The former are the preferable.

(*l*) *Time required to change the Air of a School by Mechanical Ventilation*.—By mechanical ventilation the whole of the air in a school may be easily changed in less than fifteen minutes, and when the system is well arranged in less than ten minutes.

EXAMINATION OF THE SUFFICIENCY OF VENTILATION.

The sufficiency of ventilation should be examined—

1*st*, By determining the amount of cubic space and floor space assigned to each person, and their relation to each other, and by determining the amount of movement of the air, or, in other words, the number of cubic feet of fresh air which each person receives per hour.

2*nd*, By examining the air by the senses, and by chemical, biological, and mechanical methods, so as to determine the presence, and, if possible, the amounts and characters of suspended matters, including micro-organisms, organic vapour, carbon dioxide, hydrogen sulphide, watery vapour, ammonia, &c., as already explained in the previous chapter.

Measurement of Cubic Space.—The three dimensions of length, breadth, and height are simply multiplied into each other. If a room is square or oblong, with a flat ceiling, there is, of course, no difficulty in doing this, but frequently rooms are of irregular form, with angles, projections, half-circles, or segments of circles. In such cases the rules for the measurement of the areas of circles, segments, triangles, &c., must be used. By means of these, and by dividing the room into several parts, as it were, so as to measure first one and then another, no difficulty will be felt. After the room has been measured, recesses containing air should be measured, and added to the amount of cubic space; and, on the other hand, solid projections, and solid masses of furniture, cupboards, &c., must be measured, and their cubic contents (which take the place of air) deducted from the cubic space already determined. The bedding also occupies a certain amount of space; a soldier's hospital mattress, pillow, three blankets, one coverlet, and two sheets will occupy almost 10 cubic feet—about 7 if tightly rolled up. It is seldom necessary to make any deduction for tables, chairs, and iron bedsteads, or small boxes, or to reduce the temperature of the air to standard temperature, as is sometimes done.

A deduction may be made, however, for the bodies of persons living in the room; a man of ordinary size may take the place of about $2\frac{1}{4}$ to 4 cubic feet of air (say 3 for the average). The weight of a man in stones, divided by 4, gives the cubic feet he occupies. Thus a man weighing 12 stones occupies 3 cubic feet.

In linear measurement, it is always convenient to measure in feet and decimals of a foot, and not in feet and inches. If square inches are measured, they may be turned into square feet by multiplying by 0·007

RULES—*Area or Superficies.*

Area of circle, $= D^2 \times \cdot 7854$ (or πr^2, where r is the radius).

,, ,, $= C^2 \times \cdot 0796 \left(\text{or } \frac{C^2}{4\pi}\right)$.

Circumference of circle, $= D \times 3\cdot 1416$ $(\pi 2r)$.

Diameter of circle, $= C \div 3\cdot 1416 \left(= \frac{C}{\pi}\right)$ or $C = \times \cdot 3183$.

Area of ellipse, = Multiply the product of the two diameters by ·7854 $\left(\frac{\pi l s}{4}\right)$.

Circumference of ellipse, = Multiply half sum of the two diameters by 3·1416 $\left\{\pi \frac{l+s}{2}\right\}$.

Area of a square, = Square one of the sides, or multiply any two sides into each other.

Area of a rectangle, = Multiply two sides perpendicular to each other.

Area of a triangle, = Base $\times \frac{1}{2}$ height, or Height $\times \frac{1}{2}$ base.

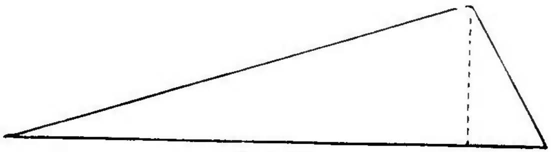


Fig. 31.

Area of a parallelogram, = Divide into two triangles by a diagonal, and take sum of the areas of the two triangles.

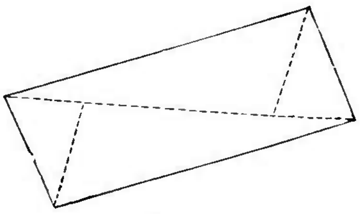


Fig. 32.

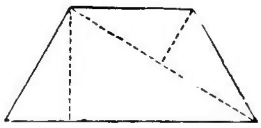


Fig. 33.

Any figure bounded by right lines, = Divide into triangles, and take the sum of their areas.

Area of segment of circle, = To $\frac{2}{3}$ of product of chord and height add the cube of the height divided by twice the chord

$$(Ch \times H \times \tfrac{2}{3}) + \frac{H^3}{2Ch}.$$

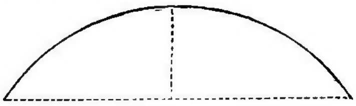


Fig. 34.

Cubic Capacity of a Cube or a Solid Rectangle.—Multiply together the three dimensions, length, breadth, and height.

Cubic Capacity of a Solid Triangle.—Area of section (triangle) multiplied by depth.

Cubic Capacity of a Cone or Pyramid.—Area of base × $\frac{1}{3}$ height.

Cubic Capacity of a Dome.—Two-thirds of the product of the area of the base multiplied by the height (area of base × height × $\frac{2}{3}$).

Cubic Capacity of a Cylinder.—Area of base × height.

Cubic Capacity of a Sphere.—$D^3 \times \cdot 5236 \left(\text{or } \frac{4\pi r^3}{3}\right)$.

The cubic capacity of a bell-tent may be taken as that of a cone resting on a short cylinder.

The cubic capacity of an hospital marquee must be got by dividing the marquee into several parts—1*st*, body; and, 2*nd*, roof:—

1. Body, as a solid rectangle, with a half cylinder at each end.
2. Roof, solid triangle, and two half cones.

The total number of cubic feet, with additions and deductions all made, must then be divided by the number of persons living in the room; the result is the cubic space per head; whilst the total area of floor space divided by the number of persons gives the floor space per head, which should be as near as possible $\frac{1}{12}$ of the cubic space.

Determination of Air Movement in a Room.—The direction must first be determined, and then the rate of movement.

First enumerate the various openings in the room—doors, windows, chimney, special openings, and tubes—and consider which is likely to be the direction of movement, and whether there is a possibility of thorough movement of the air. Then, if it is not necessary to consider further any movement through open doors or windows, close all these, and examine the movements through the other openings. This is best done by smoke disengaged from smouldering cotton-velvet, and less perfectly by small balloons, light pieces of paper, feathers, &c. The flame of a candle, which is often used, is only moved by strong currents. It may be generally taken for granted that one half of the openings in a room will admit fresh air, and half will be outlets. But this is not invariable, as a strong outlet, like a chimney, may draw air through an inlet of far greater area than itself, or may draw it through a much smaller area with an increased rapidity.

The direction being known, it is only necessary to measure the discharge through the outlets, as a corresponding quantity of fresh air must enter.

By the Anemometer.—This is best done by an anemometer, or air-meter, of which there are several in the market. The one commonly used is in principle that invented by Combes in 1838: four little sails, driven by the moving air, turn an axis with an endless screw, which itself turns some small toothed wheels, which indicate the number of revolutions of the axis, and consequently the space traversed by the sails in a given time, say one minute. By a careful graduation of each instrument, the rate per second is determined, and indicated by a small dial and index. A very beautiful instrument of this kind has been made by Casella of Holborn (fig. 35). It is thus used:—Being set at the zero point, or the reading of the instrument at the time being recorded, it is placed in the current of the air: if it is placed in a tube or shaft, it should be put well in, but not quite in the centre, as the central velocity is always greater than that of the side; a point about two-fifths from the sides of the tube will give the mean velocity. The time when the sails begin to move is accurately noted, and then, after a given time, the instrument is removed, and the movement in the time noted is given by the dial. If this linear discharge is multiplied by the section area of the tube or opening (expressed in feet or decimals of a foot), the cubic discharge is obtained. If the current varies in intensity, the movement should be taken several times, and the mean calculated; but if the tube is so small that the sails approach closely to the circumference, the results cannot be depended on. If placed at the mouth of a tube, it often indicates a much feebler current than really exists in the tube.

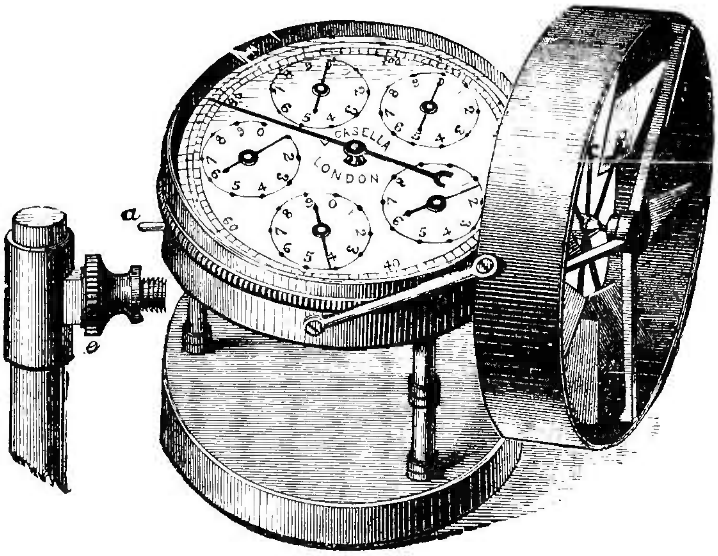


Fig. 35.

The cubic discharge per minute being known, the amount per hour is obtained by multiplying by 60, and this divided by the number of persons in the room, gives the discharge per head for that particular aperture.

By the Manometer.—Sanderson has made an ingenious alteration of a manometer described by Péclet, which can also be employed to measure the pressure, and, by calculation, the velocity, of the air. The current of air is allowed to impinge on a surface of water, and the height to which the water is driven up a tube of known inclination and size gives at once a measure of force. But, as necessitating a little calculation, this instrument is less useful than the anemometer, though it is adapted for cases where the anemometer cannot be used, as it may be connected by a long tube with a distant room, and probably would be well fitted to measure constantly the velocity in an extraction shaft. The velocity of the air-current is conveniently calculated by the following formula: $v = 3{\cdot}784\sqrt{\frac{w}{s}}$, in which w is expressed in millimetres of water as read off on the manometer, while s is the specific gravity of 1 litre of air at the existing temperature and height of the barometer.

By Calculation.—Supposing the external air is tranquil, and that the only cause of movement is the unequal weights of the external colder and the internal warmer air, the amount of discharge may be approximately obtained by the law of Montgolfier, already given. There is a fallacy, however, as the amount of friction can never be precisely known. Still, as an approximation, and in the absence of an anemometer, the rule is useful; and the following table has therefore been calculated.

On testing this table, however, by the air-meter, it has been found to give too much when the tubes are long, on account of the great friction, and it is therefore advisable to make a further deduction of $\frac{1}{6}$th when the shaft or tube is long, and is at the same time of small diameter. If the tube have any angles, or is curved, this table is too imperfect to be used, unless attention be paid to the correction for friction already noted.

If the movement of the external air influences the movement in the room, as when the wind blows through openings, calculation is useless, and the anemometer only can be depended on.

TABLE *to show the Velocity of Air in linear feet per minute. Calculated from Montgolfier's formula; the expansion of air being taken as* 0·002 *for each degree Fahrenheit, and one-fourth being deducted for friction.* (*Round numbers have been taken.*)

Height of column.	DIFFERENCE BETWEEN INTERNAL AND EXTERNAL TEMPERATURE.																						
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**30**
10	88	102	114	125	135	144	153	161	169	176	183	190	197	204	210	216	222	228	233	239	244	249	254	279
11	92	107	119	131	141	151	160	169	177	185	192	200	207	213	220	226	233	239	245	250	256	261	267	292
12	96	111	125	136	147	158	167	176	185	193	201	209	216	223	230	237	243	249	255	261	267	273	279	305
13	100	116	130	140	153	164	174	183	192	201	209	217	225	232	239	246	253	259	266	272	278	284	290	318
14	104	120	135	147	159	170	181	190	200	209	217	225	233	241	248	255	262	269	276	282	289	295	301	330
15	108	125	139	153	165	176	187	197	207	216	225	233	241	249	257	264	272	279	286	292	299	305	312	341
16	111	129	144	158	170	182	193	204	213	223	232	241	249	257	265	273	281	288	295	302	309	315	322	353
17	115	133	148	162	176	188	199	210	220	230	239	248	257	265	274	282	289	297	304	311	318	325	332	363
18	118	136	153	167	181	193	205	216	226	237	246	255	264	274	282	290	298	305	313	320	327	335	342	374
19	121	140	157	172	186	198	210	222	233	243	253	262	272	281	289	298	306	314	321	329	336	344	351	384
20	125	144	161	176	190	204	216	228	239	249	259	269	279	288	297	305	314	322	330	338	345	353	360	394
21	128	147	165	181	195	209	221	233	245	255	266	276	286	295	304	313	321	330	338	346	354	361	369	404
22	131	151	169	185	200	214	226	239	250	261	272	282	292	302	311	320	329	338	346	354	362	370	378	414
23	134	154	173	189	204	218	232	244	256	267	278	289	299	309	318	327	336	345	354	362	370	378	386	423
24	136	158	176	193	209	223	237	249	261	273	284	295	305	315	325	335	344	353	361	370	378	386	394	432
25	139	161	180	197	213	227	241	254	267	279	290	301	312	322	332	342	351	360	369	378	386	394	402	441
26	142	164	183	201	217	232	246	259	272	284	296	307	318	328	338	348	358	367	376	385	394	402	410	450
27	145	167	187	205	221	237	251	264	277	290	302	313	324	335	345	355	365	374	383	392	401	410	418	458
28	147	170	190	209	225	241	255	269	282	295	307	319	330	341	351	361	371	381	390	399	408	417	426	467
29	150	173	194	212	229	245	260	274	287	300	312	324	335	347	357	368	378	388	397	407	416	425	433	475
30	153	176	197	216	233	249	264	279	292	305	318	330	341	353	363	374	384	394	404	414	423	432	441	483
31	155	179	200	219	237	253	269	283	297	310	323	335	347	358	369	380	391	401	411	420	430	439	448	491
32	158	182	204	223	241	257	273	288	302	315	328	341	353	364	375	386	397	407	417	427	437	446	455	499
33	160	185	207	226	245	261	277	292	307	320	333	346	358	370	381	392	403	414	424	434	443	453	462	506
34	162	188	210	230	248	265	282	297	311	325	338	351	363	375	387	398	409	420	430	440	450	460	469	514
35	165	190	213	233	252	269	286	301	316	330	343	356	369	381	393	404	415	426	436	447	457	467	476	522
36	167	193	216	236	255	273	290	305	320	334	348	361	374	386	398	410	421	432	442	453	463	473	483	529
37	170	196	219	240	259	277	294	310	325	339	353	366	379	392	404	415	427	438	448	459	470	480	490	536
38	172	198	222	243	262	281	298	314	329	344	358	371	384	397	409	421	432	444	454	465	476	486	496	543
39	174	201	225	246	266	284	302	318	333	348	362	376	389	402	414	426	438	450	461	471	482	492	503	551
40	176	204	228	249	269	288	305	322	338	353	367	381	394	407	420	432	444	455	467	477	488	499	509	558
45	187	216	241	264	286	305	324	341	358	374	389	404	418	432	445	458	471	483	495	506	518	529	540	591
50	197	228	254	279	301	322	341	360	377	394	401	426	441	455	469	483	496	509	522	534	546	558	569	623
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**30**

Example.—To use the table, determine the height of the warm column of air from the point of entrance to the point of discharge. Ascertain the difference between its temperature and that of the external air. Take out number from table, and multiply by the section-area of the discharge-tube or opening, in feet or decimals of a foot. The result is the discharge in cubic feet per minute, multiply by 60—result, discharge per hour. Height of column, 32 feet; difference of temperature between internal and external air, 17 deg. Looking in the table, we find opposite to 32 and under 17, 375 feet. That would be for an area of 1 square foot.

But supposing our air opening to be only ¾ of a foot, we must multiply 375 by ¾—thus, 375 × ·75 = 281·25. Therefore we get 281·25 feet (per minute), multiplied by 60 = 16,875 feet per hour.

It is obvious that, in the preceding methods, all windows and doors opening into the room must be closed, and only those openings intended for the passage of air be allowed to remain open.

Example.—Presume a room is measured and found to contain 1500 cubic feet of air. The observations made have shown that the total outlets measure a square foot and that the average velocity of the outgoing air-current is 80 feet per minute. This shows that 4800 cubic feet of air are passing through the outlets per hour, and the capacity of the room being 1500 cubic feet, this volume of air is being completely renewed a trifle more than three times an hour.

A very ingenious method for determining the entire exchange of air going on, including not only the amount passing in and out through ventilators, but also that escaping through cracks and fissures, has been suggested by Pettenkofer. It is based upon the fact that if in a closed room we have any easily recognised gas such as CO_2, the amount of fresh air entering the room in a given time may be determined by the dilution which this gas undergoes in the time. This plan is very suitable for testing systems of so-called natural ventilation. Pettenkofer closes all openings into the room, and then artificially generates an excessive amount of CO_2 in the air of the room by burning stearine candles. These candles burn about 9·5 grammes per hour, each gramme yielding 1·404 litre of CO_2. When the experiment is begun the air of the room should contain 5 or 6 parts of this gas per 1000, the exact amount being determined and recorded. The doors and windows are kept closed, and samples of the air taken from about the centre of the room at intervals of half an hour for one hour after the ventilators are opened. To avoid grave errors, due to opening doors and the exhalation of CO_2 by the breath, it is better to arrange, by means of an aspirator and a tube passed through the keyhole, or other small opening, for samples to be taken without opening the door. When the necessary number of samples have been collected and examined, as explained in the last chapter, the calculation of the rate at which ventilation has been going on is made from the following formula by Seidel:—

$$x = 2{\cdot}303 \times m \times \log \frac{p - a}{P - a},$$

in which x is the amount of air which has passed into the room, 2·303 is a constant, m is the cubic contents of the room in feet, p is the amount of CO_2 present in the air of the room at the beginning of the experiments, of which there are practically two, namely, one for the first half hour and one for the second, P is the amount of CO_2 present at the end of each experiment, and a is the amount of CO_2 present in the outer air.

Example.—Presume that, the cubical contents of the room being 2000 feet, by the analytical method already explained, the amount of CO_2 has been found to be as follows:—At the beginning, 3·6 per 1000; after 30 minutes, 3·2 per 1000; after 60 minutes, 2·8 per 1000, and in the open air, 0·4 per 1000.

For the first half hour we get, $x = 2{\cdot}303 \times 2000 \times \log \frac{3{\cdot}6 - 0{\cdot}4}{3{\cdot}2 - 0{\cdot}4}$, or $x = 2{\cdot}303 \times 2000 \times 0{\cdot}0579742 = 267$ cubic feet of air passed in during first half hour. And for the second half hour, $x = 2{\cdot}303 \times 2000 \times \log \frac{3{\cdot}2 - 0{\cdot}4}{2{\cdot}8 - 0{\cdot}4}$, or $x = 2{\cdot}303 \times 2000 \times 0{\cdot}0669220 = 308$ cubic feet of air passed in during second half hour. Therefore, for the entire hour, we have $267 + 308 = 575$ cubic feet of air passing into a room of 2000 cubic feet capacity. At this rate, the entire volume of air in the room would require 3·4 hours for its complete removal, a rate of ventilation which we have learnt to be quite inadequate.

When this method is used for determining the amount of ventilation of rooms provided with inlets, provision must be made for closing them from without, in order to obviate inaccuracies likely to result if doors be opened.

To make any ventilation inquiry complete, supplementary observations would need to be made, not only as to the CO_2, but also as regards oxidisable and organic matter, as well as to humidity, temperature, suspended matter, micro-organisms, and the various other details mentioned when considering the practical examination of air. When these final analyses have been made, the amount of air per head per hour, supplied and utilised, can be readily calculated as before explained, and compared with the amount of movement determined by the anemometer. If the quantities accord fairly, the distribution may be considered good: on the other hand, if they differ, an excess by the air-meter shows bad distribution, whilst a deficiency indicates some other source of incoming air not yet observed.

BIBLIOGRAPHY AND REFERENCES.

Anderson, "On Emission of Heat by Hot-water Pipes," *Proc. Inst. C.E.*, xlviii. p. 257. Arnott, *On the Smokeless Fireplace*, Lond., 1855. Atkinson, *Pract. Treat. on the Gases of Coal Mines, and the General Principles of Ventilation*, Lond., 1889.

Baldwin, "Hot-water Heating and Fitting," *New York Engineering Record*, 1889. Billings, *Ventilation and Heating*, New York, 1893. Box, *A Practical Treatise on Heat*, 7th edit., New York, 1891. Briggs, "On the Ventilation of Halls of Audience," *Trans. Amer. Soc. C.E.*, vol. x., 1881, p. 53.

Carelle and Herscher, *Traité de physique industrielle, production et utilisation de la chaleur*, Paris, 1892. Carnelley, *Report on the Ventilation and Heating of Schools to the School Board of Dundee*, 1889; also *Proc. Roy. Soc. Lond.*, 1887. Coleman, "On Air-refrigerating Machinery," *Proc. Instit. C.E.*, vol. lxviii. p. 146.

Damman, *Die Gesundheitspflege landwirtschaftlicher Haussängetiere*, Berlin, 1892. Daniel, "On Mechanical Ventilation," *Proc. Instit. Mech. Engin.*, 1875, p. 317. De Chaumont, "On Ventilation and Cubic Space," *Lancet*, Sept. 1866; also *Edin. Med. Journ.*, May 1867; also "On the Theory of Ventilation," *Proc. Roy. Soc. Lond.*, No. 168, p. 187, 1875, and No. 171, 1876; also *Lectures on State Medicine*, Lond., 1875; also *Three Reports on the Sanitary Condition of St Mary's Hosp.*, *Lond.*, 1875–6; also various Reports in *Army Med. Dep. Reports*, vols. vi. to x. Degen, *Prac. Handbuch f. Einrichtungen der Ventilation u. Heizung in Öffentlichen u. Privatgebäuden nach dem System der Aspiration*, München, 1878. Deville and Troost, "On the Escape of Carbon Monoxide from Stoves," *Comptes Rendus de l'Acad. Franc.*, Jan. 1868. Donkin, *Report of Committee appointed to consider the Cubic Space of Metropolitan Workhouses*, Blue Book, 1867.

Eassie, *Sanitary Arrangements for Dwellings*, Lond., 1874.

Galton, Sir D., *Healthy Dwellings*, Clarendon Press, 1880.

Haller, *Die Lüftung und Erwärmung der Kinderstube u. des Krankenzimmers*, Berlin, 1860. Hawksley, *Proc. Instit. C.E.*, vol. vi. p. 192. Hood, *Treatise on Warming and Ventilation*, Lond., 1869.

Kennedy, "On the Employment of Compressed Air for the Production of Cold," *Proc. Brit. Assoc.*, 1889, p. 448; also in *Engineering*, Sept. 13, 1889.

Leeds, *A Treatise on Ventilation*, New York, 1871.

Märcker, *Untersuch. u. nat. u. Künstliche Ventilation*, Göttingen, 1871. Mills, J. H., *On the Production and Application of Heat to the Warming and Ventilation of Buildings*, Boston, U.S.A., 1890. Mills and Rowan, *Fuel and its Application*, London, 1889. Morin, *Rapport sur la Chauffage et la Ventilation des Batiments du Palais de Justice*, Paris, 1860; also *Etudes sur la Ventilation*, Paris, 1863; also *Manuel Pratique du Chauffage et de la Ventilation*, Paris, 1874. Morrison, "On the Ventilation of Tunnels," *Proc. Instit. C.E.*, 1876. Murgue, *Theories and Practice of Centrifugal Machines*, translated by Steavenson, London, E. & F. Spon, Charing Cross, 1883.

Péclet, *Traité de la Chaleur*, 3me edit., Paris, 1861. Pettenkofer, *Uber den Luftwechsel in Wohnegebäuden*, München, 1858. Planat, *Cours de Construction civile*, Premiere partie: "Chauffage et Ventilation des lieux habités," Paris, 1880. Putnam, *The Open Fireplace in all Ages*, Boston, U.S.A., 1881. Putzeys, *Hygiène des agglomerations militaires, et la construction des Casernes*, Liège, 1892.

Ramsay, *Treatise on Ventilating and Working Collieries*, Lond., 1882. Rankine, *The Steam-Engine*, London, 1873. Reid, *Illustrations of the Theory and Practice of Ven-*

tilation, Lond., 1844. Reiset, "Upon the Physiology of Respiration in Animals," in Hoppe Seyler's *Physiolog. Chemie*, Bd. ii. s. 536, Berlin, 1879. Reports—Of Committee appointed to inquire into the Cubic Space of Metrop. Workhouses, 1867; also Report of Barrack and Hospital Improvement Committee upon Ventilation of Cavalry Stables, 1866; also Reports upon the Ventilation of the Houses of Parliament, 1832, 1835, 1837, 1841, 1843, 1846, 1847, 1848, 1852, 1854, 1866, 1884, 1886; Reports of Metropol. Board of Works on the Ventilation of Sewers, 1866–1868–1873; Report of Parliamentary Committee on the Ventilation of Mines, 1850; Report of Parliamentary Commiss. on the Warming and Ventilation of Dwellings, 1857; also Report of Commission appointed to inquire into the Condition of all Mines in Great Britain, Lond., 1864; Report of Commissioners of Patents on the Specifications relating to Ventilation, A.D. 1632 to 1866, Lond., 1872. Richard, "Sur la toxicité de l'air expiré," *Rev. d'Hyg.*, 1889, xi. p. 338. Ritchie, *Treatise on Ventilation*, London, 1862.

Shaw, *Proc. Roy. Soc. Lond.*, March 1890; also article on "Ventilation and Heating" in Stevenson and Murphy's *Treatise on Hygiene*, Lond., 1892. Smith, F., *Veterinary Hygiene*, Lond., 1887; also in *Journ. Physiol.*, vol. xi., 1890.

Thompson, Sir W., "On Heat" in *Ency. Brit.*, 9th edit.

Wilson, *Treatise on Practical and Theoretical Mine Ventilation*, New York, 1891. Wolpert, *Theorie und Praxis der Ventilation und Heizung*, Braunschweig, 1880.

CHAPTER IV

FOOD.

In the widest acceptation of the term, Food includes everything ingested, which goes directly or indirectly to the growth or repair of the body or to the production of energy in any form. In this way it would include not only those organic and mineral solids and the usual beverages recognised as dietetic, but also water and air. For it is quite obvious that without water no function of the living body would be possible, whilst the production of energy is mainly, if not entirely, caused by the union of the atmospheric oxygen with the organic matter of the food or the tissues of the body itself. Although these facts are distinctly recognised, it has generally been the practice to restrict the term "food" to those substances which are capable of oxidation and those which act as directors or regulators of nutrition, to the exclusion of air and water,—these two last being usually considered under separate heads. No one group even of this rough classification is capable of sustaining healthy life alone, and a combination of all, or nearly all, the different constituents of diet is required to accomplish the best results. It is also necessary to limit the application, "food," so as to exclude generally medicines and poisons, which, on the one hand, either act or are intended to act upon processes of unhealthy nutrition, or, on the other hand, prevent the processes of healthy nutrition, and so induce unhealthy nutrition and ultimately dissolution. Even here the line cannot be too strictly drawn, for in many cases it is a question more of quantity than kind that determines the direction of the action.

The enumeration and classification of the foods or aliments necessary to maintain human life in its most perfect state have been usually based on the deduction of Prout that milk contains all the necessary aliments and in the best form. The substances in milk are—1st, the nitrogenous matters, viz., the casein principally, and, in smaller quantities, albumin, lacto-protein, and perhaps other proteid bodies; 2nd, the fat and oil; 3rd, sugar in the form of lactose; 4th, water and salts, the latter being especially combinations of magnesium, calcium, potassium, sodium, and iron, with chlorine, phosphoric acid, and, in smaller quantities, sulphuric acid.

In addition to their occurrence in milk, which is admitted to be a perfect food for the young, this enumeration of aliments appears to be justified by two considerations. First, that the different members of each class, *inter se*, have a remarkably similar composition, while there are broad lines of physical and chemical demarcation between the classes; and secondly, that the different classes appear to serve different purposes in nutrition, and are all necessary for perfect health.

The various substances which constitute food are conveniently spoken of as *proximate principles*, because, consisting as they do of carbon, hydrogen, oxygen and nitrogen, combined more or less into highly complex bodies, they really are elementary constituents or proximate principles of the human organism. These elementary or proximate principles may be conveniently classified as follows :—

Organic,	Nitrogenous, as proteids or albuminoids.	
	Non-nitrogenous,	Fats or hydrocarbons. Starches and sugars or carbo-hydrates. Vegetable acids.
Inorganic, .	Mineral salts.	
Food accessories,	Such as tea, coffee, &c.	

It must be noted that the simplest division of the organic constituents of food is into the nitrogenous and the non-nitrogenous, or those which contain nitrogen and those which do not. Now, the proteids alone contain nitrogen. Just as the greater part of the air is made up of nitrogen, so is the greater part of our body (bone excepted) made up of proteid, or nitrogen containing substances. A large amount of nitrogen in the form of urea, uric acid, and other substances, is daily being lost from our bodies by the urine; and to repair this loss, a daily intake of nitrogenous food is required. The only form of nitrogen food which the body can make use of is that of proteid or albuminoids. A plant equally needs nitrogen, but this it obtains from the ammonia and nitrates of the soil, which are much simpler bodies than proteids.

Proteids may be regarded as the most important food-stuffs, as they are the only organic food-substances of which it can be said with certainty that they are indispensable, and that they cannot be replaced by any other nutrient material. They are to be found in every animal and vegetable tissue, forming the chief part of every cell, and are never absent from any vegetable or animal food.

All proteids resemble each other in being composed, in similar weight proportions, of carbon, hydrogen, oxygen, nitrogen, and sulphur, with occasionally a little phosphorus. Their general percentage composition may be taken as being: nitrogen, 16 parts; carbon, 54 parts; oxygen, 22 parts; hydrogen, 7 parts; and sulphur, 1 part. The chemical constitution of proteids is not known, but the nitrogen seems to exist in two distinct conditions, partly loosely combined, so as to yield ammonia when they are decomposed, and partly in a more fixed condition. The proteid molecule is not only very large, but also very complex: a small part of it is composed of substances from the group of aromatic bodies, which become so conspicuous during putrefaction, while a larger part belongs to the fatty bodies, as during the oxidation of albumin, fatty acids are especially developed. Carbo-hydrates may also appear as decomposition products. In the alimentary canal, proteids are changed into peptones, while the chief products derived from their oxidation within the body are CO_2, H_2O, and urea, which latter contains nearly all the nitrogen of the proteids.

The chief character of proteids is that they are colloids, and, therefore, do not diffuse easily through animal membranes: they are also amorphous and do not crystallise, hence are isolated with difficulty. Some are soluble, others are insoluble in water: they are insoluble in alcohol and ether, rotate polarised light to the left, and when burned give off an odour of burned horn. They are precipitated from their solution by various metallic salts and alcohol; they are coagulated by heat, mineral acids, and the prolonged action of alcohol. Caustic alkalies dissolve them, and from this solution they are precipitated by acids.

Chemically, the proteids can be recognised by the following reactions:—

1. When heated with strong nitric acid, they give a yellow colour, which, on the subsequent addition of ammonia, turns a deep orange. This is the so-called xantho-proteic reaction.

2. With nitrate of mercury, they give a precipitate, and when heated with this reagent above 60° C. they give a red one, probably owing to the formation of tyrosin.

3. The addition of a few drops of a dilute solution of cupric sulphate, and the subsequent addition of caustic potash, gives a violet colour which deepens on boiling. The same colour is obtained by adding a few drops of Fehling's solution, the so-called biuret-reaction.

4. When rendered strongly acid with acetic acid and boiled with an equal volume of a concentrated solution of sodic sulphate they are precipitated. This method is used for removing proteids from other liquids, as it does not interfere with the presence of other substances.

Saturation with sodio-magnesic sulphate precipitates the proteids but not peptones, and the same is the case if saturated with neutral ammonium sulphate.

The proteids, when regarded as foods, are divisible into two great groups, according to their nutritive value. The more nutritious one is the group of true proteids, consisting of albumin, myosin, glutin, legumin, casein, globulin, syntonin, fibrin, and peptones : in them the proportion of nitrogen to carbon is nearly as 2 is to 7. The other, or less nutritious class is sometimes called the albuminoid group : its members include substances obtained only from animals, such as gelatin, chondrin, ossein, and keratin : in these latter, the proportion of nitrogen to carbon is as 2 is to $5\frac{1}{2}$.

The first group of proteid foods is the most important: it may be divided into:—*Native albumins*, such as serum albumin and egg albumin. They are soluble in water, and are not precipitated by alkaline carbonates, common salt, or by very dilute acids. Their solutions are coagulated by heating at 65° to 73° C.

Globulins.—The myosin of muscle, the globulin of the serum and of the blood, and the vitellin of egg-yolk are examples from the animal kingdom, while from the vegetable world are the globulins contained in the cereals and leguminosæ. These native proteids are insoluble in distilled water, but soluble in dilute neutral saline solutions, such as NaCl, KCl, NH_4Cl, and $MgSO_4$. These solutions are coagulated by heat and precipitated by the addition of a large quantity of water.

Derived Albumins.—Syntonin or acid albumin and alkali albumin formed by the action of dilute acids and alkalies on ordinary proteids. Closely allied to alkali albumin is casein, or the chief proteid in milk and the legumin and conglutin of peas, beans, &c. None of these proteids are coagulated by heat, but can be precipitated from solution by sodic chloride, acetate or phosphate or by neutralisation by alkalies and acids respectively.

Insoluble Proteids.—That is, those insoluble in water and in saline solutions at ordinary temperatures, such for instance as the fibrin of blood and the glutin of wheat.

Albumoses and Peptones.—The former are found largely in the cereals, and are probably very widely distributed in the vegetable kingdom. In the animal kingdom they are merely bodies formed by the action of pepsin upon ordinary proteids, the albumoses being precursors of the peptones. The latter are remarkable for their extreme diffusibility and ready absorption by the alimentary canal. Owing to the easiness of their digestion, these forms of proteid are now largely given in the various kinds of partly artificially digested foods for the sick, though it must be remembered that they do not possess the same nutritive value as the real proteids of food.

The second group of the proteid foods is sometimes called the *albuminoids*. The substances contained in this group closely resemble true proteids in their origin and composition, and are amorphous non-crystalline colloids. Though some of them do not contain sulphur, their reactions and decomposition products closely resemble those of the proteids. The chief members of this group are gelatin, mucin, chondrin, ossein, keratin, and nuclein. These bodies are easily dissolved in hot water, and yield more or less the same products after digestion as the true proteids, but appear, on the whole, to have a less nutritive value than them. Gelatin is the only important member of this group; it contains a larger percentage of nitrogen than the ordinary proteids, namely, from 17 to 18 per cent., and differs also in some chemical reactions, as well as not yielding tyrosin on decomposition.

Fats or Hydrocarbons.—These are combinations of a trivalent alcohol, glycerin, with three molecules of monobasic acids, principally stearic acid, palmitic acid, and oleic acid. They all contain hydrogen and oxygen, but no nitrogen, and may be represented by the general formula $C_{10}H_{18}O$. The proportion of oxygen in them, however, is insufficient to combine with all the hydrogen present so as to form water. When taken as food, the fats are chiefly in the form of neutral fat, but may also exist in the form of fatty acids and of their compounds, the alkaline soaps. The neutral fat taken as food always contains free fatty acids in greater or less proportion, and in some foods, such as cheese, the fatty acids may exist in large proportions indeed.

Carbo-hydrates occur in plants and animals, and are so-called because, in addition to at least six atoms of carbon, they contain hydrogen and oxygen in the proportion in which these occur in water. They are all solid, chemically indifferent, and without odour. They have either a sweet taste (sugars) or can be readily changed into sugars by the action of dilute acids; they rotate the ray of polarised light either to the right or left, and, as far as their chemical constitution is concerned, may be regarded as hexatomic alcohols in which two atoms of hydrogen are wanting. Until recent times the true chemical nature of these bodies was not understood, but the researches of E. Fischer have shown that the simplest carbo-hydrates (the old grape-sugars or glucoses) are aldehydes or ketones of a hexatomic alcohol, having the formula $C_6H_8(OH)_6$. Just as during the oxidation of ordinary alcohol, C_2H_6O, the aldehyde C_2H_4O is formed, so from mannitic alcohol the molecule $C_6H_{12}O_6$, representing the simplest carbo-hydrate, is produced. Such carbo-hydrates are spoken of as *Monosaccharids*, and the best known are glucose, lævulose, and galactose.

These monosaccharid molecules may link together (polymerise) with the loss of water. When two such molecules thus unite, *Disaccharids* are produced, and these really split to yield their constituent monosaccharids. The most important of these are maltose, formed from two molecules of dextrose, and cane-sugar, formed from a molecule of dextrose connected to a molecule of lævulose, and milk-sugar or lactose, in which dextrose and galactose are linked together.

Further combination (polymerisation) and dehydration produces a set of bodies having molecules of increased size. The simpler members of this series, or those most nearly resembling the sugars, are the dextrins, while among the more complex are starch and glycogen. The whole series may be conveniently called *Polysaccharids*. In some of the higher members of the group, such as the starches, more than a hundred monosaccharid molecules may be connected together. These polysaccharids tend to break down into their constituent disaccharid and monosaccharid molecules. A comprehension of these facts is essential for a study of the changes which these food-substances undergo in the animal body.

In the first group, or the monosaccharids, we have the following:—

Grape-sugar, $C_6H_{12}O_6$ (glucose, dextrose or diabetic sugar), when occurring in animal tissues, is mainly formed by the action of diastatic ferments upon other carbo-hydrates during digestion. In the vegetable kingdom, it is extensively distributed in the sweet juices of many fruits and flowers. It is formed from cane-sugar, maltose, dextrin, glycogen, and starch by boiling them with dilute acids. By fermentation with yeast, it splits up into alcohol and CO_2; with decomposing proteids it splits into two molecules of lactic acid, while this latter, under the same conditions in alkaline solutions, splits up into butyric acid, CO_2 and H_2.

Galactose is obtained by boiling lactose or milk-sugar with dilute mineral acids: it crystallises, is fermentable, and gives all the reactions of glucose. Its specific rotatory power is +88°·08 for A_j or median yellow ray of light.

Lævulose, sometimes called *invert* sugar, occurs as a colourless syrup in honey and juices of some fruits. It is non-crystallisable, and rotates −106° for A_j.

In the second group, or disaccharids, we have carbo-hydrates which may be regarded as anhydrides of the monosaccharids, with the formula of $C_{12}H_{22}O_{11}$. Thus, *Lactose* or milk-sugar occurs only in milk. It rotates polarised light +61°·5 for A_j, and is much less soluble in water and alcohol than grape-sugar. When boiled with dilute mineral acids, it passes into galactose, and can be directly transformed into lactic acid only by fermentation: the galactose, however, is capable of undergoing alcoholic fermentation with yeast (koumiss).

Maltose has one molecule of water less than grape-sugar, and is the final product of the action of diastase on starch. It has a rotatory power of +155° and is soluble in alcohol.

Cane-sugar or saccharose occurs in sugar-cane and some plants; it does not reduce a solution of copper, is insoluble in alcohol, is right rotatory, 73°·8 for A_j, and not capable of fermentation. When boiled with dilute acids, it becomes changed into a mixture of glucose and lævulose (invert sugar).

In the third group we have carbo-hydrates with the formula, $nC_6H_{10}O_5$, which may be regarded as anhydrides of the second group. The chief among them are:—

Starches, which constitute the chief portion of the seeds of the various cereals and potatoes. Starch combines with iodine to form a blue colour, constituting thereby a simple test for its presence. In cold water or alcohol, starch is insoluble, but at 72° C. (161°·6 F.) it swells up in water and forms a mucilage. Starch-grains always contain more or less cellulose and a substance, erythrogranulose, which is coloured red with iodine. Heat and dilute acids, also the digestive ferments in the saliva, pancreatic and intestinal juices, convert starch into a gum-like substance, called dextrin, and if carried further into grape-sugar.

Glycogen, or the so-called animal starch, has a dextro-rotatory power of 211°, and does not reduce cupric oxide. It occurs in the liver, muscles, and various other tissues of man and animals. It occurs also in the oyster and some other molluscs.

Dextrin occurs in beer, and in the juices of most plants. In water, it forms a sticky solution, from which it is precipitated by alcohol or acetic acid; it also slightly reddens with iodine. Dextrin is largely present in the crust of bread, and if examined with polarised light in dilute solutions, rotates $+222°$ for A_j. It is further formed from cellulose by the action of dilute sulphuric acid.

Among carbo-hydrates of this group must be included cellulose and pectose. *Cellulose* constitutes the chief framework of plants, it is quite insoluble, and apparently without any dietetic value. When boiled with dilute sulphuric acid, it yields dextrin and glucose. In a similar way, *pectose* or vegetable jelly is found in various ripe fruits, being really a later stage of the insoluble body present in most unripe fruits, and known as pectin. Its precise composition is unknown.

Vegetable Acids.—These, though not strictly speaking foods, play so important a part in preserving the health of man that they demand some considerable notice. The chief among them are tartaric, citric, malic, oxalic, and acetic acids. *Tartaric acid*, $C_4H_6O_6$, exists largely in grape juice chiefly as the acid tartrate of potassium; *Citric acid*, $C_6H_8O_7$, is found in oranges, lemons, and gooseberries; *Malic acid*, $C_4H_6O_5$, is met with in fruits belonging to the rose order, such as apples and pears; *Oxalic acid*, $C_2H_2O_4$, is present largely in rhubarb and sorrel; *Acetic acid*, $C_2H_4O_2$, constitutes the active element in vinegar. Except it be the latter, all these vegetable acids contain more than sufficient oxygen to convert all their hydrogen into water. These acids exist mainly in fresh fruits and vegetables, either as free acids or in combination with alkalies as alkaline salts, and, when taken into the body, form carbonates, which exercise a controlling influence in preserving the alkalinity not only of the blood but other fluids; they also furnish a small amount of energy and heat by oxidation. Their absence for any length of time from any dietary leads to a peculiar lowering or weakening of the blood, resulting in the disease called scurvy. It is possible that some of these acids are not only derived from fruits and vegetables, but also in a small degree from the splitting up of carbo-hydrates, so that even the latter, in an indirect way, help in maintaining the alkalinity of the blood and other animal fluids.

Mineral Salts.—Among the mineral salts which constitute a part of the proximate principles of food must be included chloride of sodium or common salt, the phosphates of lime, potash, soda, and magnesium, along with small quantities of sulphates and possibly iron. These, in their various and respective ways, are essential for the repair and growth of all parts of the body. The uses of the chlorides, as typified by common salt, are very important. The complete withholding of ordinary salt from food leads to rapid disease and even death. The chlorides generally keep in solution the globulins of the blood and other fluids, while at the same time they are the source of the hydrochloric acid of the gastric juice, and materially aid in the solution of albumin. The phosphates of lime, potash, and magnesia contribute, especially in the young, to the formation of bone; while iron forms an important part of the hæmoglobin of the red blood-corpuscles.

THE NUTRITIVE FUNCTIONS OF THE FOOD-STUFFS.

The physiological evidence that these classes of aliments serve different purposes in nutrition is not so complete as that of their chemical differences.

A broad distinction must, of course, be drawn between the nitrogenous and non-nitrogenous substances. Modern researches, which have much modified our opinion of the direction in which the potential energy of the dietetic principles may be manifested (as heat, or electricity, or mechanical movement), and of the mode in which the nitrogenous substances in particular aid or restrain this transformation, do not impeach the proposition that the presence of nitrogen in an organised structure, and its participation in the action going on there, is a necessary condition for the manifestation of any energy or any chemical change. Whether, when energy is manifested, the nitrogenous framework of any nitrogenous structure is a mere stage on which other actors play, or whether it is used up and destroyed, or is, on the other hand, built up or renovated during action, is, so far as classification of food is concerned, a matter of no consequence.

In the digestive tract, both animal and vegetable **proteids** are transformed by the gastric juice into syntonin, albumoses, and peptones; by the pancreatic juice into peptones and an intermediate body, while part of the peptone is further split up into leucin and tyrosin. Gelatin is also transformed into albumoses by the stomach and small intestine, but keratin is not digested by the stomach, only by the pancreatic juice. Brücke thinks that some of the native proteids, taken as food, may be absorbed as such, but the more general opinion is that proteids are absorbed mainly if not only in the form of albumoses and peptones. Albumoses and peptones thus form an important element in artificial foods for invalids, but it is more than doubtful whether they possess the same nutritive value as the ordinary proteids of food. The great danger in regard to them is, that when a large quantity is given, much of the peptone is split up by the pancreatic juice into leucin and tyrosin, and may thus be lost as food to the organism.

The following considerations seem to prove the necessary participation of the nitrogenous structures in manifestations of energy. Every structure in the body in which any form of energy is manifested (heat, mechanical motion, chemical or electrical action, &c.) is nitrogenous. The nerves, the muscles, and gland cells, the floating cells in the various liquids, the semen and the ovarian cells, are all nitrogenous. Even the non-cellular liquids passing out into the alimentary canal at various points, which have so great an action in preparing the food in different ways, are not only nitrogenous, but the constancy of this implies the necessity of the nitrogen, in order that these actions shall be performed; and the same constancy of the presence of nitrogen when function is performed, is apparently traceable through the whole world. Surely such constancy proves necessity. Then, if the nitrogen be cut off from the body, the various functions languish. This does not occur at once, for every body contains a store of nitrogen, but it is at length inevitable. Again, if it is wished to increase the manifestation of the energies of the various organs, more nitrogen must be supplied. The experiments of Pettenkofer and Voit show that the nitrogenous substances composing the textures of the body determine the absorption of oxygen. The condensation of the oxygen from the atmosphere, its conversion into its active condition (ozone), and its application to oxidation are, according to their experiments, entirely under the control of the nitrogenous tissues (fixed and floating), and are apparently proportional to their size and vigour, and to changes occurring in them. The absorption of oxygen does not determine the changes in the tissues, but the changes in the tissues determine the absorption of oxygen. In other words, without the participation of the nitrogenous bodies, no oxidation and no manifestation of energy is possible.

The experiments show that the absorption of oxygen by the lungs is dependent on its disposal in the body, and that this disposal is in direct relation with the absolute and relative amount and action of the nitrogenous structures. Mechanical motion, electricity, or heat may be owing to the oxidation of fat or of starch, or of nitrogenous substance ; but whatever be the final source, the direction is given by the nitrogenous structures.

The proteids are further a source of fats and possibly of carbo-hydrates, so that they really play two parts, first, that of regulators of oxidation and of the transformation of energy; and second, they may form a non-nitrogenous substance which is oxidised and transformed. That fats are formed from proteids is shown by the following: 1. Carnivora giving suck, when fed on plenty of flesh and little fat, yield milk rich in fat. 2. A cow which produces one pound of butter daily does not take nearly this amount of fatty matter in her food, so that the fat would appear to be formed in this case from vegetable proteids.

That the proteids are a source of carbo-hydrate also, is shown by the fact that, in an animal deprived of glycogen by strychnine poisoning, this carbo-hydrate appears again in the liver and muscles under the influence of chloral, even though the animal is starved. As to how this is brought about, considerable diversity of opinion prevails. The question practically is, does the proteid molecule contain carbo-hydrate molecules which are set free when it breaks down; or do the elements of the proteid molecule, after breaking down and then becoming part of the protoplasm, change into the carbo-hydrate molecule? According to Pflüger, the latter is the probable explanation, while Pavy attempts to furnish evidence that the proteid molecule does contain a carbo-hydrate moiety, which is the source of carbo-hydrates formed from proteids. No matter which view is correct, the fact that proteids are a partial source of both fats and carbo-hydrates must not allow us to consider a proteid as an aliment which may replace fat or starch or sugar in the case of man. The digestive system of man is framed so differently from that of the carnivora, that fat must be taken in its own form, for it either cannot be formed in sufficient quantity from proteids, or the body is poisoned by the excess of nitrogen which is necessarily absorbed to supply it.

The use of **fats** in the organism is that they are sources of energy and of heat to the body. In the majority of national dietaries, fat finds a place, and in some cases, as that of the Esquimaux, it is greatly increased in the dietary. When hard work is to be done, an excess of fat is involuntarily taken. Whatever the mixture of fats taken in as food, the fat of the body always has the same composition; this fact agrees with the conclusion that the deposition and metabolism of fat in the body is due to cell activity, and that the fat comes in part from the proteid, and part from the carbo-hydrate foods.

The consumption of **carbo-hydrates** spares not only proteid food, but also fat. They lessen the need of fat by being a source of energy in the body, and thus when present in a diet poor in fat, they diminish the oxidation of fat in the body. The experiments of E. Smith, Haughton, and others, on muscular action, prove that we must look for the main source of energy which is apparent during muscular action in the oxidation of the non-nitrogenous substances, but no experiments have yet shown whether these are fats or carbo-hydrates. It seems to be inferred that it is fat which is thus chiefly acted upon, but this opinion is rather derived from a reference to the universal presence of fat when energy is manifested, to the known necessity of it in diet (for though the dog and the rat (Savory) can live on fat-free meat alone, man cannot do so), and from the large amount of energy its oxidation can produce, than from actual observation. If it were true, a broad distinction would be at once drawn between fatty and starchy food, but it is not experimentally proved. If, on the other hand, it were certain that the starchy aliments formed fat in the human body as a rule, this would be a reason for drawing no distinction between the groups. Independent of the argument drawn from bees fed on sugar alone and forming wax, from the fattening of ducks and geese, and the older experiments on pigs, the later experiments of Lawes and Gilbert seem to show clearly that the fat stored up in fattened pigs cannot be derived from the fat given in the food, but must have been produced partly from nitrogenous substances, but chiefly from the carbo-hydrates. So also it seems now probable that the fat in milk is not derived at once from blood, but from changes of albumin in the lacteal gland cells. There seems no reason why we should not extend the inference to man. If so, a man could live in perfect health on a diet composed only of fat-free meat and starch, with salts and water, just as he can certainly live (though perhaps not in the highest health) on meat, fat, salts, and water. The carbo-hydrates would then be proved to be able to replace fats. The experiment has not yet been performed, or at least recorded, but it seems important it should be.

Many authorities state that fat is formed *directly* from carbo-hydrates, and the weight of evidence appears to favour this view; but whether it is so formed directly, or indirectly, by retarding the metabolism of the fatty and proteid constituents of the food, there is no doubt that the consumption of carbo-hydrates results in the formation of fat within the body.

Grouven's experiments also suggest that in cattle the carbo-hydrates may split up in the alimentary canal into glycerin, lactic and butyric acids, and carbon dioxide and marsh gas. If this be true, in the herbivora the starches would be merely another form of fat.

In man it has been pointed out that, as fermentative changes occur in the small intestines with the production of lactic acid, so the butyric acid fermentation may possibly take place in the sugar of the intestinal contents. By this change the sugar would be removed from the carbo-hydrate group into the fatty acid group, and, as Foster says, "put on its way to become fat."

The possibility of the conversion of fats to carbo-hydrates in the animal body has so far not been fully investigated. Seegen has suggested that fats do yield sugar in the body, but his experiments are unsatisfactory. The glucoside constitution of proteid matter, and the partial origin of carbo-hydrates from proteids, as advanced by Pavy, has already been mentioned: he further maintains that the carbo-hydrates, stored as glycogen, or as they pass through the intestinal wall, go to form proteid. Possibly he is right: but to argue, as he does, from plants to animals is somewhat dangerous. Though asparagin and carbo-hydrates may be built into the protoplasm molecules of plants, the direct experimental evidence against the utilisation of the former substance in animals is very strong. His further views that carbo-hydrates are changed to fats is in conformity with the results of many experimenters, though how this actually takes place is not quite so clear.

As to the changes which the carbo-hydrates of food undergo in the alimentary canal, the most recent research has demonstrated the important action of the intestinal secretions in bringing about the complete conversion of polysaccharids and disaccharids to monosaccharids. Starches and maltose are entirely converted to dextrose, while cane-sugar is split into dextrose and lævulose. It is probable that the conversion of starch is not always completed before absorption, and that some of the lower dextrins may pass through the intestinal wall along with dextrose. Cane-sugar, too, when in excess, may escape conversion and pass into the blood as such. On the other hand, milk-sugar does not appear to be acted upon unless by the intestinal bacteria, which split it up in part to lactic acid, &c.

An argument against the fats and carbo-hydrates being mutually replaceable under ordinary conditions in the diet of men is drawn from a consideration of the diets used by all nations. In no case in which it can be obtained is an admixture of starch, in some form, with fat omitted. Moreover, in all cases (except in those nations, like the Esquimaux, who are under particular conditions of food) we find that the amount of fat taken is comparatively small as compared with that of starches. The fats when taken into the body enter like the proteids into the structure of the tissues, of which fat forms in probably all cases an essential part. The carbo-hydrates, on the other hand, in the human body do not appear to be parts of the tissues, though they are contained in the fluids which bathe them, or are contained in them. The special direction which the chemical changes in the carbo-hydrates take in the body seems also to point to special duties. Thus, the formation of lactic and other acids of the same class must arise from carbo-hydrates chiefly or solely. But the formation of these acids is certainly most important in nutrition, for the various reactions of the fluids, which offer so striking a contrast (the alkalinity of the blood, the acidity of most mucous secretions, of the sweat, urine, &c.), must be chiefly owing to the action of lactic acid on the phosphates, or the chlorides, and to the ease with which it is oxidised and removed. If the direction of the changes which the carbo-hydrates undergo within the body is different from that of the fats, the products of these changes must be inferred to play dissimilar parts.

Without pushing these arguments too far, and with the admission that the subject is still obscure, we are fairly entitled to assert that the two groups of fats and carbo-hydrates are not so immediately and completely convertible as to permit us to place them together in a classification of diets.

The **salts** and **water** are as essential as the nitrogenous substances. Lime, chiefly in the form of phosphate, is absent from no tissue; and there is reason to think no cell growth can go on without it; certainly, in enlarging morbid growths, and in rapidly growing cells, it is in large amount.

When phosphate of calcium was excluded from the diet, the bones of an adult goat were not found by H. Weiske to be poorer in lime, because probably lime was drawn from other parts; but the goat became weak and dull, so that nutrition was interfered with. Experiment has shown that the growth of wheat is more quickly and effectually checked by the absence of phosphoric acid than of any other constituent from the soil. The lowest forms of life will not grow without earthy phosphates.

Magnesia is probably also an essential constituent of growth in some tissues. Potash and soda, in the forms of phosphates and chlorides, are equally important, and would seem to be especially concerned in the molecular currents; forming parts of almost all tissues, they are less fixed, so to speak, than the magnesian and lime salts. It is also now certain, that the two alkalies do not replace each other, and have a different distribution; and it is so far observable, that the potash seems to be the alkali for the formed tissues, such as the blood cells or muscular fibre; while the soda salts are more largely contained in the intercellular fluids which bathe or encircle the tissues.

The chlorine and phosphoric acid have also very peculiar properties,—the former apparently being easily set free, and then giving a very strong acid, which has a special action on proteids, its presence being also necessary for maintaining the globulin in solution: the latter has remarkable combining properties with alkalies. Both are furnished in almost all food; the sodium chloride also separately. Carbonic acid is both introduced and made in the system, and probably serves many uses. Iron is, of course, also essential for certain tissues or parts, especially for the red blood-corpuscles, and for the colouring matter in muscle, and in small quantity is found almost in every tissue and in every food. The sulphur and phosphorus of the tissues appear to enter especially as such with the proteids.

Some salts, especially those which form carbonates in the system, such as the lactates, tartrates, citrates, and acetates, give the alkalinity to the system which seems so necessary to the integrity of the molecular currents. The state of malnutrition, which in its highest degree we call scurvy, appears to follow inevitably on their absence; and, as they exist chiefly in fresh vegetables, it is a well-known rule in dietetics to supply these with great care, though their nutritive power otherwise is small. So important are those substances, that they might well be placed in a separate class, although Pavy remarks that "these principles are hardly of sufficient importance, in an alimentary point of view, to call for their consideration under a distinct head." Surely this is an under-estimate of their importance, considering the inevitable malnutrition that follows on their absence.

In addition to the substances composing these four classes, there are others which enter into many diets, and which have been termed "accessory foods," or by some writers "force regulators" (like the salts). The various condiments which give taste to food, or excite salivary or alimentary secretions, and tea, coffee, cocoa, alcohol, &c., furnish the chief substances of this class. Much discussion has taken place as to the exact action in nutrition of these substances, but little is definitely known.

With regard to the necessity of all four classes of aliments, it can be affirmed with certainty that (putting scurvy out of the question) men can live for some time and can be healthy with a diet of proteids, fat, salts, and water. But special conditions of life, such as great exercise, or exposure to very low temperature, appear to be necessary, and under usual conditions of life health is not very perfectly maintained on such a diet. It has not yet been shown that men can live in good health on proteids, carbo-hydrates, salts, and water, &c., without fat.

The exact effect produced by the deprivation of any one of these classes is not yet known. An excess of the proteids causes a more rapid oxidation of fat (and in dogs an elimination of water), while an excess of fat lessens the absorption of oxygen, and hinders the metamorphosis of both fat and albuminous tissues. The carbo-hydrates have the same effect when in excess, and appear to lessen the oxidation of the two other classes.

It is generally admitted that the success of Banting's treatment of obesity is owing to two actions: the increased oxidising effect on fat consequent on the increase of meat (especially if exercise be combined), and the lessened interference with the oxidation of fat consequent on the deprivation of the starches.

Health cannot be maintained on proteids, salts, and water alone; but, on the other hand, it cannot be maintained without them.

A classification, on a simplified plan, may be made as follows:—

			Examples.		Functions.
Nitrogenous.	1. *Proteids.* All substances containing nitrogen, of a composition identical with, or nearly that of albumin; proportion of nitrogen to carbon being nearly as 2 to 7, or 4 to 14.	Animal.	Albumin, Fibrin, Syntonin, Myosin, Globulin, Casein, Albumoses, Peptones,		Formation and repair of tissues and fluids of the body. Regulation of the absorption and utilisation of oxygen. May also form fat and carbo-hydrate, also yield energy under special conditions.
		Vegetable.	Glutin, Legumin, Albumoses,		In most foods, the above, both animal and vegetable, are largely converted into albumoses and peptones during digestion. Native albumoses are present in many cereals.
	1 (*a*). Substances containing a larger proportion of nitrogen and apparently less nutritious. Proportion of nitrogen to carbon about 2 to $5\frac{1}{2}$, or 4 to 11.		Gelatin, Ossein, Chondrin, Keratin,		These perform the above functions less perfectly, or only under particular circumstances.
	1 (*b*). Extractive matters, such as are contained in the juice of the flesh.				These substances appear essential as regulators of digestion and assimilation, especially with reference to the gelatin group.
Non-nitrogenous substances.	2. *Fats* (or Hydrocarbons). Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the proportion of oxygen being *less* than sufficient to convert all the hydrogen into water. Proportion of unoxidised hydrogen to carbon about 1 to 7.		Olein, Stearin, Margarin,		Supply of fatty tissues, nutrition of nervous system. Supply of energy and animal heat by oxidation.
	3. *Carbo-hydrates.* Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being exactly sufficient to convert all the hydrogen into water. Proportion of water to carbon being about 3 to 2.		Starch, Dextrin, Cane-sugar, Grape-sugar, Lactose (or milk-sugar),		Production of energy and animal heat by oxidation. Form fats and possibly some proteid.
	3 (*a*). *Vegetable acids* (*and pectous substances* ?). Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being generally in greater amount than is sufficient to convert all the hydrogen into water.		Oxalic acid, Tartaric ,, Citric ,, Malic ,,	In these the oxygen is *more* than sufficient to convert all the hydrogen into water.	Preserving the alkalinity of the blood by conversion into carbonates; furnish a small amount of energy or animal heat by oxidation.
			Acetic ,, Lactic ,,	In these there is no excess of oxygen.	
Mineral.	4. *Salts* (mineral),		Sodium chloride, Potassium ,, Calcium phosphate, Magnesium ,, Iron, &c.,		Various: support of bony skeleton, supply of HCl for digestion, &c. Regulators of energy and nutrition.

THE NUTRITIVE VALUE OF THE FOOD-STUFFS.

In the preceding section we have learnt the part the various food-stuffs play when taken into the body: it is now necessary to learn their nutritive value. To begin with, if we lift a weight by our hands, muscular force is employed in the act, and the energy evolved in this or any other muscular action must have its origin or source in something. As a matter of fact, the energy so evolved has its source in the material which has been supplied to the body in the form of food. Every process of our bodies, no matter whether it be the moving of a hand or a foot, the beating of our heart, or the secretion of saliva, is attended with some manifestation of energy, and this energy is shown in one or other of two forms, namely, either mechanical labour or heat. These facts will be more clearly understood if it is borne in mind that what is called *energy* in an agent is merely an expression that that agent is capable of doing work, and that the quantity of energy it possesses is measured by the amount of work it can do. An agent or force is said to do work when it produces any change in the condition of bodies: therefore energy is the capacity for producing physical change. This capacity for producing change or energy is of two kinds, namely, *kinetic energy* or the energy of movement, and *potential energy* or that of position. This latter term means various forms of energy which are suspended in their action, and which, although they may cause motion, are not in themselves motion. Thus, a coiled watch-spring possesses energy of position or potential energy, and only wants a touch to transform the energy of position into energy of movement, or potential into mechanical energy. Moreover this transformation of potential into kinetic energy, or *vice versâ*, can take place without any part of the energy being lost, and it is further possible to convert the whole of the energy possessed by any body into heat. Thus if a piece of lead be thrown from a high tower to the ground, and if it strike some hard, unyielding substance, the movement of the lead mass is not only arrested but its kinetic energy is transformed into violent vibratory movements of the lead atoms. As a result of this violent vibration of atoms, heat is produced, and the amount of this is proportional to the kinetic energy of the lead, which again was proportional to its potential energy when in position on the tower. In the human body the ordinary movements of the whole system and of individual organs are constantly being transformed into heat. If we regard, therefore, the food we consume as the direct source of all this heat and the mechanical energy displayed by the body, it is obvious we can obtain by their measurement a fair idea of the nutritive values of various food-stuffs. The problem is, however, not of a uniformly simple nature. In the case of the water and mineral salts of the food, their nutritive value is not difficult to ascertain, because they are simple bodies, and do not undergo any very great chemical change in the body. The nutritive value of the proteids, fats, and carbohydrates, however, is not so easy to determine, because not only are they complex bodies in themselves, but, moreover, undergo complicated and ill-understood changes within the body; their nutritive value, therefore, cannot be very accurately expressed.

The simplest measure of the potential energy is the amount of heat which can be obtained by complete combustion of the chemical compounds representing the potential energy. The various statements as to the amount of potential energy possessed by various food-stuffs and expressed either in terms of heat or work, are based upon the researches and discoveries of Mayer and Joule, that the amount of power or energy which can be obtained from a given weight of matter is connected with and proportional to the heat given out during its combustion. As a standard of measure of heat, we have the "heat-unit," or *calorie*. This heat-unit, or calorie, is the amount of energy required to raise the temperature of 1 gramme of water 1° C. The heat-unit corresponds to 425·5 units of work, which are gram-metres: that is, the same energy required to heat 1 gramme of water 1° C. would raise a weight of 425·5 grammes to the height of 1 metre; or a weight of 425·5 grammes, if allowed to fall from a height of 1 metre, would by its concussion produce as much heat as would raise the temperature of 1 gramme of water 1° C.

According to the English system, the heat-unit is the amount of energy required to raise the temperature of a pound of water 1° F., and will, if manifested as a mechanical force, raise 772 ℔. a foot high, or, what amounts to the same thing, 1 ℔. 772 feet high. Thus the dynamic or mechanical equivalent of one degree of heat on the Fahrenheit scale is said to be 772 foot-pounds. Adopting the Centigrade scale, then the mechanical equivalent of 1° C., or 1°·8 F., will be 1389 pounds: that is, the energy which will raise the temperature of 1 ℔. of water 1° C., or 1°·8 F., will be capable, as a motive power, of raising 1 ℔. in weight 1389 feet high. In England, the amount of work done is commonly expressed as foot-tons or tons lifted 1 foot, while in France it is often expressed as kilogram-metres or kilogrammes lifted 1 metre.

Units of work, expressed according to the continental system as gram-metres, can be converted into foot-pounds by multiplying them by 0·007233, and into foot-tons by dividing by 311,000. Similarly, kilogram-metres are converted into foot-pounds by multiplying by 7·233, and into foot-tons by dividing by 311.

Applying this principle, that as heat production is related to the amount of chemical action ensuing so likewise is mechanical power production, we find that as a measure of the utility of food, the value of the various food principles as mechanical power producers will correspond with their value as heat producers. Those food principles, which by oxidation give rise to the greatest amount of heat, will, of course, theoretically have the greatest capacity for the production of working power; that is, will possess the greatest potential energy. This theoretical potential energy is not only different in the case of each class of food-stuffs, such as proteid, fat, and carbo-hydrate, but differs also in different foods of each of these classes. In the case of many food-stuffs, their actual value in respect of capacity for heat production has been determined experimentally, and expressed in relation to the performance of work. The heat-equivalent of the organic substances cannot be exactly computed from the known heat-equivalents of carbon and hydrogen, because of the amount of heat which is set free by the union of the oxygen with the carbon and hydrogen; further, a part is used up in the separation of the hydrogen atoms from the carbon atoms, and of the carbon atoms from each other. This amount of heat may vary greatly in different compounds, because the atoms are more or less firmly combined with each other, and varying amounts of heat are set free by their union. Metameric compounds are known to produce different heat-equivalents.

To overcome these difficulties, the heat-equivalents of foods have been determined by direct calorimetric methods, first by Frankland, then by an improved method by Stohmann and Rechenberg, lastly by Danilewski and by Rubner. Taking the above mentioned estimate of the mechanical equivalent of heat as a basis of calculation, the following table has been constructed, showing both the units of heat and energy developed by one ounce and one gramme of various substances when fully oxidised: the units of heat and energy being expressed according to both the English and metric systems.

Substance.	One ounce (dried) yields		One gramme (dried) yields	
	English Heat-units.	Energy as Foot-tons.	Metric Heat-units.	Energy as Kilogram-metres.
Acetic acid,	394	135	3,505	1,489
Albumin (egg),	628	216	5,577	2,370
Ale (Bass's),	754	260	6,682	2,841
Alcohol (fluid ounces),	786	271	6,980	2,966
Arrowroot,	438	151	3,912	1,664
Bacon,	997	344	8,847	3,760
Barley meal.	417	144	3,703	1,574
Barley (pearl),	414	143	3,678	1,563
Beef, fat,	1,017	351	9,069	3,860
Beef, lean,	572	197	5,103	2,170
Biscuit,	417	144	3,703	1,574
Bread (wheaten).	490	169	4,351	1,849
Butter,	815	281	7,264	3,077
Cabbage,	417	144	3,703	1,574
Carbon,	910	314	8,080	3,434
Carrots,	310	107	2,752	1,169
Casein,	658	227	5,855	2,488
Cellulose,	466	160	4,146	1,762
Cheese,	687	237	6,095	2,590
Chondrin,	552	190	4,909	2,086
Dextrose,	443	153	3,939	1,674
Eggs,	745	257	6,610	2,809
Fibrin (blood).	620	213	5,508	2,340
Fish (white),	553	191	4,912	2,087
Gelatin,	618	213	5,493	2,334
Glutin,	690	238	6,141	2,610
Glycerin,	484	166	4,305	1,829
Horseflesh,	542	187	4,809	2,043
Hydrogen,	3,880	1,337	34,462	14,664
Lactose,	412	142	3,667	1,558
Liebig's Extract.	495	171	4,400	1,870
Macaroni,	411	142	3,652	1,552
Maltose,	467	161	4,163	1,769
Milk (cows),	644	222	5,733	2,436
Milk (human),	545	188	4,837	2,055
Oatmeal,	443	153	3,935	1,672
Peas,	551	190	4,889	2,077
Pemmican,	849	293	7,531	3,202
Peptone,	553	190	4,914	2,088
Potatoes,	475	164	4,234	1,799
Poultry,	556	192	4,934	2,098
Rice,	540	186	4,806	2,042
Starch (wheat),	504	174	4,479	1,903
Sugar (cane),	374	129	3,348	1,423
Sugar (grape),	368	127	3,277	1,394
Tartaric acid,	158	54	1,408	598
Urea,	238	82	2,121	903
Vinegar,	74	25	660	280

A table of this kind is useful in showing what can be obtained from our food, but it must not be supposed that the value of food is in exact relation to the possible energy which it can furnish. In order that the energy shall be obtained, the food must not only be digested and taken into the body properly prepared, but its energy must be developed at the place and in the manner proper for nutrition. The mere expression of potential energy cannot fix dietetic value, which may be dependent on conditions in the body unknown to us.

In the case of non-nitrogenous foods, it is probable that the same heat-equivalent is produced in our bodies as in a calorimeter, because the ultimate products of their combustion are the same; but it is different in the case of food containing nitrogen. In a calorimeter, nitrogen is liberated in a free state from nitrogenous food-stuffs, but after the decomposition and oxidation in the body of a nitrogen containing food, the nitrogen issues, as an organic compound, in union with carbon and hydrogen, and, in the case of man, principally as urea. Ordinary albumin, which may be taken as a fair type of the proteids, yields about one-third of its weight as urea. In order, therefore, to ascertain the heat-equivalent of the proteid in our organism, we must deduct one-third of the heat-equivalent of urea from that of the albumin. But this figure would come out rather too high, because the nitrogen leaves our body not only as urea, but partly as a compound containing more carbon and hydrogen. We shall be nearer the mark if we subtract at least 800 metric heat-units, per gramme, from the heat-equivalent of any proteid in the above table; thus, taking albumin and potatoes as examples, we obtain a figure from the proteid which is only a little higher than that from the carbo-hydrate. As a store of energy in our bodies, therefore, the carbo-hydrates are, in a quantitative respect, about equivalent to the proteids. The heat-equivalent of fats, on the other hand, is twice as great.

From what has been said, it is evident that it is difficult to compare rightly the potential energy available by the burning of a food-stuff outside the body with that which is obtained as the result of combustion within the body, and in attempting to estimate the nutritive values therefrom, allowance must be made for the different degrees of digestibility, the effects of cooking, and even the actual bulk taken. In the case of fats, their nutritive value seems to depend largely on their digestibility, while of the carbo-hydrates there is little reason to think that starch, grape-sugar, or cane-sugar differ much in their nutritive value, though Lawes' and Gilbert's experiments indicate that cane-sugar is more fattening than starch. Among the proteids, we know that gelatin and chondrin have a lower nutritive value than the ordinary proteids, and that vegetable proteids are as nourishing as the animal.

As illustrative of the loss on the consumption of different foods, the following table is suggestive:—

On the consumption of	There are wasted per cent. of the Ingested.		
	Dry substance.	Nitrogen.	Salts (ash).
Beans (boiled),	18·3	30·2	28·3
Bread,	4·4	22·2	21·3
Broccoli,	15·0	18·0	19·0
Cabbage,	16·2	17·5	18·4
Carrots,	21·0	39·0	34·0
Eggs,	5·2	2·6	18·2
Macaroni,	5·0	14·0	23·0
Maize,	7·0	15·0	30·0
Meat,	5·1	2·6	18·1
Milk (by adults),	9·5	10·5	42·5
Milk (by children),	6·2	4·4	42·2
Pease pudding,	9·0	17·5	32·5
Potatoes (boiled),	9·2	32·2	15·8
Rice pudding (boiled),	4·1	20·5	15·0
Rusks,	5·0	20·0	21·0

These results having been obtained by Rubner, Prausnitz and others.

To foods which, when burnt, yield the same number of heat-units, the term *isodynamic* has been applied, as expressing in terms of energy their equivalence to each other; that is to say, that so much proteid is isodynamic with so much fat or carbo-hydrate. Rubner has calculated that 100 parts of fat during combustion, whether within or without the body, yield as much heat as 213 parts of albumin, as 232 parts of starch, as 234 parts of cane-sugar, and as 256 parts of dextrin. These, however, are scarcely practically useful values, since, as we have already learnt, the several nutritive substances are not perfect substitutes for each other. Some German authorities, notably König and Emmerling, have endeavoured to obtain a nutritive value of the food-stuffs as based on their market price ratios. Using the term "nutrient unit" as representing a mere national economic standard, they say that—

1 part of carbo-hydrate has the value of 1 nutrient unit.
1 part of fat has the value of 3 nutrient units.
1 part of proteid has the value of 5 nutrient units.

We ascertain how many nutrient units are contained in 100 parts of a substance, as calculated out from its analytical constituents: the more such units it contains, the greater is its economic value. Further, we may calculate how many nutrient units we can obtain in any case for so much money, say, for instance, one shilling (Lehmann).

Thus for instance, say 100 parts of bread contain 8 of proteid, 1·5 of fat and 50 of carbo-hydrate. Then $(8 \times 5) + (1{\cdot}5 \times 3) + (50) = 94{\cdot}5$, or the sum of nutrient units per 100 pounds of bread, and if we take bread to be roughly a penny a pound, we get rather more than 11 nutrient units for one shilling. In the same way, further values can be worked out for other articles of diet, and comparisons made between them. For the purpose of economic comparative statements of dietaries, this method is extremely ingenious, but actual figures of value will obviously vary in different places and at different periods according to the prices prevailing.

With regard to mechanical labour and the amount of energy expended by the body, it is considered that 300 foot-tons or 93,300 kilogram-metres of external work over and above what is done by the functional activity of the body itself is a good day's work. With regard to heat produced in and by the body, no accurate knowledge is available; but the ratio between the amount of mechanical labour done and heat produced by an adult during an ordinary day's work is about one-sixth mechanical labour to five-sixths heat. It is primarily to meet these losses, or to furnish sufficient energy for labour and heat production in the body, that we require and actually take food.

In round numbers, it may be said that the internal work and heat of the body amount to the following:—

Work of circulation,	242 foot-tons or	75,200 kilogram-metres.
Work of respiration,	39 ,,	12,100 ,,
Calorific work,	2519 ,,	783,400 ,,

Of the total energy developed by oxidation of the food in the body, it has been estimated by Helmholtz that the animal economy is capable of turning only one-seventh to the account of external work, after allowing for the internal work of the body.

The late Professor de Chaumont reckoned the internal work to be equal to about 2800 foot-tons daily, and, according to him, to get an ordinary day's work done (say 300 foot-tons), we require five times that amount of energy (1500) in addition to the quantity needed for the body's internal work; or 1500 *plus* 2800 = 4300 foot-tons to be provided from the material taken in as food. The proportionate increase he formulated thus :—

$$300 \times \left(5 + \frac{7}{2} + \frac{9}{4} + \frac{11}{8} + \ldots\right) = 300 \times 14 = 4200.$$

This means that if we want a harder day's work done, say 450 foot-tons, not $(450 \times 5) = 2250$ foot-tons of energy must be supplied, but $(300 \times 5) + \left(300 \times \frac{7}{2}\right) = 2550$, and so on in proportion; 2800 foot-tons being supplied in addition for the internal work, or 2550 *plus* 2800 = 5350 foot-tons.

The actual productive work is : $300 \times \left(1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8}\right) = 300 \times 2 = 600$. That is, the greatest amount of mechanical work that can be performed by the body under ordinary circumstances is 600 foot-tons. The potential energy to be supplied to obtain this work is 4200 foot-tons, with 2800 foot-tons added for internal work, making a total of 7000 foot-tons, or the maximum amount of energy that the body is able to deal with in the food.

The following estimates have been made as to man's work :—

Light work,	from	150 to 200	foot-tons, or from	46,600 to 62,200	kilogram-metres each day.
Average	,,	300 350	,,	93,300 ,, 108,800	,, ,,
Hard	,,	450 ,, 500	,, ,,	139,900 ,, 155,500	,, ,,
Laborious	,,	500 ,, 600	,,	155,500 ,, 186,600	,, ,,

QUANTITY OF THE FOOD-STUFFS REQUISITE TO PRESERVE HEALTH.

So far, we have discussed the nature, uses, and nutritive values of the food-stuffs individually; it is necessary now to consider them collectively in reference to their powers of maintaining life—whether any one of them alone is capable of supporting vitality—or what combinations and what quantity of them experience and experiment teach us are useful in the food of man. There is abundant evidence to prove that no one group of the alimentary substances is alone sufficient to sustain life for any length of time, but that a mixed diet is necessary. Such evidence is derived from instinctive proclivities, from considerations of the comparative anatomy of our digestive organs, from experience and experiment. That man cannot live upon any one group of the food-stuffs is shown by an examination of the needs of the body, as demonstrated by the daily loss by the kidneys, bowels, skin, and lungs.

Various experiments by Parkes, Smith, Playfair, Haughton, Fick, and Ranke have shown that an average man gives off 307 grains of nitrogen and 4700 grains of carbon daily. If he wishes to keep in health, this daily loss of nitrogen and carbon must be made up by a corresponding intake of those elements with his food. If such a man subsisted only on a carbo-hydrate food-stuff—say, for instance, bread, which contains 116 grains of carbon and 5·5 grains of nitrogen in each ounce—he would, in order to obtain the 307 grains of nitrogen needed by him, have to consume 3·1 ℔ of bread, while at the same time the necessary quantity of carbon is contained in 2·5 ℔. Or, to take the supposititious case of a man wishing to live on beef (representing the proteids), and having a composition of 60 grains of carbon and 10·3 grains of nitrogen in each ounce, he would, in order to obtain his 4700 grains of carbon, have to eat daily no less than 4·7 ℔ of that substance, while the required 307 grains of nitrogen are contained in 1·3 ℔. Therefore, to obtain the proper quantity of carbon, he would be consuming a quantity of meat which contains nearly four times the amount of nitrogen actually required.

The general principles of diet may be summed up thus:—(1) No single nutritive principle, whether nitrogenous or non-nitrogenous, can support life except for a very short time. (2) Life may be supported upon one nitrogenous and one non-nitrogenous principle for a very long time, but for a permanency salts would require to be added. Thus, proteids and fats, or proteids and starches, would support life. (3) For the best forms of diet, both fats and carbo-hydrates are needed in addition to nitrogenous matter, and in all probability both starch and sugar among them. It would also appear that a due admixture of more than one form of nitrogenous principle is advisable.

Standard Diets.—Experience teaches us that our requirements as to food vary much with our exposure to different conditions, and that according to the expenditure of our bodies so should the materials be supplied which are best calculated to yield what is wanted. The human body has been compared to a machine, but it differs therefrom in this, that wear is constantly going on independently of any useful work done, which is not the case in a mechanical engine. Determinations as to the quantity of food daily required by the body have been obtained by means of extended observations of the diets of classes and communities, and also by estimating the sum of excreted matters, which, of course, must be compensated by a suitable supply of food.

As the daily average output of a man weighing 70 kilogrammes or 11 stones is 230 grammes of carbon and 15 of nitrogen, it is clear that if his health and bodily weight are to be maintained, his daily diet must contain these elements in the proportion mentioned. But for the maintenance of nitrogenous equilibrium it is not required that the loss of nitrogen from the system should be just balanced. If nitrogen is not sufficiently supplied in the food it will still continue to be eliminated, its source being the metabolism of the tissues which contain it. The nitrogen import has to be considerable, in order that the equilibrium may be maintained—viz., three times the amount of nitrogen excreted when no food is taken. The channels by which this element leaves our body are the kidneys, intestine, lungs, and skin; nearly the whole of it comes away by the kidneys in the form of urea, so that the quantity of urea eliminated is taken as the measure of the nitrogenous disassimilation of the system. Thirty grammes or 500 grains of urea are regarded as the normal daily amount, and in 30 grammes of urea there are 14 of nitrogen. Add to this the quantity that leaves by the intestine—viz., 10 per cent. of the total nitrogen eliminated —and we have an accurate statement as to the daily nitrogen export, for the amount discharged by the lung in the form of ammonia in the expired air is infinitesimal, and the same remark applies to escape by the skin. A systematic examination of the diet tables of the industrial classes shows that, with few exceptions, individuals are not taking in their food that excess of proteid or animal food necessary to maintain their nitrogenous equilibrium. It is probable that poor people when long underfed become accommodated to a low minimum, and that health may for a time be thus well maintained, but this takes place at a sacrifice, for experience indicates that where the nitrogen import is kept at the minimum for any lengthened period, the individuals subsequently become the subjects of tuberculous disease.

From the researches of Playfair, Smith, and others, the usual range, in the diet of an adult man, of nitrogen is daily from 250 to 350 grains, or from 16 to 23 grammes. The extremes being 180 grains (11·6 grammes) in a minimum or sustenance diet to 500 grains (32·4 grammes) taken during very great exertion. Of carbon, the daily need seems to be from 3500 to 6500 grains, or from 230 to 420 grammes. Smith's observations show from 135 grains (8·7 grammes) of nitrogen and 3270 grains (212 grammes) of carbon in the diet of London needlewomen, to 350 grains (23 grammes) of nitrogen and 6200 grains (400 grammes) of carbon in that of railway navvies. The diets in English convict prisons show the nitrogen and carbon to vary from 226 and 4356 grains (14·5 and 282 grammes) in the light labour diets, to 263 and 5013 grains (17 and 323 grammes) in the hard labour.

The carbon seems to vary from 3600 to 5800 grains (233 to 374 grammes) in diets generally. Weston, while walking 50 miles a day on the flat, and doing something like 790 foot-tons of external work, consumed daily on an average 545 grains (35 grammes) of nitrogen and 7880 grains (510 grammes) of carbon, or just about twice the amount of each which will support ordinary work. The more recent inquiries of Oliver into the nature and amounts of the daily dietaries of the working classes are in accordance with the above figures. The experiments of Parkes and Pettenkofer upon men to a great extent confirm the conclusions as to the daily needs of man as drawn from a study of class diets. The amounts of carbon and nitrogen taken daily in food are of the highest importance, since these are the chief elements which undergo metabolism in the body. In 100 *grammes* of proteid there are 54 of carbon, 16·1 of nitrogen, and 7·1 of hydrogen; in the same quantity of fat there are 76·5 of carbon and 10·9 of hydrogen; whilst in carbo-hydrate there are 44 of carbon. According to Ranke, fat contains 79 per cent. of carbon, and carbo-hydrate, *i.e.*, starch, 37 of carbon. The following table shows the quantity of carbon, nitrogen, &c., in each *ounce* of the various dried food-stuffs:—

One ounce (dried).	Nitrogen.	Carbon.	Hydrogen.	Sulphur.
Proteids,	70 grains.	212 grains.	8 grains.	6 grains.
Fat, .	...	336 ,,	18 ,,	...
Carbo-hydrates:—				
1. Starch,	...	194 ,,	...	...
2. Cane-sugar,	...	184 ,,	...	...
3. Grape-sugar,	...	175 ,,	...	...
4. Milk-sugar,	...	175 ,,	...	...

The total carbon in an ounce of proteid is 233 grains, but of this 30 grains are only metabolised as far as urea, and oxidised as carbon monoxide; making allowance for this, we have a nett total equal to 212 grains of carbon fully oxidised from each ounce of dry proteid.

Assuming these compositions in terms of nitrogen and carbon of the various food-stuffs, and accepting that the daily need of an average adult, weighing 150 ℔ or 68 kilogrammes, to keep in health is equal to 307 grains (20 grammes) of nitrogen and 4700 grains (305 grammes) of carbon, certain standard diets have been compiled. The following proposed by Moleschott may be accepted as the most representative, though, perhaps, the fat is stated rather too low.

	For 300 foot-tons, or 93,000 kilogram-metres.				For 323 foot-tons, or 100,000 kilogram-metres.				For 480 foot-tons, or 150,000 kilogram-metres.			
	Oz. av.	Gram.	N. grs.	C. grs.	Oz. av.	Gram.	N. grs.	C. grs.	Oz. av.	Gram.	N. grs.	C. grs.
Proteids,	4·59	130	321	973	4·94	140	346	1047	6·00	170	420	1272
Fats,	2·96	84	...	994	3·17	90	...	1065	4·00	113	...	1444
Carbo-hydrates,	14·26	404	...	2710	15·31	434	...	2909	17·00	481	...	3230
Salts,	1·06	30	...	...	1·13	32	...	...	1·50	42	...	...
Total water-free food,	22·87	648	321	4677	24·55	696	346	5021	28·50	806	420	5946

As standard diets for bare subsistence and for rest, the following may be taken:—

	Subsistence.				Rest.			
	Ounces avoir.	Grammes.	N. grains.	C. grains.	Ounces avoir.	Grammes.	N. grains.	C. grains.
Proteids,	2·0	57	140	424	2·5	71	175	530
Fats,	0·5	14	...	168	1·0	28	...	336
Carbo-hydrates,	12·0	340	...	2280	12·0	340	...	2280
Salts,	0·5	14	...	...	0·5	14	...	...
Total water-free food,	15·0	425	140	2872	16·0	453	175	3146

The *subsistence* diet is calculated as sufficient for the internal mechanical work of the body, but it is doubtful if an average man could exist on it without losing weight, as it supposes absolute repose.

The diet for *rest* supposes very gentle exertion, and is probably the minimum for a male adult of average size and weight, say 150 ℔ or 68 kilogrammes.

Each constituent named above is, theoretically, absolutely water-free, but practically the amount of water present in the so-called solid food would be from 100 to 150 per cent. more, so that the weights respectively would be about 32 to 40 ounces gross (907 to 1134 grammes).

For mere subsistence, without doing visible work, a man therefore requires about $\frac{1}{10}$ of an ounce of water-free food for each ℔ weight of his body, or about $\frac{1}{150}$ of his total weight every twenty-four hours.

Assuming the water-free food to be 23 ounces, and a man's weight to be 150 ℔, each ℔ weight of the body receives in twenty-four hours 0·15 ounce, or the whole body receives nearly $\frac{1}{100}$ part of its own weight. Expressed in another way, for every kilogramme of body weight there should be 2 grammes of proteid, 1·5 gramme of fat, 6 grammes of carbohydrate, and 0·5 gramme of salts—in all about 10 grammes or 1 per cent. of solid food.

This is the dry food, but a certain amount of water (between 50 and 60 per cent. usually) is contained in ordinary food, and adding this to the water-free solids, the total daily amount of so-called dry food (exclusive of liquids) is about 48 to 60 ounces. In addition to this, from 50 to 80 ounces of water are taken in some liquid form, making a total supply of water of

70 to 90 ounces, or an average of 0·5 ounce for each pound weight of body. The proportion of the nitrogenous substances to the fats, carbo-hydrates, and salts in the standard diets is practically as follows :—Proteids 100, fats 65, carbo-hydrates 315, and salts 23. In all diets, a certain proportion between the carbon and nitrogen ought to be maintained; in the best diets this is, nitrogen 1 to carbon 15.

This average amount of food and water varies considerably from the following causes :—

1. Individual conditions of size, vigour, activity of circulation, and of the eliminating organs, &c. No men eat exactly the same, and no single standard will meet all cases. The usual average range in different male adults is from 40 to 60 ounces of so-called solid food, and from 50 to 80 ounces of water. The following table, after König, shows the *minimum* daily need of food-stuffs at different ages :—

Age or Condition.	Proteids.		Fats.		Carbo-hydrates.	
	Ounces.	Grammes.	Ounces.	Grammes.	Ounces.	Grammes.
Child up to 1½ year,	0·7–1·26	20–36	1–1·6	30–45	2·1–3·1	60–90
Child from 6 to 15 years,	2·45–2·8	70–80	1·3–1·75	37–50	8·75–14	250–400
Adult man,	4·1	118	1·96	56	17·5	500
Adult woman,	3·2	92	1·54	44	14·0	400
Old man,	3·5	100	2·38	68	12·25	350
Old woman,	2·8	80	1·75	50	9·1	260

2. Differences of exertion. If men are undergoing great exertion they take more food, and, if they can obtain it, the increase is especially in the classes of proteids and fat.

This would represent of so-called solid food from 66 to 77 ounces (1870 to 2180 grammes).

The amount of water is also increased, but is very various according to circumstances, and is apparently not so much augmented as the solid food.

3. Differences of climate. It is a matter of general belief that more food is taken in cold seasons and in cold countries than in hot. It is supposed that more energy in some form (finally in that of heat) is necessary, and more food is required; but there may be other causes, such as varying exertion.

Having, therefore, an established series of dietetic standards and a knowledge of the chief points to which attention must be directed in regard to food, it is important to be able to examine any given diet in the light of these facts, and be able as well to construct a dietary. To do this, however, it is necessary to have some knowledge of the mean composition of the various articles of diet. The following table, constructed from various sources, shows the percentage composition of the more ordinary articles of food :—

Articles of Food.	In 100 parts.					
	Proteids.	Fats.	Carbohydrates.	Salts.	Nitrogen.	Carbon.
Beef, lean,	20·0	3·5	...	1·6	3·2	12·62
,, medium,	20·5	8·4	...	1·6	3·28	15·37
,, very fat,	16·75	19·0	...	3·5	2·68	22·62
Veal, lean,	18·88	4·41	...	0·5	3·02	12·74
,, fat,	19·20	7·20	...	1·33	3·07	15·00
Mutton, medium,	17·11	5·77	...	1·33	2·73	12·87
,, very fat,	16·62	25·61	...	1·10	2·65	27·50
Pork, lean,	20·25	6·81	...	1·10	3·24	15·43
,, fat,	14·54	37·34	...	0·80	2·32	35·27
Bacon, dried,	8·80	73·30	...	2·90	1·40	59·40
Ham, smoked,	24·00	36·50	...	10·10	3·84	39·37
Meat powder, dried,	69·50	5·84	0·42	13·25	11·12	39·08
Horseflesh,	21·71	2·60	...	1·10	3·47	12·80
Herring,	14·55	9·00	...	1·78	2·32	11·25
Pike,	18·42	0·53	...	1·00	2·94	9·60
Carp,	21·86	1·00	...	1·33	3·49	11·68
Salt cod, .	27·00	0·36	...	22·00	4·32	13·77
Canned meat (American),	29·00	11·50	...	3·60	4·64	23·10
Corned beef (Chicago),	23·30	14·00	...	4·00	3·72	22·00
Pemmican,	35·40	55·20	...	1·8	5·60	59·10
Poultry,	21·00	3·80	...	1·2	3·36	13·35
Ham sausage,	12·87	24·43	10·52	3·3	2·05	29·48
Beef sausage,	27·31	19·88	15·10	5·5	4·36	35·35
Eggs, hen's,	13·50	11·60	...	1·0	2·16	15·45
Milk, cow's,	4·20	3·70	4·50	0·7	0·67	6·67
,, goat's, .	4·29	4·70	4·60	0·76	0·68	7·50
,, condensed, English,	12·00	8·40	50·80	2·00	1·92	32·62
,, ,, Swiss, sweetened,	12·30	11·00	48·70	2·40	1·96	33·88
,, ,, ,, unsweetened,	11·35	11·25	13·35	2·00	1·81	19·44
Cream,	2·70	26·70	2·80	1·80	0·43	22·49
Butter, fresh,	2·00	85·00	...	1·00	0·32	64·75
,, salt,	...	80·00	...	3·00	...	60·00
Margarin,	0·75	82·00	...	5·22	0·12	61·87
Cheese, Dutch, .	28·00	23·00	1·00	7·00	4·48	31·50
,, single Gloster,	31·00	28·50	...	4·50	4·96	36·80
,, poor quality,	32·00	9·00	7·00	4·00	5·12	25·55
Eels,	12·50	28·50	...	1·50	2·00	27·55
Goose, .	16·00	45·50	...	0·50	2·56	41·90
Bread, average wheaten,	8·00	1·50	49·20	1·30	1·28	27·25
Biscuits, .	10·60	1·30	73·40	1·70	1·70	41·94
Flour, wheat of average quality,	11·00	2·00	71·20	0·80	1·76	39·04
Barley meal,	12·70	2·00	71·00	3·00	2·03	39·80
Oat meal,	12·60	5·60	63·00	3·00	2·01	38·85
Maize,	10·00	6·70	64·50	1·40	1·60	39·03
Macaroni, .	9·00	0·30	76·80	0·80	1·44	39·87
Arrowroot,	0·80	...	83·50	0·30	0·12	38·00
Potatoes,	2·00	0·16	21·00	1·00	0·32	10·57
Peas,	22·00	2·00	53·00	2·40	3·52	36·35
Rice,	5·00	0·80	83·20	0·50	0·80	40·50
Turnips,	1·00	0·20	6·80	1·00	0·16	3·37
Parsnips,	1·30	0·70	14·50	1·00	0·20	6·96
Carrots,	1·00	0·20	10·00	1·00	0·16	4·65
Cabbage,	5·00	0·50	7·80	1·20	0·80	6·00
Soja beans, . .	33·40	17·70	29·10	4·10	5·34	41·54
Cocoa powder (Dutch),	19·66	13·61	12·60	3·60	3·13	25·00
Chocolate (French),	6·18	20·00	54·00	2·20	0·98	39·69

Calculation of Diets.—Of course the above figures are largely approximate, but are sufficiently accurate for the calculation of any dietary, the mode of doing which is very simple. The quantity of uncooked meat or bread being known, and it being assumed or proved that there is no loss in cooking, a rule of three brings out at once the proportions. Thus, the ration allowance of meat for soldiers being 12 ounces, 2·4 ounces, or 20 per cent., is deducted for bone, as the soldier does not get the best parts. The quantity of proteid in the remaining 9·6 ounces will be $\frac{20{\cdot}5 \times 9{\cdot}6}{100} = 1{\cdot}96$, the fats will be 0·8064, and the salts 0·1536 ounce. So again, in the case of eggs, if two eggs be used, each weighing 2 ounces, 10 per cent. must be deducted for shell from the weight of egg. This gives 3·6 ounces as the nett weight of egg available, and taking the composition of eggs to be as given in the table, we get, proteids 0·48 ounce, fats 0·41 ounce, and 0·036 ounce of salts from the two eggs.

Whenever practicable, the nutritive value should be calculated on the raw substance, as the analyses of cooked food are more variable. Allowance must then be made for any loss which occurs in cooking: this should not be great, but very often in ordinary domestic cooking this may amount to as much as 30 or 40 per cent.

In a converse way, supposing a diet is required to yield 5 ounces of proteid, 3 ounces of fat, 15 ounces of carbo-hydrate, and 1 ounce of salt, we can calculate how much bread, salt butter, and Dutch cheese would be needed to supply it:—

The percentage composition of these may be taken to be:—

	Proteids.	Fats.	Carbo-hydrates.	Salts.
Bread, .	8	1	50	1·5
Salt butter,	...	80	...	3·0
Dutch cheese,	28	23	1	7·0

Calling the bread *a*, the butter *b*, and the cheese *c*, we get the following equations:—

$$(1)\ \frac{8a + 28c}{100} = 5 \text{ (proteid).}$$

$$(2)\ \frac{1a + 80b + 23c}{100} = 3 \text{ (fats).}$$

$$(3)\ \frac{50a + 1c}{100} = 15 \text{ (carbo-hydrates).}$$

Simplifying these equations, we get the following:—

$$\begin{array}{ll} (1)\ 8a + 28c & = 500. \\ (2)\ 1a + 80b + 23c & = 300. \\ (3)\ 50a + 1c & = 1500. \end{array}$$

These can be further resolved thus:—

$$\begin{array}{lr} (3)\ 50a + 1c = 1500 \times 28 = & 1400a + 28c = 42{,}000 \\ (1)\ 8a + 28c = 500 \qquad = & \underline{8a + 28c = \qquad 500} \\ & 1392a \qquad = 41{,}500 \end{array}$$

$$a = 29{\cdot}8 \text{ ounces.}$$

If $a = 29{\cdot}8$, then equation 3 becomes—

$$1c = 1500 - 1490.$$
$$c = 10 \text{ ounces.}$$

If $a = 29{\cdot}8$, and $c = 10$, then equation 2 becomes—

$$80b = 300 - 20{\cdot}8 - 230.$$
$$80b = 40{\cdot}2.$$
$$b = 0{\cdot}5 \text{ ounce.}$$

The answer being *a*, that is the bread, $= 29{\cdot}8$, or say 30 ounces.
b, ,, ,, butter, $= 0{\cdot}5$, or half an ounce.
c, ,, ,, cheese, $= 10{\cdot}0$ ounces.

To find the salts, we say—

Since the bread contains 1·5 per cent. . $\frac{29\cdot8\times1\cdot5}{100}=0\cdot447$ ounce.

,, butter ,, 3 ,, $\frac{0\cdot5\times3}{100}=0\cdot015$,,

,, cheese ,, 7 ,, $\frac{10\times7}{100}=0\cdot700$,,

The total salts are 1·162 ,,

That is, from 30 ounces of bread, 10 ounces of Dutch cheese, and ½ ounce of salt butter, we can obtain 5 ounces of proteid, 3 ounces of fat, 15 ounces of carbo-hydrates, and 1 ounce of salts.

Although such a diet fulfils theoretical requirements, practical experience would soon show that it was insufficiently varied. It is the great diversity which exists as regards the food consumed by the human race in all parts of the world that is the most remarkable feature in the study of dietaries. Some people live upon a wholly vegetable, others on a wholly animal, and others on a mixed diet. It has already been explained how unsuited any single vegetable food, such as bread, or any single animal food, such as meat, is to supply the daily requirements of the body, and how a judicious mingling of the various food-stuffs affords the greatest nourishment in the least bulk. The mixed diet may be regarded as that which in Nature's plan is designed for man's sustenance. On this he appears to attain the highest intellectual and physical vigour, and it is this diet which he consumes by general inclination when circumstances allow the inclination to guide him; also it is in conformity with the construction of his teeth and the arrangements of his digestive apparatus in general. However, where custom and habit have given certain races a peculiar suitability for a purely vegetable diet, the arguments in favour of a mixed diet are not sufficiently strong for the reversal of the customs of many ages.

For translating or changing the elements of a diet into terms of food articles, or *vice versâ*, it is important to remember that no mere calculation of the amounts of food-stuffs can properly measure the efficiency of any particular diet, but that other conditions must be considered; the chief of these will be relative to absorbability of proteid, digestibility of food, and the effects of cooking.

Absorbability of Proteid.—In attempting to form an opinion concerning the value of the different animal and vegetable foods, especially from analytical tables, we should always take into consideration the following points. In the case of many articles of food the amount of proteid cannot be said to have been accurately determined; the amount of nitrogen only has been ascertained, and from this the amount of proteid has been calculated under the supposition that no other nitrogen compound exists in the food, and that all kinds of proteids contain 16 per cent. of nitrogen. Now both these assumptions are wanting in exactness. As a matter of fact, the nitrogen in the various proteids varies from 15 to 19 per cent. The other assumption, that foods contain no other nitrogenous compound but proteid, holds good only in the case of the cereals and leguminosæ; for in most of the other vegetables, ammonia, amides, amido acids, nitric acid, &c., are found in considerable quantities, so much so that, in certain kinds of vegetables the nitrogen of these compounds equals more than a third of the entire nitrogen.

Again, we are hardly justified in calculating the proteid in meat from its nitrogen, because some of this nitrogen comes from gelatin-yielding substances, which, as we have already learnt, have a somewhat different action in nutrition to that of proteid. The gelatin-yielding substances of animal food have been aptly expressed as being more analogous to the carbo-hydrates of vegetable food than to proteids. If, therefore, we judge the nutrient values of meat and vegetables too closely from tables, according to their relative values of proteid as ordinarily, and in the present state of our knowledge necessarily, expressed, we run a danger of rating meat too highly, and vegetables not highly enough.

Another point we must bear in mind is that animal food is much more completely absorbed than vegetable food. The capability of absorption of the proteid in different foods has been accurately tested by Rubner, Strümpell, Meyer, and others, by a careful comparison of the amount of nitrogen in the nutriment taken with that in the fæces. They have shown that the proteid of meat and milk almost entirely disappears, but that a considerable part of the proteid of bread reappears in the dejecta, while a still larger proportion is unabsorbed from vegetables. The actual figures for the percentage of unabsorbed proteid being 2·8, 2·9, 20, and 32 from meat, milk, bread, and potatoes respectively.

If we remember that children have to build up their organism, and to form a large amount of proteid, these facts may explain why they thrive better upon milk rich in absorbable proteid than upon dietaries affording an excess of starch, but relatively poor in digestible albumin. The frightful mortality among children of the lower classes is perhaps largely due to the want of assimilable proteid in their food. The essential difference between a child and an adult, from the dietetic point of view, is, that the child requires more proteid than carbo-hydrate, while the adult requires relatively less albumin and more carbo-hydrate; at the same time, the proteid which suits the adult does not necessarily suit the child, or *vice versâ*.

Digestibility of Food.—In order that food shall be digested and absorbed, two conditions are necessary: the food must be in a fit state to be digested, and it must meet in the alimentary canal with the chemical and physical conditions which can digest and absorb it.

Fitness for digestibility depends partly on the original nature of the substance, as to hardness and cohesion, or chemical nature, and partly on the manner in which it can be altered by cooking. Tables of degree of digestibility have been formed by several writers, and especially by Beaumont, by direct experiment on Alexis St Martin; but it must be remembered that these are merely approximative, as it is so difficult to keep the conditions of cooking equal.

Rice, tripe, whipped eggs, sago, tapioca, barley, boiled milk, raw eggs, lamb, parsnips, roasted and baked potatoes, and fricasseed chicken are the most easily digested substances in the order here given,—the rice disappearing from the stomach in 1 hour, and the fricasseed chicken in 2¾ hours. Beef, pork, mutton, oysters, butter, bread, veal, boiled and roasted fowls are rather less digestible,—roast beef disappearing from the stomach in 3 hours, and roast fowl in 4 hours. Salt beef and pork disappeared in 4¼ hours.

As a rule, Beaumont found animal food digested sooner than farinaceous, and in proportion to its minuteness of division and tenderness of fibre.

The internal conditions of abundance and proper composition of the alimentary fluids, and the action of the muscular fibres in moving the food, so that it shall be submitted to them, depend on the perfection of the nervous currents, the vigour of circulation, and the composition of the blood. Many of the digestive diseases the physician has to treat depend on alterations in these conditions, so that the food is only imperfectly digested. Experiments, by Plôsz, Maly, and Gyergyai, seem to show the value of converting the proteids into peptones by artificial digestion, so as to aid the digestion of the sick, and clinical experience has amply confirmed this opinion.

The admixture of the different classes of foods aids digestibility; thus fat taken with meat aids the digestion of the meat;* some of the accessory foods probably increase the outpour of saliva, gastric juice, or intestinal secretion.

The fat of all food is very completely absorbed, far more so than the proteids. The same is true of all the carbo-hydrates, with the single exception of cellulose. This was held to be totally indigestible until quite recently, when it was proved, by experiments on ruminants, that from 60 to 70 per cent. of woody fibre does disappear from the digestive canal. Though cellulose can scarcely be classed among the food-substances of human beings, it fulfils an important part by acting as a mechanical stimulus of peristaltic action, and from a dietetic point of view its amount is not without interest.

The degree of fineness and division of food; the amount of solidity and of trituration which should be left to the teeth, in order that the fluids of the mouth and salivary glands may flow out in due proportion; the bulk of the food which should be taken at once, are points seemingly slight, but of real importance. There is another matter which appears to affect digestibility, viz., variety of food.

According to the best writers on diet, it is not enough to give the proximate dietetic substances in proper amount. Variety must be introduced into the food, and different substances of the same class must be alternately employed. It may appear singular that this should be necessary; and certainly many men, and most animals, have perfect health on a very uniform diet. Yet there appears no doubt of the good effects of variety, and its action is probably on primary digestion. Sameness cloys; and with variety more food is taken, and a larger amount of nutriment is introduced. It is impossible, with rations, to introduce any great variety of food; but the same object appears to be secured by having a variety of cooking. In the case of children, especially, a great improvement in health takes place when variety of cooking is introduced.

Cooking of Food.—By cooking, food is rendered more pleasing to the eye, agreeable to the palate, and digestible by the stomach. Apart from its power of removing any obnoxious property in a food by killing any parasites or disease germs existing in it, cooking so alters the texture of a food as to render it more easy of mastication and subsequent reduction to a fluid state by the stomach. Thus a piece of meat, before cooking, is tough and stringy, but when cooked the muscular fibres are given a firmness from the coagulation of their albumin, and the connective tissue which binds the muscle fibres together is made into a soft and jelly-like mass: in other words, during the cooking of animal food there is a gradual but not complete coagulation of the proteid constituents, a formation of gelatin from the connective tissues, with a partial disintegration of the whole, and a loss of salts. In the same way, cooking makes vegetables and grains softer, loosens their structure, and enables the digestive juices to penetrate into their substance. During cooking, the globulins and albumins of vegetables are coagulated by the heat to which they are subjected, while the starch undergoes a complete change. The effect upon the starch is chiefly to burst the coats of cellulose, so that the grain swells and the starch is practically set free. By boiling, the starch is largely converted into the so-called "soluble starch," which, although of the same chemical com-

* As experiencias de Pawlow provam que as gorduras, diminuindo a sec[illegible], retardam a digestão.

position as natural starch, is more readily acted upon by the saliva and pancreatic juice. Bread-making is an instance of the effect of cooking upon vegetable food-substances in the direction of a more or less artificial digestion, since some of the starch of the flour is transformed into dextrin and maltose, the glutin being semi-coagulated. The warmth imparted to food during cooking further aids digestion, and exerts a salutary effect on the system.

Practically there are six common methods of cooking: namely, boiling, stewing, roasting, broiling or grilling, baking, and frying: each of these presents some special features.

Boiling.—This may have for its object either the extraction from the food of its nutritive principles or their retention in it. If we wish to extract all the goodness of meat into some surrounding liquid such as water, as when we make a soup or broth, the article should be finely cut up and placed in cold water. After it has soaked for a while, heat should be applied slowly; if a broth is to be made, the heat, though constantly applied, is not allowed to reach actual boiling for some time, by which procedure much of the albumin of the meat is extracted before the subsequent greater heat has been able to coagulate it, and, all the natural juices having for the most part flowed out, the meat itself is left in a nearly tasteless state, but still not without some nutritive value. In the making of a soup the same procedure is adopted, with this difference however, that the boiling is kept up somewhat longer, whereby more of the gelatin of the meat is extracted and the actual meat itself, owing to more complete deprivation of its constituent juices, rendered still more tasteless and less nutritious. Thus treated, the meat yields its essential principles to the surrounding liquid, which gains in flavour and nutritive properties. The essential difference between the broth and the soup being merely one of degree; that is, how much of the goodness of the meat passes out of it into the surrounding liquid. In the making of a broth some of the meat juices, gelatin and other constituents still remain in the meat, because the albumin is permitted to coagulate before they have all escaped; while in the other case practically nothing remains of the meat but fibrous tissue, all the rest having passed out into the soup. A due appreciation of this difference between a broth and a soup is important, especially the fact that after the making of a broth the meat residue has still considerable nutritive value, whereas after the preparation of a soup the meat residue has none.

If, on the other hand, the object of boiling is not to extract the constituents out of meat, but rather to retain in it all its flavour and nutriment, then it should not be cut up, but left as a large piece, plunged suddenly into hot or nearly boiling water, and quickly brought to the boil. The application of sudden heat in this manner coagulates the albuminous matter on the surface of the meat, closes its pores, and makes an impermeable external coat which stops the escape of the juices from the inner and deeper parts. The actual period of boiling need not and should not last longer than a few minutes; after the coagulation of the external parts, the process of cooking ought to be conducted at a low temperature, not exceeding 160° F. or about 71° C. This is the true cooking point of meat; if the temperature be over 70° C., the proteid matters are not only completely solidified, but become, from their hardness, indigestible. Over-heating is, therefore, to be avoided; and the slower the cooking, the better the result. During cooking by boiling, the loss of weight in meat is commonly 20 per cent.

Stewing is commonly regarded as a mere modification of boiling: this is only partially true, because they are essentially opposite processes. The essential object in boiling, say a leg of mutton, is to so raise the temperature of the meat, using water as the medium by which the heat is conveyed to the meat, that it shall as nearly as possible retain all its juices. Now, in stewing, this is largely reversed, because the water is used not only as a heat giver, but also as a solvent for extracting out from the meat more or less of its juices. Much of this extraction of meat juice in stewing is more accurately expressed as an act of diffusion rather than of solution, capable of being best secured at high temperatures than low; but experiment teaches us that albumin, which so largely constitutes the diffusible juice of meat, coagulates and gets hard and tough if long exposed to a heat anything near the boiling point of water; hence the need, if stewing is to be properly done, and the meat not rendered so tough, curled and hard as to be more or less uneatable, that the process of stewing should be performed at a temperature of 160° F. or so. This can be readily done if a *bain-marie* or water bath be used. The ordinary carpenter's glue-pot is a familiar form of water bath, being simply a vessel immersed in an outer vessel of water. The water in the outer vessel may boil, but that in the inner one never does, because evaporation from its surface keeps its temperature lower than that of the water from which it gets its heat. All well-equipped kitchens have these double vessels, and every ironmonger sells them; but in the absence of such a double saucepan, every housewife can readily improvise one by performing the stewing in an earthenware jar or glass placed within an ordinary saucepan containing water. It is the more general appreciation of the value and use of the water-bath mode of stewing by French men and women that makes their average cooking so much higher than that of the average English man or woman. English people are apt to speak with contempt of the stewed beef of the Frenchman, forgetting the fact that he never eats it alone, but always associated with a soup or *potage*, which really contains the juices of the beef; and the two dishes combined constitute identical and quite as nutritious articles of diet as the British joint.

Hashing is the same process as stewing, only that the meat has been previously cooked instead of being fresh.

Before dismissing this subject of stewing, a few remarks upon the making of ordinary beef-tea or beef extracts as sold under the names of "extract of meat" and "Bovril" may not be inappropriate, particularly as they afford some points of difference from the juices of an ordinary stew. Beef-tea is made by chopping up lean meat very finely and then macerating it in cold water, and the broth thus obtained is heated in order to alter its raw flavour. During this heating, which should not exceed 160° F., or just sufficient to coagulate the albumin and colouring matter, a sort of scum rises to the surface; much of this is fat, and is rightly removed, but if the heating is carried too high some of the other nutritious elements coagulate on the surface, and get removed instead of being left behind. If well prepared, beef-tea is a highly nutritive and restorative liquid, with an agreeable, rich, meaty flavour. If badly prepared, by being subjected to prolonged boiling, beef-tea is merely a solution of the non-coagulable saline constituents of meat—namely, bodies known as kreatin, kreatinin, lactic acid, and phosphates. These are all most excellent, but to be regarded as stimulants rather than as nutrients. This explains why in some states of prostration, during illness, when the blood is insufficiently supplied with these flesh juices, the administration of beef-tea, beef extracts, and such-like preparations does much good; but the danger lies in their being regarded as foods suitable for the normal sustenance of the body. This they are not, and, from the very nature of their composition, wanting largely of the nutritious constituents of meat, they never can be.

Roasting.—Just as stewing may be regarded as the national method of cooking on the Continent, so may roasting be regarded as our national method of flesh cooking. Roast meat is usually thought to be more savoury but less digestible than when either boiled or stewed, while, too, the loss is greater, but the same principle underlies it, namely, the retention of the nutritive juices by the formation of a coagulated layer on the surface. In roasting, the juices of the meat are retained (with the exception of those which escape as gravy on the dish), while in stewing they go more or less completely into the water. In stewing, the heat is communicated to the meat by convection or actual contact; in roasting, the heat is nearly all dry heat radiated to the surface of the joint from the fire. The high temperature rapidly given by radiation to the meat surface forms a thin crust of hardened and half-carbonised albumin; this prevents the evaporation of the meat moisture, sets up a certain amount of pressure inside the joint resulting in the gradual loosening of the fibres and raising of the deeper parts of the flesh to the cooking temperature of about 160° F. In all roasting processes, to hasten its course and prevent burning of the superficial parts, the joint is *basted* or kept constantly enveloped in a varnish of hot melted fat, which, while assisting in the communication of heat, checks the undue evaporation of the juices, or in other words, during roasting heat convection is established by the medium of a fat bath, while in stewing or boiling it is supplied by a water bath.

The average loss on roasting is from 31 to 35 per cent. in weight.

Broiling or *grilling* is the same in principle as roasting, but the scorching of the surface is greater, owing to the larger surface exposed to heat. *Baking* is analogous, except that the operation is carried on in a confined space, such as an oven. Owing to the limited space and want of ventilation in the chamber or oven in which baking is carried on, the condensed vapour from the article being cooked and the fatty acids, if it be meat, are prevented from escaping, rendering the food so cooked richer and stronger for the stomach. For these reasons, baked food is unsuitable for the sick and delicate. During baking, a joint of meat will lose from 20 to 30 per cent.

Frying, speaking generally, is a bad way of cooking, as owing to the heat being applied through the medium of fat, the article so cooked is penetrated with oily matter and is often indigestible. In frying, the heat is applied usually much above that of boiling water, as the medium, fat, can be heated much above 212° F. before it boils; and it is probably largely to the difference of temperature to which fish is subjected in the two processes that causes the difference between a boiled sole or mackerel and a fried one. Over and above this, their difference may be due to the fact that the flavouring juices are retained in the flesh of the fried fish, while more or less of them escape into the water in which they are boiled.

DISEASES CONNECTED WITH FOOD.

The diseases connected with food form, probably, the most numerous order which proceeds from a single class of causes; and so important are they, that a review of them is equivalent to a discussion on diseases of nutrition generally.

It is, of course, impossible to do more here than outline so large a topic.

Diseases may be produced by alterations (excess or deficiency) in quantity; by imperfect conditions of digestibility, and by special characters of quality.

Excess of Food.—In some cases, food is taken in such excess that it is not absorbed; it then undergoes chemical changes in the alimentary canal, and at last putrefies; quantities of gas (carbon dioxide, carburetted hydrogen, and hydrogen sulphide) are formed. Dyspepsia, constipation, and irritation, causing diarrhœa which does not always empty the bowels, are produced, sometimes some of the putrid substances are absorbed, as there are signs of evident poisoning of the blood, a febrile condition, torpor and heaviness, fœtor of the breath, and sometimes possibly even jaundice. It was, no doubt, cases of this kind which led to the routine practice of giving purgatives; and as this condition, in a moderate degree, is not uncommon, the use of purgatives will probably never be discontinued.

The excess of food may be absorbed. The amount of absorption of the different alimentary principles is not precisely known. Dogs can digest an immense quantity of meat, and especially if they are fed often, and not simply largely once or twice a day. In men, also, much meat and albuminous matter can be digested, though it is by no means uncommon, in large meat-eaters, to find much muscular fibre in the fæces. Still, enough ordinary meat (and fat) can be taken, not merely to give a large excess of nitrogen, but even to supply carbon in sufficient quantity for the wants of the system.

There is certainly a limit to the digestion of starch (though sugar is absorbed in large amount), as after a very large meal much starch passes unaltered. This is also the case with fat. But in all cases habit probably much affects the degree of digestive power; and the continued use of certain articles of diet leads to an increased formation of the fluids which digest them.

When excess of proteids continually passes into the system, congestions and enlargements of the liver, and probably of other organs, and a general state of plethora, are produced. If exercise is not taken at the same time, there is a disproportion between the absorbed oxygen and the absorbed proteids, which must lead to imperfect oxidation, and therefore to retention in the body of some substances, or to irritation of the eliminating organs by the passage through them of products less highly elaborated than those they are adapted to remove.

Although not completely proved, it is highly probable that gouty affections arise partly in this way, partly probably from the use of liquids which delay metamorphosis, and therefore lead to the same result as increased ingestion, and in some degree also from the use of indigestible articles of food.

Very often large meat-eaters are not gouty, and do not appear in any way over-fed. In this case either a great amount of exercise is taken, or, as is often the case in these persons, the meat is not absorbed, owing frequently to imperfect mastication.

A great excess of proteids, without other food, produces, in a short time, marked febrile symptoms, malaise, and diarrhœa; and, if persevered in, albumin appears in the urine. Ranke has attributed the depression especially to the effect of the salts of the meat.

Excess of starches and of fats delays the metamorphosis of the nitrogenous tissues, and produces excess of fat. Sometimes acidity and flatulence are caused by the use of much starch. It is not understood if profounder diseases follow the excessive use of starches, unless decided corpulence is produced, when the muscular fibres of the heart and of many voluntary muscles lessen in size, and the consequences of enfeebled heart's action occur. When an excessive quantity of starch is used to replace proteids, in physiological experiments, the condition becomes of course a complex one.

If an excess of starch be taken under any circumstances, much passes into the fæces, and the urine often becomes saccharine.

There may be also excess of food in a given time,—that is, meals too frequently repeated, though the absolute quantity in twenty-four hours may not be too great.

Deficiency of Food.—The long catalogue of effects produced by famine is but too well known, and it is unnecessary to repeat it here. But the effects produced by deficiency in any one of the four great classes of aliments, the other classes being in normal amount, have not yet been perfectly studied.

The complete deprivation of proteids, without lessening of the other classes, produces marked effects only after some days. In a strong man kept only on fat and starch, Parkes found full vigour preserved for five days; in a man in whom the amount of nitrogen was reduced one half, full vigour was retained for seven days. If the abstention be prolonged, however, there is eventually great loss of muscular strength, often mental debility, some feverish and dyspeptic symptoms. Then follow anæmia and great prostration. The elimination of nitrogen in the form of urea greatly lessens, though it never ceases, while the uric acid diminishes in a less degree. If starch be largely supplied, the weight of the body does not lessen for seven or eight days.

If the deprivation of proteids be less complete (70 to 100 grains of nitrogen being given daily), the body gradually lessens in activity, and passes into more or less of an adynamic condition, which predisposes to the attacks of all the specific diseases (especially of tuberculosis, typhus and of pneumonia); it also modifies the course of some of these diseases, as, for instance, of enteric fever, which runs its course, with less elevation of temperature than usual, and with less or with no excess of ureal excretion.

The deprivation of starches can be borne for a long time if fat be given, but if both fat and starch be excluded, though proteids be supplied, illness is produced in a few days. Nor is it difficult to explain this; as proteids contain 53·3 per cent. of total carbon (of which about 49 per cent. is available for nutrition) and 16 per cent. of nitrogen, to supply 4800 grains of carbon, no less than 1585 grains of nitrogen must be introduced, a quantity five times as great as the system can easily assimilate, unless enormous exertion be taken, and then the quantity of carbon becomes insufficient.

Men can be fed on meat for a long time, as a good deal of fat is then introduced, and if the meat be fresh (and raw?), scurvy is not readily induced.

The deprivation of fat does not appear to be well borne, even if starches be given; but the exact effects are not known. The great remedial effects produced by giving fat in many of the diseases of obscure malnutrition prove that the partial deprivation of fat is both more common and more serious than is supposed. In all the diets ordered for soldiers, prisoners, &c., the fat is greatly deficient in every country. The deprivation of the salts is also evidently attended with marked results, which are worthy of more attention than they have yet received.

Bad effects are also produced if the intervals between meals are too long; this is a matter in which there is great individual difference, and need not be further referred to.

Scurvy.—Closely connected with the subject of food and dietetics is the peculiar state of malnutrition called scurvy. This is now known not to be the consequence of general starvation, though it is doubtless greatly aided by it. Men have been fed with an amount of nitrogenous and fatty food sufficient not only to keep them in condition, but to cause them to gain weight, and yet have developed scurvy. The starches also have been given in quite sufficient amount without preventing it. It seems, indeed, clear that it is to the absence of some of the constituents of the fourth dietetic group, the salts, that we must look for the cause.

Facts seem to show with certainty that in the diet which gives scurvy there is no deficiency of soda or of iron, lime, or magnesia, or of chloride of sodium. Nor is the evidence that salts of potash or phosphoric acid are deficient at all satisfactory. And when we think of the quantity of phosphoric acid which must have been supplied in many diets of meat, and cerealia, which yet did not prevent scurvy, it seems very unlikely that the absence of the phosphates can have anything to do with it.

The same may be said of sulphur. Considering the quantity of meat and of leguminosæ which some scorbutic patients have taken, it is almost impossible that deficiency in sulphur should have been the cause.

By exclusion, we are led to the opinion that if the cause of scurvy is to be found in deficiency of salts, it must be in the salts whose acids form carbonates in the system. For, if we are right in looking to a deficiency in the fourth class of alimentary principles as the cause of scurvy, and if neither the absence of soda, potash, lime, magnesia, iron, sulphur, or phosphoric acid can be the cause, then the only mineral ingredients which remain are the combinations of alkalies with those acids which form carbonates in the system, viz., lactic, citric, acetic, tartaric, and malic. That these acids are most important nutritional agents no one can doubt. The salts containing them are at first neutral, afterwards alkaline, from their conversion into carbonates; they thus play a double part, and moreover, when free, and in the presence of albumin and chloride of sodium, these acids have peculiar powers of precipitating albumin, or perhaps of setting free hydrochloric acid. Whatever may be their precise action, their value and necessity cannot be doubted. Without them, in fact, one sees no reason why there should not be a continual excess of acid in the system, as during nutrition a continual excess of acids (phosphoric, sulphuric, uric, hippuric) is produced, sufficient, even when the salts with decomposable acid are supplied, to render all excretions (urinary, cutaneous, intestinal) acid. The only mode of supplying alkali to the acids formed in the body is by the action of the phosphates, which is limited. The only manufacture of alkali in the body is the formation of ammonia, so that these salts are most important as antacids. Yet it is not solely the absence of alkali which produces scurvy, else the disease would be prevented or cured by supply of pure or carbonated alkalies, which is not the case.

When, in pursuing the argument, we then inquire whether there is any proof of the deficiency of these particular acids and salts from the diets which cause scurvy, we find the strongest evidence not only that this is the case, but that their addition to the diet cures scurvy with great certainty. They will not, of course, cure coincident starvation arising from deficiency of food generally, or the low intercurrent inflammations which occur in scurvy, or the occasionally attendant purpura, but the true scorbutic condition is cured with certainty.

This was most clearly shown in the Arctic Expedition of 1875–6. The rations on board ship during the winter were ample, containing dried potatoes and other vegetables, preserved vegetables, pickles, bottled fruits, vinegar, and a daily ration of lime juice, besides raisins and currants. In the sledge expeditions all these were cut off except two ounces of preserved potatoes, an inadequate ration under any circumstances. The meat was pemmican and bacon, and there was, of course, no fresh bread. The result was, that this imperfect diet, conjoined with most laborious work, produced a severe outbreak of scurvy which nearly proved fatal to the whole party. The rapidity with which the sick recovered, on being supplied with lime juice and more favourable diet, was noticeable.

Of the five acids, it would appear unlikely that the lactic should be the most efficacious. If so, how is it that in starch food, during the digestion of which lactic acid is probably formed in large quantities, scurvy should occur? Is, in such a case, an alkali necessary to insure the change of the acid into a carbonate?

Vinegar is an old remedy for scurvy, and acetic acid is known to be both a preventive of (to some extent) and a cure for scurvy. But it has always been considered much inferior to both citric and tartaric acids. Possibly, as in the case of lactic acid, an alkali should be supplied at the same time, so as to enable the acid to be more rapidly transformed.

Tartaric and (especially) citric acids, when combined with alkalies, have always been considered to be the antiscorbutic remedies, *par excellence*, and the evidence on this point seems very complete.

It is based on a very wide experience, and should not be set aside by the statements of men who have seen only three or four cases of scurvy, often complicated, which happen not to have been benefited by lemon juice. The process of preventive medicine is checked by assertions drawn from a very limited experience, yet made with great confidence. We must remember that many cases of scurvy are complicated—that the true scorbutic condition, inanition, and low inflammation of various organs, lungs, spleen, liver, and muscles, may be all present at the same time.

Of malic acid little is known as an antiscorbutic agent, but it is well worthy of extended trials.

Deficiency of fresh vegetables implies deficiency in the salts of these acids, and scurvy ensues with certainty on their disuse. Its occurrence is, however, greatly aided by accessory causes, especially deficiency in food generally, by cold and wet, and mental and moral depression.

The preventive measures of scurvy are, then, the supply of the salts of citric, tartaric, acetic, lactic, and malic acids, and of the acids themselves, and perhaps in the order here given, and by the avoidance, if it can be done, of the other occasional causes.

Experience seems to show that the supply of these acids in the juices of the fresh succulent vegetables and fruits, especially the potato, the cabbage, orange, lime, and grape, is the best form. But fresh fruits, tubers, roots, and leaves are better than seeds. The leguminosæ, and many other vegetables, are useless.

Fresh, and especially raw, meat is also useful, and this is conjectured to be from its amount of lactic acid; but this is uncertain.

The dried vegetables are also antiscorbutic, but far less so than the fresh; and the experience of some recent wars has not been so favourable to them as might have been anticipated. Do the citric and other acids in the dried vegetables decompose by heat or by keeping? We know that the citric acid in lemon juice gradually decomposes. It does not follow that it should be quite stable in the dried vegetables.

The measures to be adopted in time of war, or in prolonged sojourns on board ship, or at stations where fresh vegetables are scarce, are—

1. The supply of fresh vegetables and fruits by all the means in our power. Even unripe fruits are better than none, and we must risk a little diarrhœa for the sake of their antiscorbutic properties. In time of war *every* vegetable should be used which it is safe to use, and, when made into soups, almost all are tolerably pleasant to eat.

2. The supply of the dried vegetables, especially potato, cabbage, and cauliflowers; turnips, parsnips, &c., are perhaps less useful; dried peas and beans are useless. As a matter of precaution these preserved or dried vegetables should be issued early in a campaign, but should never supersede the fresh vegetables.

Probably dried fruits, such as raisins and currants (which contain some acid and vegetable salts) are useful as antiscorbutics. The American pemmican contains them, and men are said to live upon it for months together without suffering from scurvy. It appears to have been that kind of pemmican on which the crew of the "Polaris" lived, who drifted on an iceberg for six months. Other dried fruits, such as apples, would probably also be efficacious.

3. Good lemon juice should be issued daily (1 ounce), and it should be seen that the men take it.

4. Vinegar (½ or to 1 ounce daily) should be issued with the rations, and used in the cooking.

The evils or diseased states which are the results of defects in the quality of food are not only many but so diverse, that it will be more convenient to discuss them under the headings of the different articles of food which immediately follow.

MEAT.

The advantages of meat as a diet are—its large amount of nitrogenous substances, the union of this with much fat, the presence of important salts (viz., chloride, phosphate, and carbonate of potassium, or a salt forming carbonate on incineration), and iron. It is also easily cooked, and is very digestible; it is probably more easily assimilated than any vegetable, and there is a much more rapid metamorphosis of tissue in carnivorous animals than in vegetable feeders. Whether the use of large quantities of meat increases the bodily strength or the mental faculties more than other kinds of nitrogenous food is uncertain. The great disadvantage of meat is the want of starch.

The composition of fresh and salt meat has been already given; but the figures in such tables give a very imperfect idea of the value of a ration. For the most part they refer to the meat proper, without taking into consideration the amount of gristle, &c., which makes up part of the ration. Thus in rations analysed at Netley the following results were obtained:—

	Rump of Beef.		*Shank of Mutton.*	
	Flesh alone.	Whole Ration, exclusive of Bone.	Flesh alone.	Whole Ration, exclusive of Bone.
Water,	74·0	60·5	71·9	52·7
Proteids,	22·0	21·5	18·8	13·0
Fat,	2·2	9·1	8·4	25·3
Ash,	1·6	1·3	1·0	0·9
Total,	99·8	92·4	100·1	91·9

In each case it will be observed that the analysis of the flesh alone does not deviate very widely from the tabulated statements, whereas the whole ration does so materially. In particular, there is about 8 per cent. of total weight unaccounted for, due to tough gristle and fibrous tissues not amenable to the ordinary methods of analysis. The detailed constituents of the proteids are also important, as the following results will show:—

Rump of Beef.

	Flesh alone.	Whole Ration, exclusive of Bone.
Digestible proteids,	13·5	14·2
Peptones,	2·5	2·2
Meat extracts,	1·2	0·9
Total useful,	17·2	17·3
Indigestible proteids,	4·8	4·2
Total proteids per cent. as above,	22·0	21·5

Shank of Mutton.

	Flesh alone.	Whole Ration, exclusive of Bone.
Digestible proteids,	7·6	4·0
Peptones,	2·0	1·5
Meat extracts,	5·5	2·9
Total useful,	15·1	8·4
Indigestible proteids,	3·7	4·6
Total proteids per cent. as above,	18·8	13·0

From this we see that there is great diversity in the value of different rations; the numbers given here may be taken to represent the extremes, so that the mean value may be assumed at about 17 per cent. of total proteids, and about 13 per cent. of useful (*i.e.*, assimilable) proteids.

Bone forms about 20 to 25 per cent. of the meat as sold. It is relatively more in young animals; in veal it constitutes as much as 30 per cent. Bones contain a large amount of nutrient matter, a considerable part of which is extracted by boiling, and more could be obtained if the bones were crushed. The following was the composition of the bones in the beef ration:—

Water,	12·1
Proteids,	24·5
Fat,	11·0
Ash,	48·6
Loss,	3·8
Total,	100·0

Constituents of proteids—	
Digestible proteids,	10·3
Peptones,	1·9
Extractives,	1·0
Total useful,	13·2
Indigestible proteids,	11·3
Total,	24·5

Bones make a most palatable soup, and, as above shown, may be made to yield an important addition to the useful proteids.

Another measure of the value of meat is the amount of extract which can be obtained from it by means of hot and cold water. Pure flesh should yield about 6 per cent., of which about 5 per cent. should be organic; but the average of a ration would, of course, be less. Thus in the beef ration already mentioned the total extract of the flesh was 6·1, and the organic 4·95; whilst the whole ration (bone excluded) gave a total of 3·6, of which 2·8 was organic.

The salts or ash of meat consist of chlorides and phosphates chiefly, more than a third of the ash consisting of phosphoric acid. Stölzel found 8·9 per cent. of carbonic acid in the ash, which probably indicates lactic acid, and it is suggested that this may perhaps give fresh raw meat some anti-scorbutic properties which may be altered by cooking. The ash is alkaline.

Preserved tinned beef (from Chicago, Australia, and New Zealand) is very good meat, palatable, and more nutritious than the more strongly salted beef. Only 10 per cent. of its total proteids (which ranged from 18 to 31 per cent.) was found to be indigestible in experiments at Netley. The amount of extract is a little less than in fresh meat, as some is necessarily lost in the salting and compressing, but it was found to be 6 per cent., of which 4 was animal. The nutritious value of fully salted rations is much more uncertain.

Inspection of Animals.—Animals should be inspected twenty-four hours before being killed. In this country killing is done twenty-four or forty-eight hours before the meat is issued; in the tropics only ten or twelve hours previously.

Animals should be well grown, well nourished, and neither too young nor too old. The flesh of young animals is less rich in salts, fat, and syntonin, and also loses much weight (40 to 70 per cent.) in cooking.

Weight.—An ox should weigh not less than 600 ℔, and will range from this to 1200 ℔. The French rules fix the minimum at 250 kilogrammes (= 550 ℔). The mean weight in France is 350 kilogrammes (= 770 ℔). A cow may weigh a few pounds less; a good fat cow will weigh from 700 to 740 ℔. A heifer should weigh 350 to 400 ℔. The French rules fix the minimum of the cow's weight at 160 kilogrammes (= 352 ℔). The mean weight of cows in France is 230 kilogrammes (= 506 ℔).

There are several methods of determining the weight; the one most commonly used in this country is to measure the length of the trunk from just in front of the scapulæ to the root of the tail, and the girth or circumference just behind the scapulæ; then, by multiplying the square of the girth by 0·08 and the product by the length, the dimensions in cubic feet are obtained; each cubic foot is supposed to weigh 42 ℔ avoirdupois. The formula is $(C^2 \times 0{\cdot}08) \times L \times 42$; or $\frac{2}{3}(C^2 \times 5L)$; the result in either case gives the weight in pounds avoirdupois.

The animal is divided into carcass and offal; the former includes the whole of the skeleton (except the head and feet), with the muscles, membranes, vessels, and fat, and the kidneys and fat surrounding them. The offal includes the head, feet, skin, and all internal organs except the kidneys. An ox or cow gives about 60 per cent. of meat, exclusive of the head, feet, liver, lungs, and spleen, &c. The skin is $\frac{1}{18}$ of the weight; the tallow $\frac{1}{12}$. In very fat cattle the weight may be 5 per cent. more, and in very lean cattle 5 per cent. less than the actual weights found by this rule.

A full-grown sheep will weigh from 60 to 90 ℔, but the difference in different breeds is very great. It also yields about 60 per cent. of available food. The average weight of a sheep in India is from 30 to 40 ℔.

A full-grown pig weighs from 100 to 180 ℔ or more, and yields about 75 to 80 per cent. of available food.

Age.—The age of the ox should be from three to eight years, and a heifer or cow not under two or more than four years old; the age is told chiefly by the teeth, and less perfectly by the horns. The temporary teeth are in part through at birth, and all the incisors are through in twenty days; the first, second, and third pairs of temporary molars are through in thirty days; the teeth are grown large enough to touch each other by the sixth month; they gradually wear and fall in eighteen months; the fourth permanent molars are through at the fourth month; the fifth at the fifteenth; the sixth at two years. The temporary teeth begin to fall at twenty-one months, and are entirely replaced by the thirty-ninth to the forty-fifth month; the order being—central pair of incisors gone at twenty-one months; second pair of incisors at twenty-seven months; first and second temporary molars at thirty months; third temporary molars at thirty months to three years; third and fourth temporary incisors at thirty-three months to three years. The development is quite complete at from five to six years. At that time the border of the incisors has been worn away a little below the level of the grinders. At six years the first grinders are beginning to wear, and are on a level with the incisors. At eight years the wear of the first grinders is very apparent. At ten or eleven years the used surfaces of the teeth begin to bear a square mark surrounded with a white line; and this is pronounced on all the teeth by the twelfth year; between the twelfth and fourteenth year this mark takes a round form.

The rings on the horns are less useful as guides. At ten or twelve months the first ring appears; at twenty months to two years, the second; at thirty to thirty-six months, the third ring; at forty to forty-six months, the fourth ring; at fifty-four to sixty months, the fifth ring, and so on. But at the fifth year the first three rings are indistinguishable, and at the eighth year all the rings. Besides, the dealers file the horns.

In the sheep, the temporary teeth begin to appear in the first week, and fill the mouth at three months; they are gradually worn and fall at about fifteen or eighteen months. The fourth permanent grinders appear at three months, and the fifth pair at twenty to twenty-seven months. A common rule is "two broad teeth every year." The wear of the teeth begins to be marked at about six years. Sheep fit for slaughter should always have a clean even set of teeth. In the army, those with broken teeth are rejected.

The age of the pig is known up to three years by the teeth; after that there is no certainty. The temporary teeth are complete in three or four months; about the sixth month the premolars, between the tusks and the first pair of molars, appear; in six or ten months the tusks and posterior incisors are replaced; in twelve months to two years the other incisors; the four permanent molars appear at six months; the fifth pair at ten months; and the sixth and last molars at eighteen months.

Condition and Health.—The condition of live cattle is generally told by the handling points, of which as many as twelve are given, but only five need be mentioned, as an animal which is good in these five points is sure to be good in the rest. They are the natches, or the bones by the side of the tail, the twist, the flank, the cod or udder, and the rib. The flesh on all these handling points should feel compact and firm, the twist or parts between the two buttocks should stand prominently out, the flank should be the full of the hand and should appear to meet your hand and drop into it as you handle the animal, the rib should be well covered with compact flesh, and the cod or udder should be a large lump of firm fat. In half-fed animals the flesh will not be so firm to the touch as in fully fed ones; the meat of such half-fed cattle wastes very considerably in the cooking, owing to the cells of the adipose tissue being filled with imperfectly formed fat. To be able to tell the condition of a beast by handling requires some practice.

As showing health, we should look to the general ease of movements, the quick bright eye; the nasal mucous membrane red, moist, and healthy-looking; the tongue not hanging; the respiration regular, easy; the expired air without odour; the circulation tranquil; the excreta natural in appearance.

When sick, the coat is rough or standing; the nostrils dry or covered with foam; the eyes heavy; the tongue protruded; the respiration difficult; movements slow and difficult; there may be diarrhœa; or scanty or bloody urine, &c. In the cow the teats are hot.

Diseases of Animals used for Food.—The diseases of cattle which the inspecting officer should watch for are—

1. *Pleuro-pneumonia.*—The commencement of the attack is very insidious: it is not easily recognised at first. The temperature

soon rises to 104° or 105° F. and the animal refuses food; a short dry cough develops and the breathing becomes laboured and painful.

2. *Foot-and-Mouth Disease* (murrain, aphtha, or eczema epizoötica).—At once recognised by the examination of the mouth, feet, and teats.
3. *Cattle Plague* (typhus contagiosus, Steppe disease, Rinderpest).—Recognised by the early prostration (hanging of head, drooping of ears), shivering, running from eyes, nose, and mouth, peculiar condition of tongue and lips, cessation of rumination, and then by abdominal pain, scouring, &c.
4. *Anthrax.*—This either appears as a general, or as a localised affection: in the former case it is called apoplectic anthrax, splenic fever, or anthrax fever: in the latter, anthracoid erysipelas or carbuncular fever. If boils and carbuncles form, they are at once recognised: if there is erysipelas, it is called black quarter, quarter ill, or blackleg (erysipelas carbunculosum), and is easily seen. The peculiar organism, *Bacillus anthracis*, may be detected in the blood.
5. *Tuberculosis* (perlsucht, "grapes").—Sometimes acute, more often chronic: at first dulness and indifference, increased sensibility, especially of back-muscles and chest-walls, but no emaciation and no diminution of production of milk; later, emaciation comes on, loss of appetite, shortness of breath, and cough; these symptoms become intensified, with hectic.
6. *Actinomycosis.*—Caused by "ray-fungus"; attacks by preference the lower jaw and tongue, also the lungs and bones; leads to general malnutrition, and is sometimes fatal.
7. *Dropsical affections* from kidney or heart disease.
8. *Indigestion*, often combined with apoplectic symptoms.

A great number of other diseases attack cattle, which it is not necessary to enumerate. All the above are tolerably easily recognised. The presence of *Tænia mediocanellata* cannot, it would seem, be detected before death.

The diseases of sheep are similar to those of cattle; they suffer also in certain cases from splenic apoplexy or "braxy," which is considered by Professor Gamgee to be a kind of anthrax, and is said to kill 50 per cent. of all young sheep that die in Scotland; the animals have a "peculiar look, staggering gait, bloodshot eyes, rapid breathing, full and frequent pulse, scanty secretions, and great heat of the body." The disease is induced by errors in feeding.

The small-pox in sheep (*Variola ovina, clavelée* of the French) is easily known by the high fever, especially during the pustular stage, by the flea-bitten appearance of the skin in the early stage, and by the rapid appearance of nodules or papulæ and vesicles.

The sheep is also subject to black quarter (*Erysipelas carbunculosum*); one limb is affected, and the limp of the animal, the fever, and the rapid swelling of the limb are sufficient diagnostic marks.

The sheep, of course, may suffer from acute lung affection, scouring, red water (hæmaturia), and many other diseases. Of the chronic lung affections, one of the most important is the so-called "phthisis," which is produced by the ova of *Strongylus filaria.* This entozoon has not yet been found in the muscles, and the meat is said to be good. The rot in sheep (fluke disease) is caused by the presence of *Distomum hepaticum* in large numbers in the liver, and sometimes by other parasites. The principal symptoms are dulness, sluggishness, followed by rapid wasting and pallor of the mucous membrane, diarrhœa, yellowness of the eyes, falling of the hair, and dropsical swellings. The animal is supposed to take in *Cercaria* (the embryotic stage of *distoma*) from the herbage. The so-called "gid," "sturdy," or "turnsick," is caused by the development of *Cœnurus cerebralis* in the brain.

The pig is also attacked by anthrax in different forms, by muco-enteritis, and by hog cholera. The swelling in the first case, and the severe fever, accompanied with fœtid diarrhœa and prostration in the second, are sufficient diagnostic marks. It has no relation whatever to enteric fever in man (Walley). The condition of the flesh is similar to that produced by septic disease, and it is totally unfit for human food.

Cobbold pointed out that the pig is affected, both in America and Australia, with a large parasite (*Stephanurus dentatus*). This worm is found chiefly though not solely in the fat, and is at first free and then encysted; the cyst is large, and may be 1¾ inch in length and ½ inch in diameter. The full grown worm may be as much as 1½ inch in length. Three to six eggs are found in the cyst, and the young worms migrate. During their migration, it has been surmised that they cause the "hog cholera."

The so-called measle of the pig is caused by the presence in the muscular connective tissue of *Cysticercus cellulosæ.* During life there are few indications of the existence of this worm in the animal: the only positive sign to be obtained is in the mouth, where it may be detected on the inferior and lateral aspect of either side of the tongue, or between this and the lower jaw. The body of the animal has a bloated appearance, and a soft flabby feel; and on firm pressure a crackling sensation may be imparted to the fingers.

Trichina spiralis has its habitat also in swine: it is not confined to the muscle alone, but has been demonstrated in the fat of the body of the pig in large numbers. Animals fed on such fat did not, as a rule, become trichinised. Its presence is indetectable before death, unless found in the muscles under the tongue.

Inspection of Meat.—Meat should be inspected, in temperate climates, twenty-four hours after being killed; in the tropics, earlier.

The following points must be attended to:—

(*a*) *Quantity of Bone.*—In lean animals the bone is relatively in too great proportion; taking the whole meat, 17 to 20 per cent. may be allowed.

(*b*) *Quantity and Character of the Fat.*—The amount of fat varies with the feeding of the animals. In a fat ox it constitutes about one-third of the flesh, in a fattened pig one-half. In beef surplus fat is the excessive fat at the kidneys, pelvic cavity, cod fat, and udder. In mutton that on the back and in the region of the kidneys. In thin or badly fed animals the fat may be as low as 1 per cent. of the meat. The fat usually solidifies after death, and in beef consists chiefly of palmitates, in bacon oleates, in mutton stearates, these respective kinds of fats being soft and fusible in the order named. The colour varies from white to straw colour and yellow, being whiter in young bulls than in bullocks and cows. The kind of feeding has an effect on the colour of the fat; some oil-cakes give a marked yellow colour. The fat of the horse is always of a yellow colour, and softer; it has a rather unpleasant sickly taste.

Gamgee stated that pigs fed on flesh have a peculiarly soft diffluent fat, and emit a strong odour from their bodies. According to the same authority, the butchers rub melted fat over the carcass of thin and diseased animals to give the glossy look of health.

(*c*) *Condition of the Flesh.*—The muscles should be firm, and yet elastic; not tough; the pale moist muscle marks the young animal, the dark-coloured the old one; the muscular fasciculi are larger and coarser in bulls than oxen. A deep purple tint is said to indicate that the animal has not been slaughtered, but has died with the blood in it (Letheby). When good meat is placed on a white plate, a little reddish juice frequently flows out after some hours. It should be tolerably dry after being exposed for a short time to the atmosphere: it should possess a pleasant sweet flavour, and when heated should give a savoury odour. Good meat has a marbled appearance from the ramifications of little veins of fat among the muscles (Letheby). There should be no lividity on cutting across some of the muscles; the interior of the muscle should be of the same character, or a little paler; there should be no softening, mucilaginous-like fluid, or pus, in the intermuscular cellular tissue. This is an important point, which should be closely looked to. The intermuscular tissue becomes soft, and tears easily when stretched in commencing putrefaction.

The degree of freshness of meat in commencing putrefaction is judged of by the colour, which becomes paler; by the odour, which becomes at an early stage different from the not unpleasant odour of fresh meat, and by the consistence. Afterwards the signs are marked, the odour is disagreeable, and the colour begins to turn greenish. In diseased meat there is a disagreeable odour, sometimes a smell of physic; very evident when the meat is chopped up and drenched with warm water. It is a good plan to push a clean knife into the flesh up to its hilt. In good meat the resistance is uniform; in putrefying meat some parts are softer than others. The smell of the knife is also a good test. *Cysticerci* and *Trichinæ* should be looked for.

(*d*) *Condition of the Marrow.*—In temperate climates the marrow of the hind legs is solid twenty-four hours after killing; it is of a light rosy red. If it is soft, brownish, or with black points, the animal has been sick, or putrefaction is commencing. The marrow of the fore legs is more diffluent; something like honey—of a light rosy red colour.

Age.—In the young animal the bones are small, soft, porous, and of a pinkish colour, but as the animal grows older the bones become large, harder, less porous and whiter in colour. The inside part of the ribs is very pink in young animals, but as age increases the pinkness fades away and the ribs at about six or seven years old become quite white. The tops of the spinous processes forming the chine are in the young animal composed of gristle, but ossify about the age of six years. The pubes or aitch-bone is only joined by gristle in the young animal, but this ossifies also about the age of six years. Before this gristle has ossified, the butcher divides it with his knife in dressing the animal and the blue cartilage is plainly seen in the side or quarter afterwards, but after it has ossified the saw has to be resorted to. In an old cow which has had several calves, the aitch-bone is very thin and very hard and the pelvic cavity is large. If the head is left attached to the carcass the age can be told with great certainty by the teeth.

Bovines.

2 years old,	2 permanent teeth.
3 ,, ,,	4 ,, ,,
4 ,, ,,	6 ,, ,,
5 ,, ,,	8 ,, ,,

After six, the teeth get worn down gradually, the centre incisors first, then the ones next to them, and so on.

Sheep.

1 year old,	2 permanent teeth.
2 ,, ,,	4 ,, ,,
3 ,, ,,	6 ,, ,,
4 ,, ,,	8 ,, ,,

And after this the teeth become worn down, as in the case of bovines.

Distinctions of Sex.—In the hind quarter of ox beef is situated at the root of the pizzle, the erector muscle, which is about 3 inches in length by 1½ inch in breadth. In the bull this muscle is much more fully developed than in the ox; and in the bull this muscle is much wider, darker in colour, and coarser in grain.

The pizzle in the ox is small and undeveloped, not thicker than the finger, but in the bull it is largely developed; it is often split and partly removed in order to make it appear of the same size as that of the ox, or entirely removed, and the retractor muscle left in. There is more cod fat in ox than in bull beef, and in the bull the cavity is generally seen from which the testicle has been removed.

In bull meat generally, owing to the superior muscular development of that animal, the proportion of muscular tissue or lean meat is much greater than it is in the ox. In the bull the fat is not "marbled" through the lean as is the case with well-fed oxen. This gives the whole quarter of bull a darker and redder appearance than that of the ox. The lean of the young ox is juicy, smooth, and silky to the touch, florid in colour and marbled with fat; but in the bull it is coarse and stringy in texture, harsh to the touch and the marbling absent. The bony structure, and especially the aitch-bone, is very much more massive in the bull than in the ox.

The chief distinguishing features of a fore quarter of an ox from that of a bull is the collar or crest, which in the bull is very large and muscular, requiring at least the whole hand to grasp it, but in the ox is very much smaller, and can be grasped between the forefinger and thumb. In the ox there is a plentiful coating of fat on the exterior coming right to the point of the shoulder, but in the bull the exterior coating of fat is almost entirely absent, the lean being directly covered by the outer skin. In the bull the brisket is coarser, harder, and darker than in the ox.

The quarters of bull stags present very much the same characteristics as those of bulls, but in a somewhat less degree. A bull stag is an animal which has been castrated too late in life, or has had one testicle or a part of one left in.

A cow which has had no calf is called a heifer, but the term heifer by itself is often applied to a young cow that has not had more than one calf.

The principal means of distinguishing cow from heifer beef is the udder. In the heifer the udder is but slightly developed; it is in fact enveloped in fatty tissue, and forms a uniform thick wall on either side of the flank. When a cow has had one calf, the surface of the udder will be slightly soft, but the main portion will still consist of solid fat, and the small ducts through which the milk has come will be just visible.

After the second calf the udder will be composed partly of a tough, brown, spongy substance and partly of fine fat, and the ducts through which the milk has come will be very much larger. As the number of calves the cow has had increases, the udder becomes looser, browner, and more spongy in appearance. To make the hind quarter of a cow resemble that of a heifer, the udder is cut out while the carcass is warm and the skin cleverly fixed over the excised part.

It is very difficult to tell the fore quarter of a heifer from that of an ox. In the fore quarter of a cow the chief indications that the animal is old are the bleached ribs, want of fat on the ribs, a very prominent scapula or shoulder-bone, with a hollowness or falling away on either side of it.

The flesh of the heifer is generally silky and juicy to the touch. In the old cow it is generally coarse, dry, and stringy. There is a want of marbling of fat and the fat streaks are poor or absent altogether.

The differences of sex in sheep can be told in much the same way as in cattle. The ram in relation to the wether presents very much the same appearances as the bull does in relation to the ox. The ram has a thick neck, a generally muscular and massive appearance, and a pizzle twice as thick as an ordinary lead pencil. The wether has a thin neck and a pizzle about the size of a lead pencil.

In old ewes the surface of the kidney fat and also the back will be much veined; the knuckle cartilages, instead of showing the pinkish blue colour of young animals, will be quite bleached, and the udder large and spongy, the holes through which the milk has come being visible.

Horse Flesh.—This can be detected by the horse having eighteen pairs of ribs, while the ox has only thirteen pairs; the tongue of the horse is smooth at tip and base of blade, and the ox's tongue is rough; the colour of the flesh of the horse is much darker and coarser in fibre than that of the ox; and the bones are heavier than the ox; the whole of the fat of the horse is oily, yellow, has a disagreeable flavour, and is separated from the lean. The odour of the meat is different from that of beef.

Goat Flesh.—The flesh of an old goat is dark, harsh, and strong, with a peculiar goaty smell; the shanks of the fore and hind legs are very thin, ribs white, outer coating of carcass deep red, neck very thin in nanny-goat and very thick in the he-goat.

Sausages.—Decomposing sausages are difficult of detection until the smell alters. Artmann recommends mixing the sausage with a good deal of water, boiling and adding freshly-prepared lime water. Good sausages give only a faint, not unpleasant, ammoniacal smell; bad sausages give a very offensive, peculiar ammoniacal odour.

Refrigerated Meat.—This is largely imported from North America. The meat is wrapped in thin canvas, and hung up in specially constructed chambers in ships, through which a current of cold air is continually passing. The air is pumped into the chamber at such a temperature as to keep the carcasses a few degrees above freezing point, but never to allow them actually to freeze. It is, generally speaking, excellent meat, the produce of very good, well-fed cattle.

Refrigerated meat can be distinguished by—

1. The bruised condition of the shanks, owing to the chain which is passed round the hind legs during the process of slaughtering.
2. The fat of the meat is pink, owing to its being stained by the juice of the lean meat which escapes.
3. The outside of the meat will present a *dead* colour, when compared with the lustre seen on the outside of good fresh meat.
4. The dressing is not always so clean and neat as in English dressed meat, and the pizzle and root are always entirely removed.

On removing the canvas cloth a slightly unpleasant smell is sometimes perceptible, but care should be taken not to reject the meat without further examination, as the smell may only be a surface smell caused by the cloth.

Plate I.

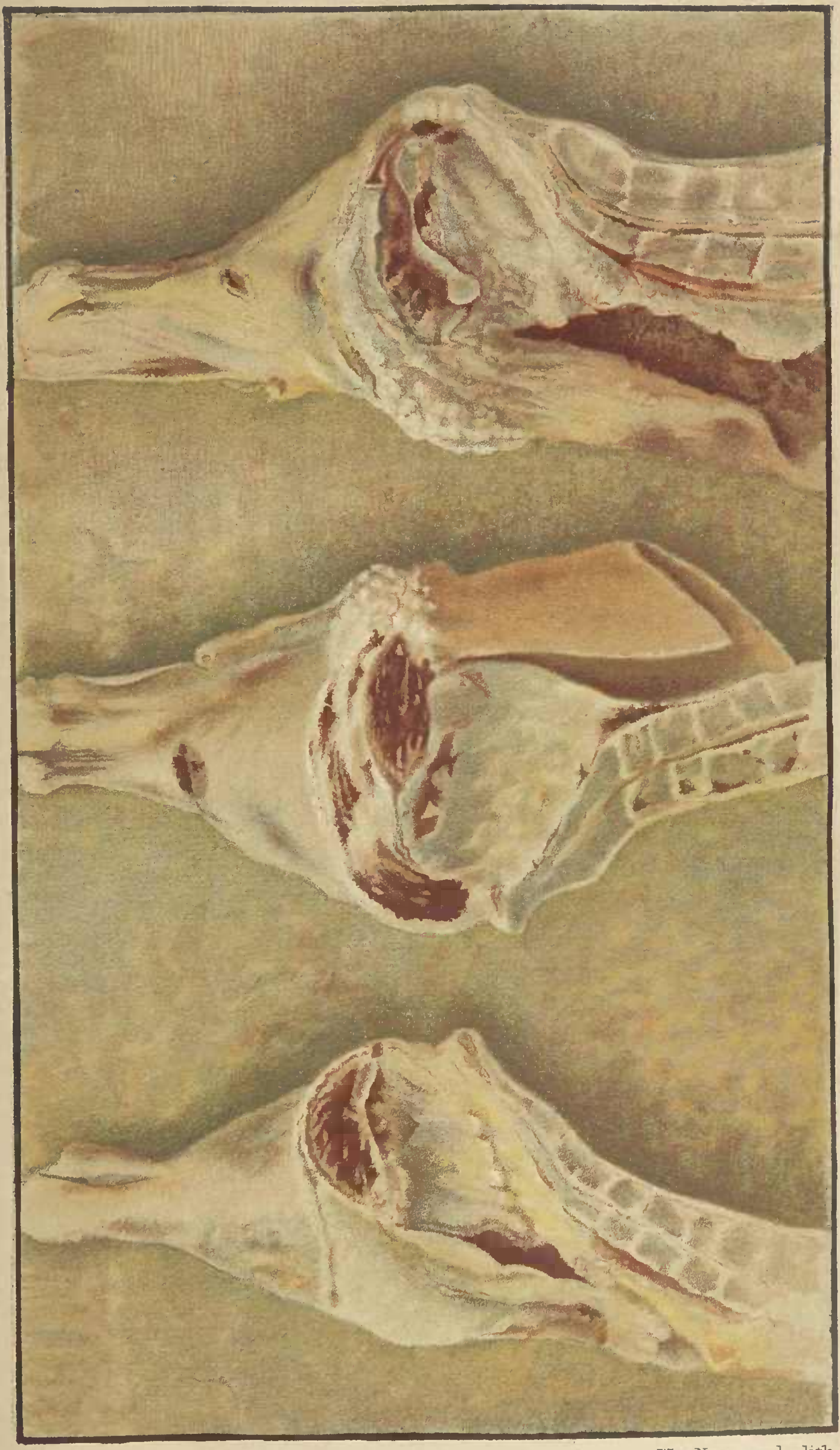


Fig. 3.
Fig. 2.
Fig. 1.

West, Newman chr. lith.

Fig. 1, Hind-quarter of Cow or Heifer.
" 2, Hind-quarter of Bull.
" 3, Hind-quarter of Ox.

When this is removed the fore and hind quarters should invariably be cut through in the ordinary manner, when, if any taint exists, it will be easily detected.

Frozen Meat.—This is imported largely from Australia and South America. It can easily be distinguished, before it is thawed, by its cold, hard touch. The fat is not stained, as in the case of refrigerated meat.

When frozen meat has been thawed, the outside will have a wet, parboiled appearance, and there will be oozing and dripping of liquid from the meat. The fat is of a deadly white colour. The flesh has a uniform pink appearance owing to diffusion of the colouring matter of the blood, and on a fresh section being made, the watery condition will be very apparent: this loss of juice must be, more or less, deteriorating to its quality.

Frozen mutton comes generally from Australia and New Zealand; being naturally drier than beef, it suffers but little deterioration in the freezing process.

Salt Meat.—It is not at all easy to judge salt meat, and the test of cooking must often be employed. The following points should be attended to:—

(*a*) *The salting has been well done, but the parts inferior.*—This is at once detected by taking out a good number of pieces; those at the bottom of the cask should be looked at, as well as those at the top.

(*b*) *The salting well done, and the parts good, but the meat old.*—Here the extreme hardness and toughness, and shrivelling of the meat, must guide us. It would be desirable to have the year of salting placed on the cask of salt beef or pork.

(*c*) *The salting well done, but the meat bad.*—If the meat has partially putrefied, no salting will entirely remove its softness; and even there may be putrefactive odour, or greenish colour. A slight amount of decomposition is arrested by the salt, and is probably indetectable. *Cysticerci* are not killed by salting, and can be detected.(1) Measly pigs are said to salt badly, but according to Gamgee this is not the case.

(*d*) *The salting badly done, either from haste or bad brine.*—In both cases signs of putrefaction can be detected; the meat is paler than it should be; often slightly greenish in colour, and with a peculiar odour.

It should be remembered that brine is sometimes poisonous; this occurs in cases where the brine has been used several times; a large quantity of animal substance passes into it, and appears to decompose. The special poisonous agent has not been isolated, but is probably a ptomaine.

Microscopic Examination of Meat.—In the flesh of cattle, or of the pig, *Cysticerci* may be found. *Cysticercus cellulosæ* of the pig gives the meat a pale flabby appearance, making it soft and apparently dropsical. The cysts are generally located in very large numbers in the liver, giving that organ on section a mottled appearance. They are generally visible to the naked eye as small round bodies; when placed under a microscope with low power, their real nature is seen; they are sometimes so numerous as to cause the flesh to crackle on section. The smallest *Cysticercus* noticed by Leuckart in the pig was about $\frac{4}{100}$ths of an inch long and $\frac{3}{100}$ths broad; but they are generally much larger, and will often measure to $\frac{2}{10}$ths or $\frac{3}{10}$ths or $\frac{3}{4}$ths of an inch. In some countries they are extremely common in cattle (*Cysticercus bovis*), and have been a source of considerable trouble in North-West India. The muscles of the haunch are those most frequently affected. *Cysticercus* of the ox produces in man *Tænia mediocanellata*. In sheep Cobbold described a small *Cysticercus* with a double crown of hooks, 26 in number. He thought that possibly a special *Tænia* might arise from this. Oldham describes *Cysticercus tenuicollis* (from *Tænia marginata* of dogs) as common in

(1) Perroncito (I Parassiti dell'Uomo, etc., p. 189), dice: "[illegible] ...iono sicuramente col congela- [illegible] colla salagione, coll'affumicamento d [illegible] ...inatura."

the sheep of the Punjaub; it has four suckers and a double coronet of 32 hooks. In diagnosing *Cysticerci* of pork the hooklets should always be seen.

Trichinæ may be present in the flesh of the pig; if encapsuled they will be seen with the naked eye as small round specks; but very often a microscope is necessary. A power of 25 to 50 diameters is sufficient. The best plan is to take a thin slice of flesh; put it into liquor potassæ (1 part to 8 of water), and let it stand for a few minutes till the muscle becomes clear; it must not be left too long, otherwise the *Trichinæ* will be destroyed. The white specks come out clearly, and the worm will be seen coiled up. If the capsule is too dense to allow the worm to be seen, a drop or two of weak acetic acid should be added. If the meat is very fat, a little ether or benzine may be put on it in the first place. The parts most likely to be infected are said to be the muscular part of the diaphragm, the intercostal muscles, and the muscles of the eye and jaw. In diagnosing *Trichinæ*, the coiled worm should be distinctly seen. *Stephanurus dentatus* in the pig has already been referred to.

The so-called *Psorospermia*, or Rainey's capsules, must not be mistaken for *Trichinæ*, nor indeed with care is error possible. These are small, almost transparent, bodies, found in the flesh of oxen, sheep, and pigs. They are in shape oval, spindle-shaped, or sometimes one end is pointed and the other rounded, or they are kidney-shaped. The investing membrane exhibits delicate markings, caused by a linear arrangement of minute, hair-like fibres, which are stated to increase in size as the animal gets older. They sometimes are pointed, and the appearance under a high power (1000 diameters) is as if the investment consisted of very delicate, transparent, conical hairs, terminating in a pointed process. The contents of the cysts consist of granular matter, the granules or particles of which, when mature, are oval, and adhere together, so as to form indistinct divisions of the entire mass. The length varies from $\frac{1}{300}$th to $\frac{1}{4}$th of an inch. They are usually narrow; they lie within the sarcolemma, and appear often not to irritate the muscle.

Up to the present time no injurious effect has been known to be produced on men by these bodies, notwithstanding their enormous quantities in the flesh of domestic animals, nor have they been discovered in the muscles of men. But in pigs these bodies sometimes produce decided illness; besides general signs of illness, there are two invariable symptoms, viz., paralysis of the hind legs, and a spotty or nodular eruption. In sheep, they have been known to affect the muscle of the gullet, and produce abscesses, or what may be called so, viz., swellings sometimes as large as a nut, and containing a milky, purulent-looking fluid, with myriads of these capsules in it. Sheep affected in this way often die suddenly.

It is by no means improbable that some effect on man may be hereafter discovered to be produced.

Some bodies, which have been also termed *Psorospermia*, found in the liver and other parts of the rabbit, and in the liver of man, and which have been described by many observers in different terms, may possibly be found in other animals, as they have been seen in the dog by Virchow. They are quite different from Rainey's corpuscles; they are oval or rounded bodies, at first with granular contents, and then with aggregations of granules into three or four rounded bodies, in which something like a nucleolus is seen. They have often been mistaken for pus cells.

Some other bodies occur in the flesh of pigs, the nature of which is not yet known. Wiederhold described a case in which little white specks, with all the appearance at first of encapsuled *Trichinæ*, were present; their real nature, however, could not be determined.

Virchow has described little concretions in the flesh of the pig, which seemed to be composed of guanin; these were also at first taken for encapsuled *Trichinæ*.

Roloff has noted little hard round nodules in the flesh of the pig; some seem very small, others as large as the head of a pin, with little prolongations running to the surrounding muscular fibres to which they are attached. On the outside of these bodies are bundles of fine hairs or needles, sometimes arranged in quite a feather-like form. The bodies have a great resemblance to the guanin bodies of Virchow, but the needles are not crystalline. Roloff asked if these bodies were of *post-mortem* origin.

It is hardly necessary to state that in cutting across meat small bits of tendons or fascia, sometimes very like a little cyst, will be found; but common care will prevent a mistake.

Diseases arising from altered Quality of Meat.—A very considerable quantity of meat from diseased animals is probably brought into the market, but the amount is uncertain.

1. *The flesh of apparently healthy animals may produce Poisonous Symptoms.*—Among the *Mammalia* the flesh of the pig sometimes causes diarrhœa—a fact noticed by Parkes in India, and often mentioned by others. The flesh is probably affected by the unwholesome garbage on which the pig feeds. Sometimes pork, not obviously diseased, has produced choleraic symptoms. In none of these cases has the poison been isolated.

2. *The flesh of healthy animals, when decomposing*, is eaten sometimes without danger; but it occasionally gives rise to gastro-intestinal disorder—vomiting, diarrhœa, and great depression; in some cases severe febrile symptoms occur, which are like typhus, on account of the great cerebral complication. Cooking does not appear entirely to check the decomposition. It appears to be, in some cases, the acid fluids of cooked meat which promote this alteration.

Sausages, and pork-pies, and even beefsteak-pies, sometimes become poisonous from the formation of a ptomaine. The symptoms are severe intestinal irritation, followed rapidly by nervous depression and collapse. Neither salts nor spices hinder the production of this poison.

If the meat is kept in dark, damp, and unventilated places, to which sewer gases can gain access, the probability of the development of poisonous properties in the meat is largely increased. In many cases of meat poisoning this fact has been clearly brought out. The remedy for this is obvious.

Ballard has reported two remarkable cases of poisoning by ham and hot baked pork. The first occurred at Welbeck in 1880, and the second at Nottingham in 1881. In both instances a number of persons who partook of the meat were taken ill, and some died. Klein examined the meat, and found it loaded with *Bacilli*, which were also found in the organs of the fatal cases. Guinea-pigs and mice, inoculated with the fluids of the body, died with pneumonia and peritonitic symptoms: *Bacilli* were found in the organs.

Another case of sausage poisoning, which occurred at Chester, has been recorded by Ballard, presenting different characters. The symptoms were those of gastro-intestinal irritation, which passed off, but was followed by pneumonia, that proved fatal. No *post-mortem* examination could be made. In the Welbeck and Nottingham cases there was an incubation period; in this case the illness came on at once: in the former the poison was probably that of an acute specific disease; in the latter an organic chemical poison.

Many similar cases have since been recorded, all of which were associated with the development of ptomaines in the meat; the only common factor being, as stated above, the insanitary conditions under which the meat was kept.

3. *The fresh and not decomposing flesh of diseased animals* causes in many cases injurious effects. A good deal of difference of opinion, however, exists on this point, and it would seem that a more careful inquiry is necessary. The probability is that, when attention is directed to the subject, the effect of diseased meat will be found to be more considerable than at present believed. At the same time, we must not go beyond the facts as they are at present known to us, and at present certainly bad effects have been traced in only a few instances; perhaps the heat of cooking is the safeguard.

The flesh of animals killed on account of *accidents* is usually dark and discoloured by reason of not having been bled; the thoracic and abdominal walls are stained from contact with viscera; the odour is offensive, and there is discolouration from incipient decomposition. Most meat of this class must always be condemned. If the injuries are localised, and the animal at once slaughtered, the carcass being properly dressed, the undamaged parts are normal in condition, and may be eaten without injury.

If an animal is killed by *lightning*, the flesh putrefies so rapidly that it cannot escape detection; the same applies to apoplexy. In each case the peritoneum and pleura are discoloured, the flesh has a pungent odour and a dark colour gorged with blood, and the whole exterior is dark red. The flesh of *over-driven* animals is harsh in character and wanting in that juicy characteristic noticed in good, well-fed animals which have been rested before slaughter.

Carcasses of animals slaughtered before, during, or immediately after *parturition* are not necessarily unfit for food. If there is evidence of extravasation or inflammation of the pelvic cavity, and the flesh elsewhere pale and livid and ill-set, it should be condemned. But if it be a case of abnormal presentation, and the animal be slaughtered and properly bled and dressed, the flesh may be perfectly fit for consumption.

The meat is not apparently altered in the *early stage* of acute inflammatory disease, and it is said that some of the primest meat in the London market is taken from beasts in this condition; it is not known to be injurious, but it has been recommended that the blood should be allowed entirely to flow out of the body, and should not be used in any way.

It is now generally accepted that *tuberculosis* in cattle cannot exist without the tubercular bacillus having been the exciting cause. Certain predisposing conditions may be present in the case of all animals, such as malnutrition, bad ventilation, damp soil, hereditary predisposition, &c. The bacillus gains access to the body either by inhalation of contaminated air, by inoculation, or by the ingestion of food containing the specific organism or its spores: these when swallowed adhere to the mucous membrane of the different organs, and may there undergo further development: from the mucous surfaces they pass into the surrounding tissues and to the lymphatic glands, which become largely affected: after them the serous membranes of the abdomen and thorax are the most frequent seat of the disease. Cattle, pigs, poultry and rarely sheep are all liable to be affected with tubercle, but it is in cattle, and more especially milch-cows, that tuberculosis is met with. The organs most frequently affected are the lungs, liver, kidneys, and brain, and, in the cow, the udder. In cattle localised tuberculosis is the exception. The muscles appear to be rarely affected, although bacilli have been found in the expressed juice, which had infective properties: they have also been found in the blood and in the secretions of the diseased organs.

From the appearance presented by tubercular deposits in the serous linings of the thorax and abdomen, animals suffering from well-marked symptoms are said to have the "grapes"—the little nodules in the substance of organs resemble fruit stones, and are called "kernels." There may be no visible symptom of the disease in the animal, unless in the case of an acute attack, in which case there is always fever and rapid wasting of the body. When the disease attacks the external organs, such as the udder, there is generally no constitutional disturbance; this is much more likely to be present when the internal viscera are affected, so that an animal may be extensively diseased and yet exhibit no symptom to call for special attention. The question of the use of the flesh, as of the milk, of tuberculous animals has been extensively debated. From the nature of the case there is great difficulty in obtaining direct evidence of the transmission of the disease from animals to man. According to Johne, the flesh of tuberculous animals may be eaten if the tuberculosis is not general, but the internal organs affected and the lymphatic glands should be destroyed. In general tuberculosis the flesh should not be eaten.

The Commission appointed in Victoria, Australia, to report on the extent of tuberculosis, considered that the meat of animals strongly affected with the disease should be forbidden, but in less severe cases it could be consumed.

According to the experiments of Kastner infection is not to be feared except in those rare cases in which tubercles are found in the muscles. In nine out of eleven cases he has, however, obtained positive results by the injection of the juice expressed from the confiscated flesh of seven tuberculous animals. In the light of his previous experiments he states that complete calcification of the tuberculous processes in the animal would appear to render the chances of infection slight, but if caseous masses are found, the dangers of infection must be admitted. In some other experiments by Steinheil, it appeared that tuberculosis could be transmitted to guinea-pigs, by administering the expressed juice from flesh in which no tubercles could be seen.

At the Congress on Tuberculosis, held at Paris in 1888, Nocard introduced the subject of transmission by meat of infected animals, and considered that their flesh could be eaten with safety, when the tubercles were limited to the viscera and lymphatics; and was only exceptionally dangerous when the disease was generalised: the general opinion, however, was that *all* tuberculous meat should be condemned, and finally the Congress passed a resolution to this effect.

An official decree was promulgated by the French Government in July 1888, forbidding the sale of tuberculous meat, (1) if the lesions are generalised; (2) if the lesions, though localised, have invaded the greater part of an organ, or are manifested by an eruption on the walls of the chest or of the abdominal cavity: such flesh not to be used for feeding animals but destroyed. In Austria when the tuberculosis is localised the meat is passed as healthy. According to a recent Prussian rescript, the flesh of tuberculous cattle is looked upon as dangerous to health, either when the flesh contains tuberculous nodules or when the tuberculous animal is wasted, even if no such nodules are present in the flesh. The great infrequency of tuberculous nodules in the muscles is also referred to.

A judicial inquiry of great importance was held at Glasgow before Sheriff Berry in June 1889. The question was whether sanitary authorities could condemn a whole carcass, however sound it might appear, if tubercle was undoubtedly present, however localised it might seem to be. Much expert evidence was given on both sides. The Sheriff decided that the evidence clearly showed that the disease, though to the naked eye only local, was in point of fact generalised; that the bacilli, which are the cause of tuberculosis, were found in a portion of the body, which, in the ordinary course, would not have been "stripped," or removed; that cooking was not certain to destroy such bacilli; that tuberculosis was proved to be transmissible from animal to man by ingestion of meat; that therefore there is danger to the public health in the consumption of such meat.

The Report of the recent Royal Commission appointed to inquire into the effect of food derived from tuberculous animals clearly indicates that the danger is a real one, especially with regard to the meat of tuberculous bovines. Martin's evidence, in particular, shows that a great difficulty exists with regard to meat, inasmuch as a number of butchers are very careless in the cutting up of carcasses partially affected with tuberculosis. Matter finds its way to the knives used, and this is transferred to joints which would otherwise remain untainted. Roasting before a fire was the least, and boiling the most, effective method of cooking the flesh.

Epidemic pleuro-pneumonia is a disease peculiar to the ox, and is a contagious inflammation of the lungs and pleura; but it has never been transmitted to other than bovine animals, its effects are localised in the lungs alone, and even in these organs the disease is a limited one. In the advanced stages, and when a large area of lung tissue is destroyed, with extensive pleurisy, the flesh becomes altered in colour and consistence. The rule is to pass the carcasses of animals affected with pleuro-pneumonia as marketable and innocuous, if they present no departure from natural conditions.

Anthrax occurs in cattle, sheep, horses, and sometimes pigs; the disease is rapidly fatal, the animal often dying within a few hours. It is readily transmissible to other animals by inoculation. The specific micro-organism associated with this disease—*Bacillus anthracis*—is found chiefly in the blood and spleen of infected animals, and is rod-shaped, multiplying by division, and can be artificially cultivated when spores make their appearance, which, when injected into other animals, germinate into characteristic bacilli. This disease is known in man as "wool-sorters'" disease, and the usual mode of infection in such cases is by inhaling the spores adhering to the wool of animals dead of anthrax or by inoculation into abrasions upon those handling it.

In animals the liver, kidneys, and spleen are congested, the spleen being much enlarged, congested, and dark in colour, and sometimes found to be ruptured—a condition which gives rise to the name of "splenic fever" or "splenic apoplexy."

"Black-quarter" or "quarter ill" is an anthracoid disease characterised by hæmorrhagic effusion into the subcutaneous or intermuscular tissues of one or both of the anterior or posterior extremities. This disease is very infectious and fatal. Characteristic bacilli are found in the extravasations and in the abdominal viscera.

Fleming considers that the facility with which anthrax can be communicated by actual contact with matter impregnated with the virus, and the great rapidity with which putrefaction sets in after death, prove the inadvisability of using the flesh for food. Walley goes so far as to say that, however firm and good the meat may appear to be, it should be unhesitatingly condemned and destroyed if indubitable evidence of the existence of anthrax is forthcoming.

The flesh of an infected animal should not be consumed even if slaughtered in the earliest stage of its illness. The flesh should be at once destroyed: decomposition is very rapid.

Braxy.—According to Walley, the term "braxy" is used in a very vague and indefinite manner with regard to sheep; in some instances referring to a cachexy from bad feeding, in which case the flesh is not deleterious, though unmarketable; in other instances being applied to conditions resulting from anthrax and septicæmia, when the flesh should certainly be condemned.

Acute rheumatism in cattle is sometimes known as "joint-ill" or "joint-felon." The serous fluid effused into the joints may become purulent, and abscesses may sometimes be found in the neighbourhood of the affected joints. The meat becomes dropsical and the carcasses of animals so affected are totally unfit for human food.

Small-pox of Sheep.—The flesh has a peculiar nauseous smell, and is pale and moist. It produces sickness and diarrhœa, and sometimes febrile symptoms.

Foot-and-Mouth Disease.—Lévy states that at different times (1834, 1835, 1839) the aphthous disease has prevailed among cattle both at Paris and Lyons without the sale of the meat being interrupted or giving rise to bad results. Occasionally in chronic cases, or when the infected animals have been exposed to wet or neglect, the flesh may become deteriorated to an extent which renders it unfit for food. In ordinary cases the condition of the carcass differs in no respect from that of one which has been slaughtered in perfect health. Of course the affected parts should not be used for food.

Cattle Plague (Rinderpest).—*A priori*, such flesh would be considered highly dangerous, and the Belgian Academy of Medicine so consider it; but there is some strong evidence on the other side. In Strasbourg and in Paris, in 1814, many of the beasts eaten in those cities for several months had rinderpest, and yet no ill consequences were traced. But it may be questioned whether they were looked for in that careful way they would be at the present day. Some other evidence is stronger: Renault, the director of the Veterinary School at Alfort, made, for several years after 1828, many experiments, and asserts that there is no danger from the *cooked* flesh of cattle, pigs, or sheep dead of any contagious disease ("quelle que soit la répugnance bien naturelle que puissent inspirer ces produits"). So, also, during the occurrence of the rinderpest in England (1865), large quantities of the meat of animals killed in all stages of the disease were eaten without ill effects. In Bohemia also, in 1863, the peasants dug up the animals dead with rinderpest, and ate them without bad results. The constitution is, however, gravely affected, and at the present time the majority of experts condemn the flesh as unfit for human food.

Rabies in the dog and cow produce no bad effects. Walley, however, is of opinion that the flesh of an animal that has suffered from rabies should not knowingly be passed as fit for food.

Swine fever, called also "hog cholera," "soldier," &c., is a very fatal disease amongst swine. It is very difficult to detect in the early stages of its development, and in the varying modes of its onset and progress shows an analogy with typhoid fever in man. The *post-mortem* appearances are also somewhat similar—ulceration and inflammation of alimentary canal, most commonly the large intestine, being present. This disease is one which renders the flesh of the animal unfit for consumption.

Parasitic Diseases. — *Cysticercus cellulosæ* of the pig gives rise to a disease known as "measles" and produces *Tænia solium* in man, and that of the ox and cow *Tænia mediocanellata.* These entozoa often arise from eating the raw meat, but neither cooking nor salting are preservative, though they may lessen the danger. Smoking appears to kill *Cysticerci*, and so, according to Delpech, does a temperature of 212° F. Lewis found that a much lower temperature sufficed. When *Cysticerci* had been exposed for five minutes to a heat of 130° F. he could detect no movements, and he considered that a temperature of from 135° to 140° F. for five minutes would certainly kill them. Lewis considered there was no danger if the cooking were well done, as the temperature of well-done meat is never below 150° F.

Trichina spiralis in the pig gives rise to the curious *Trichina* disease caused by the wanderings of the young *Trichinæ.* The affection is highly febrile, resembling enteric fever, or even typhus, or acute tuberculosis, but attended with excessive pains in the limbs and œdema. Boils are also sometimes caused. The eating of raw trichiniferous pork is the chief cause, and the entozoon is not easily killed by cooking or salting. A temperature of 144° to 155° F. kills free *Trichinæ*, but encapsuled *Trichinæ* may demand a greater heat (Fiedler). During cooking a temperature which will coagulate albumin (150° to 155° F.) renders *Trichinæ* incapable of propagation, or destroys them. As a practical rule, it may be said that if the interior of a piece of boiled or roasted pork retains much of the blood-red colour of uncooked meat, the temperature has not been higher than 131° F., and there is still danger. Intense cold and complete decomposition of the meat do not destroy *Trichinæ.* Hot smoking, when thoroughly done, does destroy them (Leuckart); but the common kinds of smoking, when the heat is often low, do not touch *Trichinæ* (Küchenmeister).

Distomum Hepaticum in Sheep.—It is said that many persons will eat freely of, and even prefer, the liver of the sheep full of flukes. No direct evidence has been given of the production of disease from this cause, at least in this country. The affected liver should in all cases be destroyed and the carcass should be condemned if it be deteriorated. In Iceland *Echinococcus* disease, which affects a large number of persons, is derived from sheep and cattle, who, in their turn, get the disease from *Tænia* of the dog (Leared and Krabbe). Wet seasons are conducive to the spread of the disease, as the eggs and embryo of the parasite are developed in water.

Glanders and *farcy* in horses do not appear to produce any injurious effects when such horseflesh is eaten as food. Parent-Duchâtelet quotes two instances, in one of which 300 glandered horses were eaten without injury. In 1870, during the siege of Paris, large quantities of flesh from horses with farcy and glanders were eaten without producing ill effects.

Medicines, especially *antimony*, given to the animals in large quantities, have sometimes produced vomiting and diarrhœa. *Arsenic*, also, is occasionally given, and the flesh may contain enough arsenic to be dangerous.

Enteric Fever.—In Germany five outbreaks have been recorded of an illness resembling enteric fever, and resulting from eating the flesh of calves. The Andelfingen epidemic in 1839 followed a banquet, at which from 500 to 600 people were present: of these, 450 were attacked: the symptoms were very much those of enteric fever, but only nine cases were fatal: the usual enteric ulcerations were said to be found. At Kloten in 1878, 717 persons were affected: rose-coloured lenticular spots were usually abundant; the mortality was small, but typhoid lesions were present. The other outbreaks occurred at Birmenstorf, Würenlos, and Spreitenbach, in 1879, 1880, and 1881, the numbers affected being much smaller. In two of the calves lesions resembling those of enteric fever were observed *post-mortem.* Unfortunately the observations were not conducted in a manner calculated to prevent criticism, and the question therefore cannot be considered as settled; but the possibility of the transmission of enteric fever from man to animals, and *vice versâ*, must not be overlooked.

FISH.

Of the great nutritive value of fish as an article of diet, there can be no doubt. The varieties which are used as food are almost infinite, and whole populations appear to exist on it. It is less satisfying and not so stimulating as the flesh of animals, but is easily digested. Its use is greatest in those places where it is readily caught, and recommends itself on account of its abundance and cheapness. Lately it has been said that fish diet predisposes to diseases of the skin, especially leprosy; but the evidence on this point is not by any means conclusive: indirectly this connection, or alleged predisposition, may be associated with the poverty prevalent in those countries where the poorer classes are obliged to subsist altogether on this class of food, and where meat is never partaken of, and indicates that fish should not alone be the source from which nitrogenous food is taken.

Fish contains a large proportion of phosphorus, which makes it a suitable diet for those who have to perform much brain work; and for this class, who are mostly of sedentary habits, it has the further advantage of being easily digestible as well.

The flavour and digestibility of fish depend on the amount of fat it contains, which varies in different species, the white fish, as sole and whiting, containing a small proportion, whereas the salmon and eel have a large amount. As a rule, white fish have least oil.

The following table gives the composition per cent. of some of the most important kinds:—

	Water.	Proteids.	Fat.
Salmon (Pavy),	77·00	16·10	5·50
Herring,	80·71	10·11	7·11
Sole,	86·14	11·94	0·25
Mackerel,	68·70	23·50	6·76
Eel (Letheby), .	75·00	9·90	13·80
White fish (Pavy),	78·00	18·10	2·90

Inspection of Fish.—As in the case of animals, fish when eaten should be fairly fresh. A fresh fish is firm and stiff: the drooping or not of its tail is a fair criterion of freshness in a fish. Flat fish keep better than herrings or mackerel. Cod, haddock, and whiting keep the best, particularly if rinsed with salt water and stored in a cool place. All fish intended for food should be unbruised, unbroken, and clean. If the scales are dull and damaged it is very suggestive of either ill usage or staleness; softening in places indicates the same.

The inspection of "food fishes" may be divided into two heads, namely, ground and surface fish.

It is an established fact that decomposition in the surface fishes, such as herrings, mackerel, sprats, mullet, pilchards, &c., is extremely rapid. Ground fish, like halibut, skate, cod, sole, plaice, turbot, &c., decompose much less rapidly, and if properly packed remain fresh and fit for human food from seven to ten days after being taken from the sea. Fish which have been ungutted are the most difficult to inspect, more especially those with large oily livers. Externally they appear good, the eyes being bright, gills red, but internally they are full of decomposition and decay.

With strong pressure of the thumb and fingers upon the under side, the deeper flesh readily crushes, leaving the skin only between the fingers. This is an infallible test of unsoundness. Immediately after death the blood of fish becomes congealed. When decomposition sets in, on cutting the fish this blood will run out as a liquid of a dull red colour, and giving off an offensive smell. On removing the bones, moreover, each one leaves a dull red mark, showing where the decomposition processes are extending to the more solid portions of the fish. To avoid rapid decomposition, all fish should be at once bled and gutted on being caught; neglect of this procedure is the cause of a very large amount of fish quickly decomposing, and being in consequence condemned for use as food.

Shell-fish form not only an important article of food, but are extensively used alive as bait. Mussels and oysters are unfit for food very soon after death. Crabs and lobsters, if boiled a few hours after death, are nearly flavourless, decomposition being much more rapid than if killed just before cooking. No crab may be held in possession or exposed for sale less than 4¼ inches across the back, and no lobster less than 8 inches from beak to tail when extended flat, the penalties being in these cases £2 for the first offence, and £10 for the second and every subsequent offence. Under the Crab and Lobster Act, no crab may be consigned for sale with spawn outside attached to the tail, but the lobster may.

Parasites of Fish.—The majority of fishes are infested with different kinds of parasitic worms. As examples of this excessive parasiticism, von Linstow assigns to the cod nine species of nematoda, fifteen cestodes and five trematodes; the herring is credited with six nematodes, three cestodes, three trematodes; the salmon with five nematodes, nine cestodes, six trematodes. Fortunately, the greater number of these are killed in cooking, while none of them, so far, are known to be parasitic or hurtful to man. The oyster, which is the one fish eaten raw in this country, is at times afflicted with a trematode worm, but we have no evidence to show that it has ever adapted itself to live in man.

The only parasitic worm known, with any certainty, to be conveyed to man through fish is the *Bothriocephalus latus*. The encysted stage of this worm is passed in either the pike or the turbot. These fish, moderately smoked or salted, are, or were till recently, almost the staple food round Dorpat in the Baltic Provinces; when eaten, the encysted worms, which of course are not killed by the processes of preparation, become in their new and appropriate environment the sexual tapeworm; but so far as is known, if eaten by other than the specific hosts, for example, by other fish, they die without assuming the sexual form. Fish, particularly decomposed and some preserved fish, undoubtedly contain various kinds of bacteria. Edington, in reporting to the Scotch Fishery Board, has demonstrated the presence of bacilli as the cause of the red coloration in some salt fish. Experiments made, by various observers, have shown fish to be incapable of tubercular infection even when kept in water largely impregnated with tubercle bacilli.

Poisoning by Fish.—The flesh of apparently healthy fish may produce poisonous symptoms. This is the case with certain kinds of fish, especially in the tropical seas. There is no evidence that the animal is diseased, and the flesh is not decomposed: it produces, however, violent symptoms of two kinds—gastro-intestinal irritation and severe ataxic nervous symptoms, with great depression and algidity.

The little herring (*Clupea harengo minor*), the silver fish (*Zeus gallus*), the pilchard, the white flat-fish, and others, have been known to have these effects. Mackerel has been known to produce poisonous symptoms, probably owing to the fish undergoing rapid decomposition. When the fish is cooked immediately after being caught, it does not appear to produce any bad effects. If possible, some means should be adopted to retain fish alive until they are required for the table: and they should be eaten the earliest moment after capture.

Oysters and shell-fish (even when in season) have been known to produce poisonous symptoms. The production of nettle-rash in some persons from eating shell-fish need scarcely be mentioned. When decomposing, they produce more marked symptoms of the same kind.

Mussels and oysters, especially those taken from water to which sewage gains access, have been found to possess at times very poisonous properties, and are probably also a not infrequent source of enteric fever.

Various bacteria have been isolated from fish. Recently Arustamoff has bred from sturgeons two mobile short bacilli, microscopically similar to each other, one of which liquefies gelatin while the other does not. Both were infectious to rabbits, yielding from their cultures poisonous toxines. The symptoms produced were the same as those following meat and sausage poisoning.

The processes of drying, pickling, salting, and smoking are employed for the preservation of fish. Each process considerably lessens its digestibility, and therefore unsuits it for either the dyspeptic or the invalid. Moreover, unless the fish, originally, be thoroughly sound, there is reason to believe that preservation processes may aggravate the capabilities of fish to produce irritant symptoms; upon this point, however, our present knowledge is very inexact.

EGGS.

Though both duck's eggs and those of sea fowl are used, those of the hen are the usual form in which eggs are eaten as food. The average weight of a hen's egg is about 58 grammes, or about 2 ounces avoir.: 10 parts are shell, 60 white, and 30 yolk. The white contains chiefly egg-albumin, with a trace of fat and a small proportion of salts; the yolk contains a globulin (vitellin), a large quantity of fat and more salts than the white. Duck's eggs contain more fat than do those of the hen. Traces of grape-sugar have been found in some egg yolks, while of the mineral constituents iron in organic combination is the most important. In the yolk, potassium salts and phosphates predominate; in the white, sodium salts and chlorides are in excess. Gautier claims to have isolated albumoses and ptomaines from eggs: both these bodies are probably the result of decomposition processes. The following table represents the average composition of ordinary hen's eggs:—

	Water.	Proteids.	Fats.	Salts.
Whole egg (with shell),	73·50	13·50	11·60	1·20
White of egg,	85·50	12·87	0·25	0·63
Yolk of egg,	51·03	16·12	31·39	1·01

For preservation, eggs are packed in saw-dust or salt, or are covered with gum, butter, or oil, or placed in lime-water to which a little cream of tartar has been added. Boiling for half a minute also keeps them for some time: in fact anything which excludes air will preserve them. The lime-water is said to give them a peculiar taste and makes the albumin more fluid.

Eggs do not appear to suit all people, and if at all decomposed should not be eaten. According to Rubner, about 20 per cent. of the proteids from eggs appear unabsorbed in the fæces, while rather more of the fat also escapes unutilised.

MILK.

Milk not only constitutes the chief diet for children up to some eighteen months of age, but also enters very largely into the food of adults. All milk may be regarded as nothing more than an emulsion of fat containing proteids, salts, and carbo-hydrates in solution in water. The average composition of milk per 100 parts from the chief sources as used by man is shown in the following table:—

Kind of Milk.	Specific Gravity.	Total Solids.	Proteids.	Fats.	Carbo-hydrate.	Salts.	Water.	Proportion of nitrogenous to non-nitrogenous constituents.
Human,	1027	12·60	2·29	3·81	6·20	0·30	87·40	as 1 is to 4·4
Cow's,	1032	12·83	3·55	3·69	4·88	0·71	87·17	,, 1 ,, 2·5
Mare's,	1035	9·21	2·00	1·20	5·65	0·36	90·79	,, 1 ,, 3·4
Ass's,	1026	10·40	2·25	1·65	6·00	0·50	89·60	,, 1 ,, 3·4
Goat's,	1032	14·30	4·30	4·78	4·46	0·75	85·71	,, 1 ,, 2·0
Buffalo's,	1032	18·60	6·11	7·45	4·17	0·87	81·40	,, 1 ,, 1·9

Although all the above are used at times by man for food, the most important kinds are undoubtedly human milk and cow's milk; and these differ from each other in some essential particulars. As seen by the preceding table, while there is more carbo-hydrate in human milk than in cow's, the reverse is the case with the proteids and salts; the fat being much the same in them both. Ass's milk, except in regard to its fat, is most like human milk; but mare's milk contains even less fat and proteid than the ass's; while, on the other hand, milk from both the goat and buffalo are very rich in fat.

The proteids of milk consist largely of casein; but there is also some albumin, with traces of globulin. The casein probably exists in milk in combination with phosphate of lime, which helps to keep it in solution.

The salts of milk are both numerous and various, being composed really of all the mineral constituents necessary to the growing body. Citric acid is a normal constituent of the milk of various animals. In human milk, the quantity is about 0·5 gramme to the litre, in cow's milk about 1·5 grammes. It does not appear to be dependent upon citric acid present in the food. Minute amounts of nitrogenous bases and a starch converting ferment also occur.

The fat of milk is nothing more than minute oil globules suspended in the milk, and which, upon standing, rise slowly to the surface, forming cream. One part of cream is said to correspond roughly to 0·2 of fat; the proportion of cream yielded by a pure milk varies, but may be said to average 8 per cent., being as high as 14 in some cases, and as low as 6 in others. The amount found in a given time is no measure of the richness of the milk; water added to milk causes a more rapid separation of the cream. When milk is subjected to centrifugal action, as in the *separator* so largely used now in commercial dairies, a much larger proportion of cream is obtained than by the mere skimming process. As a result of this, skim milk contains 1 per cent. of fat, while separated milk has practically none.

The carbo-hydrate of milk is a peculiar sugar, somewhat like cane-sugar, and called lactose or sugar of milk, $C_{12}H_{22}O_{11} + H_2O$. It is a hard variety of sugar, grating under the teeth, and tastes but slightly sweet: it rotates polarised light $+61°{\cdot}5$. This body, like other sugars, undergoes fermentation under the influence of micro-organisms, and one especially, called the *Bacterium lactis*, abounds in dairies and other places where milk is kept. This micro-organism converts the milk-sugar into lactic acid, while at the same time the proteids are partly decomposed and partly coagulated, the milk itself becoming sour with enclosure of the fat in the coagulated casein.

After the lactic acid fermentation of milk has set in, the casein gradually decomposes, and, during the early decomposition of the proteids, very frequently highly poisonous compounds are formed, such often being the cause of the violent poisonous effects which at times are produced by ice-creams and other articles of food into the making of which milk enters.

Many other micro-organisms produce coagulation of milk, notably the *Bacillus butyricus* of butyric acid fermentation. Some others have the power of changing the colour of milk, particularly if lactic acid fermentation has occurred. Thus the *Bacillus cyanogenus* causes blue milk; the *Bacillus synxanthum* causes yellow milk; the *Micrococcus prodigiosus* produces red milk; while other bacteria at times cause milk to become ropy and stringy. In nearly all these cases, the milk is apt to cause diarrhœa, and is unsuited for food. Alcoholic fermentation of the milk-sugar can also be set up by certain micro-organisms. "Koumiss" is the result of the alcoholic fermentation of mare's milk, and "Kéfir" is that of cow's, goat's, and sheep's.

The following analysis of Russian koumiss will give an idea of its composition:—

Acid, as lactic,	1·96
Casein,	2·11
Sugar,	0·40
Fat,	1·10
Alcohol,	2·12
Ash,	0·34
Water,	91·97
Total,	100·00

Boiling of milk produces coagulation of the albumin, some obscure changes in the sugar, and greater coalescence of the fat globules. Micro-organisms and ferments are at the same time destroyed, a fact which explains the better keeping qualities of boiled milk. Hot weather tends to hasten fermentation and decomposition in milk.

As an article of diet, milk holds the highest place. When digested, either by the gastric or pancreatic juices, milk clots, the casein being precipitated as large curds. The curds are subsequently changed to albumoses and peptones by the digestive ferments, a bitter substance being formed, which makes all peptonised milk unpleasant in taste.

For infants, human, mare's, and ass's milk constitutes a typical food, the nitrogenous and non-nitrogenous constituents being in the right proportion, or as 1 is to 4·4: whereas, in cow's milk the ratio is as 1 is to 2·5, a fact which renders the milk of the cow, by itself, not a perfect food. This fact is of great practical importance, as if cow's milk is to become a complete and true food for either young children or adults, its non-nitrogenous organic food-stuffs must be increased by adding sugar or arrowroot to it. The artificial approximation of the composition of cow's milk to that of the human being is best carried out in the following manner:—"The cream is separated from a pint of milk, and the casein of one-half of the skimmed milk coagulated with a small quantity of rennet and strained off. To this whey, the cream which has been removed and the rest of the skimmed milk is added. The composition of this artificial human milk varies: it contains on the average a little over 2 per cent. of proteid, 4·5 per cent. of fat, 5 per cent. of lactose, and 0·6 per cent. of salts."

To render ordinary cow's milk suitable for infants or others whose digestive powers are feeble, it must be diluted with either water, lime-water, or barley-water: dilution lessening the size of the casein clots and indirectly favouring their digestion. After dilution, sugar should be added to cow's milk to bring it nearer to the human standard: the proportion to be added should be about 30 grammes of lactose to each litre of diluted milk, or about three-fifths of an ounce to each pint. The exact dilution to which the milk should be submitted of course varies with the child's age; thus, for the first month of life, two parts of water must be added to one of milk; after the second and third months, more milk may be added, until about the sixth month the child attains to undiluted milk. These must be taken only as general statements, as frequently milk needs to be more diluted even than this. The percentage composition of diluted cow's milk with added lactose may be thus given as quoted by Martin:—

	Water.	Proteids.	Fats.	Lactose.	Salts.	Proportion of nitrogenous to non-nitrogenous food-stuffs—as
Cow's milk with equal parts of water,	90·59	1·77	1·85	5·44	0·35	1 : 4
Cow's milk with two parts of water,	92·73	1·18	1·23	4·63	0·23	1 : 4·8

Accepting this statement, and assuming that a child at five months requires about 2 litres of mother's milk daily, representing nearly 45 grammes of proteid, 80 grammes of fat, 125 grammes of sugar, and 6 grammes of salts: it would require, therefore, 3 litres of milk diluted with 2 parts of water to obtain similar amounts of the food-stuffs.

In the case of an adult requiring daily 4·59 ounces of proteid, 2·96 ounces of fat, and 14·2 ounces of carbo-hydrate, and assuming that 1 litre (35 ounces) of average cow's milk contains 1·24 ounce of proteid, 1·29 ounce of fat, 1·7 ounce of lactose, and 0·27 ounce of salts, it would require at least 4 litres or about 7 pints of milk to furnish him with the necessary amount of proteid, while at the same time the fats and water would be in excess and the carbo-hydrates deficient.

Variations in the composition of normal cow's milk are of frequent occurrence, and may result not only from the kind of feeding, but also from peculiarities of race, the time since calving, and methods of milking the cow. As evidence of this we find that, in what are really normal milks, the specific gravity may range from 1·027 to 1·034, the water may vary from

85 to 88 per cent., the proteids from 2·5 to 5 per cent., the fat from 2·75 to 6 per cent., the lactose from 3·5 to 6 per cent., and total solids from 11·5 to 15 per cent.

The effect of diet is largely shown by the increase of sugar found in the milk of cows fed upon fodder rich in carbo-hydrates, such as carrots and beet-roots. The addition of proteid in the diet raises the casein but not the fat. Cows which are fed much upon refuse from breweries and distilleries commonly yield an abundance of milk, but it is simultaneously poor in fats and other solids. Diseased potatoes and turnips in the food of cattle, without actually affecting the goodness of milk, often cause it to smell and taste unpleasantly.

The quantity of milk yielded by a cow, and its proportion of total solids and fats, often vary in opposite directions. Some cows, like the Dutch, which produce an abundance of milk, usually yield low percentages of fat. Alderneys, on the other hand, commonly yield a milk rich in fat; others, like the long-horned cows, yield large quantities of casein. As a rule, the proportion of total solids in a milk is stable. They practically never fall below 11·5, and commonly average between 12 and 13 per cent. Though the fats yielded by the milks of different cows are apt to vary much, the "solids not fat" fluctuate relatively less. These rarely fall below 8·5 per cent., a figure which is now generally accepted as the minimum standard of a pure and normal milk. This question of the variations in the composition of milk is one of some complexity: in every district observations on the average composition of milk need to be collected for the several months of the year, as it is only by mean values for extensive districts or entire counties that we can arrive at any correct opinion, or formulate standards.

In skimmed milk, the proportion of fat varies greatly: extreme figures cannot be given, but the specific gravity usually amounts to from 1·032 to 1·035, unless it has been simultaneously watered. Separated milk, or that which has had its cream removed by a separator, contains from 0·2 to 0·6 per cent. of fat, and has a specific gravity of from 1·033 to 1·036. A mixture of skimmed evening milk and new morning milk, or of milk which has been partially freed from cream, is sometimes sold as "half milk." Its average composition and condition is not easily defined.

The milk secreted in the early stage of lactation, known as colostrum, is very rich in proteids, due probably to an incomplete transformation of the epithelial lining of the ducts. The colostrum corpuscle is characteristic of milk of this period, while the large proportion of serum-albumin and casein present is often sufficient to coagulate the milk on boiling.

König gives the following as a percentage composition of cow's colostrum milk:—water 74·67, casein 4·04, albumin 13·6, fat 3·59, lactose 2·67, and salts 1·67.

After the colostrum stage, the milk of the cow gradually alters in quality. Up to the second month after delivery, the casein and fat are increased. From the tenth to the twenty-fourth month the casein diminishes, while the fat becomes less from the fifth to the twelfth. The lactose lessens during the first month, but increases during the eighth, ninth, and tenth months. The salts appear to increase up to the fifth month, after which they steadily diminish.

How far the age of the cow, or the number of calvings, influence the milk is but little understood. As a rule, cows are not allowed to calve before the third or fourth year, pregnancy lasting 284 days: colostrum is secreted for a short time before and after delivery, and then milk for 300 days. Fleischmann says that the quantities of milk after the several births increases from 1550 litres at the first to 2400 at the sixth, decreasing then to 500 litres at the fourteenth. Aged cows undoubtedly give inferior milk, but that the mere number of pregnancies influence the composition of the milk is doubtful. The occurrence of the rut, during lactation, has no regular effect upon the milk: at times it is unchanged in quantity but thin and poor, on other occasions it curdles on boiling even when fresh. Transient illnesses in the cow, such as diarrhœa or indigestion, act like defective feeding, often lowering the specific gravity of the milk four or five units.

The manner of milking materially affects the quality of milk. In the udders of a cow, a separation of cream takes place exactly as in a vessel. On this account, the milk first drawn or "fore-milk" is always poor in fat, while the last portions or "strippings" are rich in fat. Hence it follows that a good average milk can be obtained only if the udder is entirely emptied, and the whole milk well mixed. The first three strokes of a milking should not be collected, but should serve to rinse out the excretory ducts and remove any impurities or microbes which have entered. The time of milking has no distinct influence upon the quality of the milk, so long as it is performed at exactly equal intervals. If cows are milked at unequal intervals, the quantity of milk after the shorter intervals is smaller, but contains a higher percentage of fats and of solids. Small differences may be produced by a change of locality and an unaccustomed milker.

No exact statements can be made as to the composition of cream, as it varies so very considerably. From a very large number of analyses, the fat may be said to average from 45 to 49 per cent. The cream rises in from four to eight hours: it is hastened by warming the milk, but its quantity is not increased. The centrifugal apparatus now in use removes all, or nearly all, the cream in a few minutes. Cream so obtained commonly contains more fat than cream which has been obtained by allowing the milk to stand.

Milk alters on standing; it absorbs oxygen, and gives off carbon dioxide; placed in contact with a volume of air equal to its own bulk, it absorbs all the oxygen in three or four days. The carbon dioxide is formed at the expense of the organic matter (probably casein), and bodies richer in carbon and hydrogen are formed; fat increases in amount, and oxalic acid is said to be formed.

Subsequently lactic acid is formed in large quantities from the lactose; the milk becomes turbid, and finally casein is deposited. The cream which had previously risen to the surface in part disappears.

Milk in Relation to Disease.—That milk, after standing some time, turns sour and coagulates under bacterial action is a fact familiar to all. Such sour milk is a fruitful source of digestive troubles in young children, causing vomiting, flatulence, and diarrhœa. By a similar action of bacteria, various coloured, stringy, or ropy milks are produced, all of which cause irritation of the intestine, producing diarrhœa, as well as in some cases giving rise to some aphthous affections of the mouth in children. Besides these alterations in milk, which occur after it has been drawn, there are others which appear to be present in the milk when it is drawn.

It is well known that in human beings, bitters and purgatives, if taken by the mother, act upon infants taking the milk. In the same way, the milk of goats which have eaten colchicum or other Euphorbiaceous plants produces poisonous symptoms, including diarrhœa: also in the case of cows affected with "trembles" due to eating the *Rhus toxicodendron*, their milk gives rise to vomiting and constipation.

The milk of cows affected with various forms of *mastitis* tends soon to decompose: it may contain colostrum cells, or heaps of granules collected in roundish masses, pus cells, or epithelium, and occasionally blood. It then soon becomes acid, and the microscope usually detects abnormal cell forms and casts of the lacteal tubes. Fürstenberg, quoted by König, gives some analyses of milk from a cow affected with interstitial inflammation of the mammary gland. In one case, the milk contained 5·78 per cent. of proteid, with only small amounts of fat and lactose : in another, the proteid was even higher : in another case, in which the mastitis was more acute, the casein, fat, and sugar were all diminished, while the albumin was very greatly increased. How far the milk yielded by these inflamed mammary glands of the cow are capable of producing disease in the human being is not clearly defined, but there can be no doubt that such milk is unsuited for dietetic purposes.

In *cattle plague* (Rinderpest) the lactose of the milk lessens, while the proteids are increased, and blood and granular cells are seen under the microscope.

In *foot-and-mouth disease* (*eczema epizootica*) the specific gravity rapidly falls, though this is not invariable; the milk contains pus and blood, with granular masses. Bacteria and round cells are common. The milk sometimes coagulates on boiling.

The following analyses are quoted by König :—

	Water.	Albumin.	Fat.	Lactose.	Salts.	Authority.
Acute stage,	87·70	3·90	3·90	3·81	0·69	Lassaigne.
During convalescence,	90·60	2·85	2·30	3·02	1·23	,,
On 2nd day of disease,	79·90	14·38	5·01	...	0·71	Wynter Blyth.
On 4th ,, ,,	83·85	3·47	7·80	4·67	0·21	,,
On 14th ,, ,,	83·88	11·48	3·96	...	0·68	,,

There has been much discussion whether the milk from foot-and-mouth disease in cows can cause affections of the mouth, or give rise in human beings to any disease similar to that of cattle. Pigs can certainly get the disease from the milk of the cow; sheep and hares, which also have the disease, perhaps get it from the saliva on herbage. In men the evidence is discordant, and in a great measure negative; still there are some striking cases, which seem sufficient to prove that disease of the mouth (aphthous ulceration, general redness, diphtheritic-like coating, swollen tongue), and sometimes, though rarely, an affection of the feet may occur. Some positive evidence has been adduced by M'Bride, Gooding, Hislop, Latham, and Briscoe.

A remarkable outbreak, which took place in Aberdeen in April 1881, has been recorded by Beveridge. The symptoms were febrile, and seem to have resembled those of foot-and-mouth disease. A marked feature in the illness was subsequent enlargement of the lymphatic glands of the neck. The cases were limited to the area of a particular milk supply, 88 per cent. of the families using the milk being attacked.

In 1884, at Dover, there suddenly broke out an epidemic of sore throat, with vesicular eruption of the throat or lips, enlarged tonsils, and in most cases also enlargement of the glands of the neck. The symptoms resembled the aphthous fever of cattle, or foot-and-mouth disease. There were 205 cases in one week, all supplied with milk from one dairy, but living in different parts of the town, and with no other common condition but that of milk supply. Foot-and-mouth disease existed at one of the farms from which this dairy derived its milk.

Tuberculosis in cows (*Perlsucht*) affects the milk, and may lead to the same disease in man; during the early stages, the quantity is sometimes increased; it contains usually an excess of water and alkaline salts, while deficient in fat, sugar, and proteids.

It is now known that tuberculosis can be transmitted from the cow to other animals through milk, that it is a disease very prevalent amongst cows, and that it is the same disease as in the human species. There is also some evidence to show that tuberculosis may be transmitted from the cow to man. A distinction, however, must be made between the milk from cows with tubercular udders and that from animals affected with general tuberculosis, as the tubercle bacilli are rare in milk unless the udders are tuberculous. Animals can be given tuberculosis by feeding them with milk from tubercular cows. Boiling the milk is a preventive measure of the first importance, as the tubercle bacilli are destroyed by heat.

Zymotic Diseases.—Milk may also be a means of conveying the poisons of enteric fever, of scarlet fever, of diphtheria, and of cholera. In the first, it has probably usually arisen from the watering of the milk with impure water containing the agent, or from the use of foul water in washing out the milk vessels; but it may possibly have in some cases arisen from the enteric effluvia being absorbed by the milk. The scarlet fever and diphtheria poisons have probably got into the milk from the cuticle or throat discharges of persons affected with those diseases, who were employed in the dairy while ill or convalescent. But the investigations by Power and Klein, in connection with the Hendon outbreak, seem to show that cows are liable to a disease which, although comparatively mild as regards the animal itself, is capable of communicating scarlatina to man. Klein, by means of careful cultivations, has shown that the *micrococci* found in such milk are probably identical with those found in scarlatina, and that they may be capable of exciting the disease in animals. There seem also grounds for believing that milk may be the means of transmitting diphtheria from diseased cows, apart from direct contamination from human beings.

That milk is not only a probable but an actual agent in the dissemination of enteric fever has long been recognised. This may occur either by adulteration of the milk with impure water containing the specific microbe; or by the use of similarly befouled water in washing out the milk vessels; or even from the milking of the cows by a person whose hands have been soiled by the enteric dejecta. An interesting case, illustrating this last method, is related by Welply as having occurred at Bandon in 1893, in which the central focus of the disease was a large creamery, and the medium was the separated milk distributed therefrom. Allen, of Pietermaritzburg, and Power have reported cases which would seem to indicate that enteric fever may be transmitted to man by milk of cows suffering from a similar malady. Though their facts are very suggestive of this sequence of events, they cannot be quite accepted as altogether conclusive.

Just as enteric fever, scarlet fever, and diphtheria may be disseminated by the specific infection of milk, so may cholera be similarly conveyed. Simpson of Calcutta gives the particulars of an outbreak of cholera on board the ship "Ardenclutha" lying off that port, in which the poison seemed undoubtedly to have been conveyed by milk. Of the crew of this ship, all those who drank milk brought by a particular native milkman suffered. The milk seller was traced, and found to live near a tank into which dejecta from a cholera patient found access; and he confessed to habitually diluting his milk, one-fourth, with water from this tank. All other likely causes were inquired into, and negatived before this apparently clear causative connection was discovered.

Vaughan of Michigan has demonstrated, in old and stale milk, the presence of a ptomaine-like body which is toxic to animals. It appears to be found in marked quantity in cheeses and ice-creams, and is probably the cause of many of the cases of poisoning by those articles which are on record. Other cases are known in which milk, stored in dirty pans and in unwholesome or filthy surroundings, has given rise to most alarming symptoms. What are the precise changes induced in milk by these conditions is not well understood, but the probable decomposition is a transformation of the proteids into highly poisonous benzene derivatives, the most important of which is diazobenzene, commonly known as tyrotoxicon.

Preserved Milks.—The simplest method, for the preservation of milk, is to boil it and then tightly cork the vessel; but, as a rule, this preservation is only temporary. The same end is attained by adding antiseptics, such as salicylic acid, boric acid, and formalin, to the milk, either before or after it has been boiled. The common forms, however, of preserved milk are the concentrated ones, such as the dried milk, and the so-called condensed milks with or without sugar. Those without sugar keep less well than those with sugar, once the tin in which they are sold is opened. The majority of condensed milks are made by evaporating down the original milk to a third or a quarter, and then adding sugar to it; this added sugar tends to make condensed milks rather fattening; but on the whole their nutritive value is below that of the fresh article, simply because the great majority of the so-called condensed milks in the market are nothing more than condensed separated milks (that is, milks from which nearly the whole of the cream has been mechanically separated) mixed with sugar, and really containing very low percentages of fat—so low as to be negligible quantities so far as value to the consumer is concerned. Of course, there are notable exceptions to this rule; such condensed milks being actually condensed whole milks as distinguished from the comparatively worthless condensed separated milks. A clear understanding upon this subject is very necessary in the interests of the feeding of infants. "Milk" at no time should be construed so as to mean "thinned milk," nor does it mean "separated milk." These, which are, as every one knows, articles of commerce, should be described at all times by their distinctive titles. Condensed milk means condensed whole milk, and if a preparation which has been obtained by condensing separated milk is called condensed milk, its sale as such amounts to a distinct fraud upon the public.

A large proportion of these so-called condensed or preserved milks are found on analysis to be prepared entirely from skimmed milk, and show an average of only 0·72 per cent. of fat. Some brands, prepared from partly skimmed milk, or from skimmed milk to which a small proportion of unskimmed milk has been added, show an average of 3·14 per cent. of fat. Samples of condensed genuine full-cream milk, such as the well-known "Milkmaid" brand prepared by the Anglo-Swiss Condensed Milk Company, have yielded from 10 to 12 per cent. of fat.

Unfortunately, in the present state of the law, as interpreted by some eminent judicial authorities, condensed skimmed milk, that is to say, milk deprived of one of its chief constituents, namely, fat, in the absence of which it ceases to be milk in the true sense of the word, may lawfully be labelled "condensed milk," although when sold uncondensed it must be distinctly stated at the time of sale that it is skimmed milk; that is, a small milk vendor is fined for selling what a condensed milk manufacturer is at liberty to sell provided he condenses it first, and in an obscure manner states upon the tin that the tin "contains skimmed milk," although upon the face of the same label it is described as "condensed milk." This defect in the state of the law regarding milk constitutes an anomaly, which, in the interests of the public health, it is to be hoped future legislation will soon remedy.

Strictly speaking, both "Koumiss" and "Kéfir," which are fermented milks of the mare, are forms of preserved milk, both containing lactic and carbonic acids, with some alcohol. In kéfir, the casein is partially changed into albumose and peptone. Both these forms of fermented and partially digested milk are used as food for the sick, or those in whom digestion is feeble. The percentage composition of some preserved milks is given in the following table :—

	Water.	Proteids.	Fats.	Lactose.	Cane-Sugar.	Ash.	Alcohol.	Lactic Acid.	Carbonic Acid.	Glycerin.
Scherff's condensed milk,	72·87	8·20	6·62	10·63	...	1·68	...	...	...	...
Nestle's condensed milk,	25·35	30·77	8·14	14·20	19·60	1·94	...	...	...	...
American condensed milk,	50·35	18·89	13·36	14·82	...	2·58	...	...	...	...
Irish Co.'s condensed milk,	25·83	35·67	3·40	15·00	18·00	2·10	...	...	...	...
Lœflund's condensed milk,	57·79	15·24	7·22	17·55	...	2·20	...	...	...	...
Lœflund's (Alpine Co.) condensed milk,	59·23	11·90	11·71	14·82	...	2·34	...	...	...	...
Cow brand condensed milk, .	32·00	16·18	0·32	17·00	24·70	1·80	...	...	...	...
Milkmaid brand condensed milk,	25·25	14·35	12·25	11·91	34·18	2·06	...	...	...	...
Swiss compressed extract of milk,	0·72	34·48	1·87	55·58	...	7·35	...	...	...	...
Koumiss from mare's milk,	90·63	2·24	1·46	1·77	...	0·22	1·91	0·91	0·86	...
,, ,,	91·97	2·11	1·10	0·40	...	0·34	2·12	1·96	...	...
Koumiss from cow's milk,	88·28	2·66	1·83	4·09	...	0·43	1·14	0·55	0·86	0·16
Kéfir, .	90·22	3·49	1·44	2·40	...	0·68	0·75	1·02	...	...
Cross brand condensed milk,	31·00	15·32	0·96	16·00	34·82	1·90	...	...	...	...
Goat brand condensed milk,	32·60	16·11	0·56	16·44	32·29	2·00	...	...	...	...

EXAMINATION OF MILK.

Although the milk from individual cows varies largely in composition, yet the mixing of the milk given by a herd averages the general composition within certain limits. The examination of a milk sample is intended primarily to determine whether it is what it is said to be; that it is pure and wholesome; and that it has not been adulterated or sophisticated so as to be, in any way, detrimental to health. The chief adulterations of milk are:—

1. The addition of water (not necessarily pure water).
2. Removal of part of the cream and adding water to bring the specific gravity up to the normal; or removal of the cream from the evening milk and adding the morning milk.
3. The addition of starch, flour, gum, dextrin, or glycerin.
4. The addition of bicarbonate of soda, borax, boric, and salicylic acid and formalin as preservatives.

In the examination of a milk sample, attention should be directed to the following preliminary observations:—

The Physical Characters.—Placed in a narrow glass, the milk should be quite opaque, of full white colour, without deposit, and without peculiar smell or taste. When boiled it should not change in appearance.

Reaction.—Reaction should be slightly acid or neutral, or very feebly alkaline; if strongly alkaline, either the cow is diseased (?) or there is much colostrum, or sodium carbonate has been added. Milk, when just drawn from the cow, is sometimes both acid and alkaline; that is, it turns blue litmus red, and turmeric brown, giving what is known as the "amphioteric" reaction. This is probably due to the presence of acid phosphates of the alkalies. Strong acidity means the presence of lactic or butyric acid, and is indicative of retrograde changes in the milk. Strong alkalinity may mean either a diseased milk, or added sodium bicarbonate.

The Cream.—When milk is allowed to stand, some of the fat rises gradually, and forms a rich layer, constituting cream. Its proportion depends on several conditions, and can be readily determined in the following way. Put some of the milk in a long glass, which is graduated to 100 parts; a 100-centimetre or litre measure will do, or a glass may be specially prepared by simply marking with compasses 100 equal lines on a piece of paper, and gumming it on the glass. Allow it to stand for twenty-four hours in a cupboard secured from currents of air. By this means the percentage of cream can be seen, and the presence of deposit, if any, observed. There should be no deposit till the milk decomposes; if there be, it is probably chalk or starch.

The cream should be from $\frac{6}{100}$ths to $\frac{11}{100}$ths; it is generally about $\frac{8}{100}$ths; in the milk of Alderney cows it will reach $\frac{30}{100}$ths or $\frac{40}{100}$ths. The time of year (as influencing pasture), and the breed, should be considered.

Unfortunately the amount of cream formed in a given time cannot be taken as a measure of the richness of the milk. Water added to milk causes a more rapid separation of the cream, and milk subjected to centrifugal action yields a much larger percentage of cream, practically all the fat being removed. The following analytical averages show this very clearly:—

	Whole Milk.	Skimmed Milk.	Cream.
Specific gravity,	1032	1034	1015
Total solids,	14·10	9·60	26·98
Casein,	3·56	3·75	1·13
Fat,	5·05	0·02	21·95
Lactose,	4·70	5·05	3·32
Salts,	0·79	0·78	0·58

For the detection of the more common adulterations of milk, namely, the removal of cream and addition of water or other matters, recourse must be made to the following determinations.

Specific Gravity.—In all milks the specific gravity is understood to be taken at 15° C. or 60° F.; if at other temperatures, the result must be corrected for 15° C. by a reference to the table given on page 311. The instrument usually employed is a lactometer. The specific gravity of normal milk varies between 1·027 and 1·034, being less in proportion as the fat is greater. A milk, the specific gravity of which has been raised by removal of fat (skimming), can be restored to its original specific gravity by adding water, so that this determination by itself cannot be taken as a reliable index of the character of a sample. But taken in conjunction with the figures for total solids or for fat, it is of the greatest value, and constitutes a reliable check upon other determinations.

Expressed in general terms, it may be said that the specific gravity of milk falls one degree for each rise of 10° F. above 60° F., and that, at that temperature, there is a loss of three degrees of gravity for every 10 per cent. of water added.

Owing to the fact that milk, especially when first drawn, often contains bubbles of air, care must be taken in mixing the samples before taking the density, and to allow sufficient time for the escape of any bubbles that may be present.

Total Solids.—Evaporate a known quantity, say 2 c.c., of the milk to dryness in a flat and shallow dish, and weigh. Calculate out as a percentage. The heat employed should not exceed 100° C. (212° F.) and should be continued for at least three hours, taking care that there is no charring. The specific gravity of the milk being known, the amount taken can be readily calculated. Thus, 2 c.c. of milk, whose specific gravity is 1·032, would weigh 2·064 grammes, and if after evaporation this amount of milk gave a solid residue of 0·284 gramme, the percentage of total solids yielded by the sample would be $\frac{0{\cdot}284 \times 100}{2{\cdot}064} = 13{\cdot}76$. The total solids found ought not to be below 11·5, but more usually average between 12 and 13 per cent.

Ash.—The residue or dried solids, in the last determination, may be incinerated, re-weighed, and calculated out in a similar manner as so much ash. In normal milks this averages about 0·73 per cent., and in no case should fall below 0·7; if the milk be watered, it will be less. Any marked degree of alkalinity or effervescence of the ash with hydrochloric acid will suggest the addition of a carbonate. The ash of milk may be said to have the following average composition :—

Ca,	18·78
NaCl,	10·73
KCl,	26·33
KHO,	21·44
P_2O_5,	19·00
H_2SO_4,	2·64
$F_2P_2O_5$,	0·21
Silica,	traces.

Fat.—The estimation of the fats constitutes a very important determination. This is best done by means of the apparatus of Gerber or of Soxhlets, in which ether is made to pass repeatedly through the solids of milk, dried after being mixed with plaster of Paris, or soaked up by bibulous paper (Adams' method). The solids dried alone are inconvenient, as they become horny in consistence, and are thus acted upon with difficulty by the ether. The ether carries down with it the fat. The ether is then evaporated and the fat weighed. Should the milk have become sour, Adams recommends the addition of ammonia, which restores the fluidity without otherwise affecting the constituents.

TABLE *for correcting the Specific Gravity of Milk according to Temperature (after Vieth).*

Specific Gravity.	Degrees of the thermometer (Fahrenheit).																													
	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
1020	19·0	19·1	19·1	19·2	19·2	19·3	19·4	19·4	19·5	19·6	19·7	19·8	19·9	19·9	20·0	20·1	20·2	20·2	20·3	20·4	20·5	20·6	20·7	20·9	21·0	21·1	21·2	21·3	21·5	21·6
1021	20·0	20·0	20·1	20·2	20·2	20·3	20·3	20·4	20·5	20·6	20·7	20·8	20·9	20·9	21·0	21·1	21·2	21·3	21·4	21·5	21·6	21·7	21·8	22·0	22·1	22·2	22·3	22·4	22·5	22·6
1022	21·0	21·0	21·1	21·2	21·2	21·3	21·3	21·4	21·5	21·6	21·7	21·8	21·9	21·9	22·0	22·1	22·2	22·3	22·4	22·5	22·6	22·7	22·8	23·0	23·1	23·2	23·3	23·4	23·5	23·7
1023	22·0	22·0	22·1	22·2	22·2	22·3	22·3	22·4	22·5	22·6	22·7	22·8	22·8	22·9	23·0	23·1	23·2	23·3	23·4	23·5	23·6	23·7	23·8	24·0	24·1	24·2	24·3	24·4	24·6	24·7
1024	22·9	23·0	23·1	23·2	23·2	23·3	23·3	23·4	23·5	23·6	23·6	23·7	23·8	23·9	24·0	24·1	24·2	24·3	24·4	24·5	24·6	24·7	24·9	25·0	25·1	25·2	25·3	25·5	25·6	25·7
1025	23·9	24·0	24·0	24·1	24·1	24·2	24·3	24·4	24·5	24·6	24·6	24·7	24·8	24·9	25·0	25·1	25·2	25·3	25·4	25·5	25·6	25·7	25·9	26·0	26·1	26·2	26·4	26·5	26·6	26·8
1026	24·9	24·9	25·0	25·1	25·1	25·2	25·2	25·3	25·4	25·5	25·6	25·7	25·8	25·9	26·0	26·1	26·2	26·3	26·5	26·6	26·7	26·8	27·0	27·1	27·2	27·3	27·4	27·5	27·7	27·8
1027	25·9	25·9	26·0	26·1	26·1	26·2	26·2	26·3	26·4	26·5	26·6	26·7	26·8	26·9	27·0	27·1	27·3	27·4	27·5	27·6	27·7	27·8	28·0	28·1	28·2	28·3	28·4	28·6	28·7	28·9
1028	26·8	26·8	26·9	27·0	27·0	27·1	27·2	27·3	27·4	27·5	27·6	27·7	27·8	27·9	28·0	28·1	28·3	28·4	28·5	28·6	28·7	28·8	29·0	29·1	29·2	29·4	29·5	29·7	29·8	29·9
1029	27·8	27·8	27·9	28·0	28·0	28·1	28·2	28·3	28·4	28·5	28·6	28·7	28·8	28·9	29·0	29·1	29·3	29·4	29·5	29·6	29·8	29·9	30·1	30·2	30·3	30·4	30·5	30·7	30·8	31·0
1030	28·7	28·7	28·8	28·9	29·0	29·1	29·1	29·2	29·3	29·4	29·6	29·7	29·8	29·9	30·0	30·1	30·3	30·4	30·5	30·7	30·8	30·9	31·1	31·2	31·3	31·5	31·6	31·8	31·9	32·1
1031	29·6	29·6	29·7	29·8	29·9	30·0	30·1	30·2	30·3	30·4	30·5	30·6	30·8	30·9	31·0	31·2	31·3	31·4	31·5	31·7	31·8	32·0	32·2	32·2	32·4	32·5	32·6	32·8	33·0	33·1
1032	30·5	30·5	30·6	30·7	30·9	31·0	31·1	31·2	31·3	31·4	31·5	31·6	31·7	31·9	32·0	32·2	32·3	32·5	32·6	32·7	32·9	33·0	33·2	33·3	33·4	33·6	33·7	33·9	34·0	34·2
1033	31·4	31·4	31·5	31·6	31·8	31·9	32·0	32·1	32·3	32·4	32·5	32·6	32·7	32·9	33·0	33·2	33·3	33·5	33·6	33·8	33·9	34·0	34·2	34·3	34·5	34·6	34·7	34·9	34·5	35·2
1034	32·3	32·3	32·4	32·5	32·7	32·9	33·0	33·1	33·2	33·3	33·5	33·6	33·7	33·9	34·0	34·2	34·3	34·5	34·6	34·8	34·9	35·0	35·2	35·3	35·5	35·6	35·8	36·0	36·1	36·3
1035	33·1	33·2	33·4	33·5	33·6	33·8	33·9	34·0	34·2	34·3	34·5	34·6	34·7	34·9	35·0	35·2	35·3	35·5	35·6	35·8	35·9	36·1	36·2	36·4	36·5	36·7	36·8	37·0	37·2	37·3

What is known as the Werner-Schmid method is a fairly satisfactory means for the determination of fat, and is especially suitable for sour milk. Measure 10 c.c. of the milk into a long test-tube of 50 c.c. capacity, graduated to tenths of a c.c., and add 10 c.c. of strong hydrochloric acid. After mixing, the liquid is boiled for one minute. The tube and contents are cooled in water, 30 c.c. of well washed ether added, shaken, and allowed to stand until the line of acid and ether is distinct. The cork is taken out, and a double tube arrangement, like that of the ordinary wash bottle, inserted. The lower end of the exit tube is adjusted so as to rest immediately above the junction of the ether and acid. The ethereal solution of fat is then blown out, and received into a weighed flask. Two more portions of ether, each of 10 c.c., are shaken with the acid liquid, blown out and added to the first. The total ether is then distilled off, the fat dried, weighed, and calculated as a percentage.

A simple but approximate estimate of the fat in milk can be made by means of the degree of transparency of the liquid, as determined by Vogel's lactoscope. Vogel's instrument consists of a little cup, formed by two parallel pieces of glass, distant 0·5 centimetre from each other, and closed everywhere except at the top, so as to form a little vessel. Varying quantities of milk (say 2 to 5 c.c.) are well mixed up with 100 c.c. of distilled water in any ordinary measuring glass. The parallel glass cup is then filled with this diluted milk, and a candle, placed about 1 metre from the eye (= 39·37 inches), is looked at in a rather darkened room; if the flame of the candle is seen, the milk is poured back into the large measure; more milk is added to it, and it is poured again into the parallel glass, and the light is again looked at; the experiment ends when the contour of the light is completely obscured. The candle should be a good one, but the difference in the amount of light is not material. The percentage amount of fat in the milk is then calculated by the following formula (which has been determined by a comparison of the results of the instrument, and of chemical analysis): x being the quantity of fat sought, and m the number of c.c. of milk which, added to the 100 c.c. of water, suffice to obscure the light.

$$x = \frac{23{\cdot}2}{m} + 0{\cdot}23.$$

Example.—Say 3 c.c. of milk, added to 100 of water, were sufficient to obscure the light, the percentage of fat is—

$$x = \frac{23{\cdot}2}{3} + 0{\cdot}23 = 7{\cdot}96 \text{ per cent.}$$

Several investigators have, from time to time, proposed formulæ by which, when any two of the data, specific gravity, fat, and total solids, are known, the third can be calculated. At times these formulæ are very serviceable. That of Hehner and Richmond is the best, and is now very extensively used, being based on an extensive range of observation and perfect processes of fat extraction. The formula is as follows:—

$F = 0{\cdot}859\,T - 0{\cdot}2186\,G$, in which F is the fat, T the total solids, and G is the specific gravity. This formula does well for ordinary milks, but in the case of poor skim milks, it has been found necessary to modify it as follows:—

$$F = 0{\cdot}859\,T - 0{\cdot}2186\,G - 0{\cdot}05\left(\frac{G}{T} - 2{\cdot}5\right).$$

This correction is only to be applied when G, divided by T, exceeds 2·5.

In these formulæ, G represents the last two units of the specific gravity and any decimal. Thus, if the observed gravity be 1029·7, G will be 29·7.

Example.—Applying the formula, in the case of a milk whose specific gravity is 1029·5, and whose total solids are 12·5, we find the fats to be 4·28 per cent. So, in the case of a poor milk whose specific gravity is 1032, and total solids 9·77, the fats per cent. are found to be but 1·36.

A ready means of applying this formula is afforded by the use of Richmond's slide rule. This has three scales, two of which, for total solids and fat respectively, are marked on the body of the rule, while that for the specific gravity is placed on the sliding portion. The divisions of the scales are arranged as follows:—On the total solids scale, 1 inch is divided into tenths; on the fat scale, 1·164 inch is divided into tenths; while on the specific gravity scale, 0·254 inch is divided into halves. To use the rule, adjust the figure of the observed specific gravity to that of the total solids found, when the arrow point will indicate the percentage of fat; or, if the fat be known, then by adjusting the arrow point to the graduation corresponding to the fat found, the figure for the specific gravity will coincide with that for the total solids. This slide rule does not allow for the correction for poor skim milks, but the error from this cause does not exceed 0·08 per cent., and may be practically disregarded.

For cases in which the fat and specific gravity are known, Richmond has recently proposed the following new formula for calculating the total solids:—$T = \frac{G + 5F}{4}$. This simple formula is correct within 0·2 per cent. up to 6 per cent. of fat. It is still more accurate if 0·05 per cent. be added for each 1 per cent. above 3 per cent., and subtracted for each 1 per cent. below 3 per cent. A milk scale to express the same relation may be constructed on which 1 per cent. total solids = 1 inch, 1 per cent. fat = 1·2 inch, or 5 per cent. = 6 inches, and 1 degree of gravity = ¼ inch; if the zero on the fat scale be placed on a line with 5 per cent. on the total solids scale, the arrow will be in its correct position, or 0·14 inch below 20 degrees on the specific gravity scale.

Casein.—Take a weighed or measured quantity of milk; add two or three drops of acetic acid, and boil. Add a good deal of water; allow to stand for twenty-four hours; pour off the supernatant fluid; wash the precipitate well with ether at 80° F.; dry and weigh. Calculate the percentage as casein; it is difficult to free it entirely from fat. Wanklyn recommends the albuminoid ammonia process, as in the case of nitrogenous matter in water, one part of casein yielding 0·065 of ammonia. This determination is not often required.

The serum-albumin may be estimated in the whey after clotting a measured quantity of milk by rennet. A measured amount of the filtered whey is precipitated by excess of alcohol, the precipitate collected, washed with ether and alcohol, dried and weighed.

Lactose may be determined either by means of a saccharometer, or by a standard solution of copper.

Of the various kinds of saccharometer, the so-called half-shadow instruments are the most satisfactory. They are so arranged, by the use of a semi-circle of thin quartz, that the field is divided into semi-circles which are equally illuminated when the instrument registers zero. On the introduction of a tube carrying the sugar solution, the illumination becomes unequal, and the angular rotation of the analyser which is required to restore the original condition, measures the rotation which has been caused by the sugar.

In the various transition tint saccharometers, as well as in Schmidt and Haensch's latest form of half-shadow instrument, the graduated scale does not directly give measurements in angular degrees, but expresses a percentage of sugar directly in terms of cane-sugar.

The optical activity of a sugar is variously expressed according to the source of light used. In the literature upon this subject, we find the activity expressed as $[a]_D$, $[a]_j$, &c. When a sodium flame, or a Bunsen burner in the middle of which is a pellet of sodium held on a platinum wire, is the source of light employed, it is indicated by $[a]_D$, while the symbol $[a]_j$ represents light from a candle or strong gas flame; this is sometimes called the yellow ray. When it is necessary to determine optical activities for rays of other refrangibility, say for the lithium or thallium flame, it is only necessary to colour the Bunsen flame with these metals in the same way as in the case of sodium above. The readings are then $[a]_{Li}$ and $[a]_{Th}$.

In the Soleil-Duboscq saccharometer the scale is so constructed that the 100 point is recorded by a solution of cane-sugar in a 200 mm. tube containing 16·35 grammes of pure cane-sugar per 100 c.c.; consequently, each degree of the scale represents 0·1635 gramme of cane-sugar per 100 c.c. According to O'Sullivan, 100 divisions of this instrument correspond to 24° angular rotation for the mean yellow ray; hence one division of this scale equals 0·24 angular degree ray j or $[a]_j$.

In the Soleil-Ventzke-Scheibler saccharometer, and in Schmidt and Haensch's modification of it, the scale is so constructed that the 100 point is recorded by a solution in a 200 mm. tube containing 26·048 grammes of pure cane-sugar per 100 c.c.; consequently, each division of the scales on these instruments represent 0·26048 gramme of cane-sugar per 100 c.c.

Taking the value of $[a]_j$ for cane-sugar as 73°·8, 100 divisions of the Ventzke scale are equal to 38°·4 $[a]_j$; that is to say, that a solution containing 26·048 grammes of cane-sugar per 100 c.c., and which produces a rotation of 100 divisions on the Ventzke scale, would record on instruments having angular graduation a rotation for the same ray through an angle of 38°·4; hence one division of the Ventzke scale equals 0°·384 angular measurement.

When the degrees of angular rotation produced by a solution of a known sugar are known or determined, the percentage composition of that solution equals $\frac{100a}{r \times l}$, where a equals the observed angular deviation, and r is the specific rotation of the sugar, while l is the length of the tube in decimetres. Conversely, the specific rotatory power or r equals $\frac{100a}{c \times l}$, where the other symbols being as before, c is the strength of solution employed. Therefore, in order to calculate the specific rotatory power from observations made with either the Soleil-Duboscq or Soleil-Ventzke-Scheibler and Haensch instruments, the equations stand $[a]_j = \frac{24a}{2c}$ and $[a]_j = \frac{38 \cdot 4a}{2c}$ respectively.

From the foregoing data, and by experimental observation, the following table has been constructed :—

Rotatory Power $[a]_j$ at 15°·5 C. of various Sugars. + equals right. – equals left.		Scale divisions on a S.-V.-S. or S. and H. Saccharometer corresponding to a one per cent. solution of the sugar.
Dextrin,	+222 ·0	+11·53
Cane-sugar,	+ 73°·8	+ 3·84
Lactose,	+ 61°·5	+ 3·20
Maltose,	+155°·0	+ 8·05
Dextrose,	+ 59°·0	+ 3·07
Lævulose,	–106°·5	– 5·54
Invert-sugar,	– 23°·75	– 1·24

In order to facilitate calculations of percentages of various sugars by those using either a Soleil-Ventzke-Scheibler, or Schmidt and Haensch's saccharometer, the following factors may be used, and by which scale divisions on those instruments may be multiplied, to obtain percentage statements of the particular sugars being examined. These factors are obvious deductions from the preceding statement.

Kind of Sugar.	Saccharometer Factor.
Dextrin,	0·0866
Cane-sugar,	0·2604
Maltose,	0·1240
Dextrose,	0·3258
Lactose,	0·3126
Lævulose,	0·1805
Invert-sugar,	0·8094

Before the estimation of lactose can be made in milk by means of the polarimeter or saccharometer, certain proteids which are always present in milk, and which possess a left-handed rotation, must be removed as well as the fat. The most reliable method for ensuring this appears to be that recommended by Wiley, which is as follows:—

The sp. gr. of the milk is first determined; if this should be 1026 (water = 1000) or thereabouts, 60·5 c.c. of the milk are transferred to a 100 c.c. flask and 1 c.c. of mercuric nitrate solution, or 30 c.c. of mercuric iodide solution (preferably the latter), added. The liquid in the flask is then made up to 102·4 c.c. with distilled water, well shaken up, filtered bright, and polarised in the 200 mm. tube of the saccharometer.

The volume is made up to 102·4 c.c. because the precipitated albumin occupies a volume of about 2·4 c.c., so that the solution is really diluted to 100 c.c. Should the sp. gr. of the milk be 1030, 60 c.c. are taken instead of 60·5 c.c., and if the sp. gr. be 1034, 59·5 c.c. are taken.

The room and milk should be at one constant temperature, and the polarisation taken at the same, about 15° C. being the best suited for the purpose, although a few degrees above or below will not appreciably affect the results.

In the absence of mercuric nitrate or iodide solution, the proteids may be precipitated from the milk by means of acetic acid and heat as subsequently explained in the copper process for the estimation of lactose. Acetic acid is less preferable, as it often fails to remove all the albumins. The mercuric solutions are prepared as follows:—Mercuric nitrate by dissolving mercury in double its weight of nitric acid (sp. gr. 1·42), then adding to the solution an equal volume of water. One c.c. of this reagent is sufficient to precipitate the proteids in 50 to 60 c.c. of milk. The mercuric iodide solution is made by taking potassium iodide 33·2 grammes, mercuric chloride 13·5 grammes, acetic acid (sp. gr. 1·04) 20 c.c., and water 640 c.c. Of this solution 30 c.c. are required for 50 to 60 c.c. of milk.

The presence of mercury in the filtrate (whey) when these reagents are used is objectionable, as the filtrate can only be used for the single purpose of polarimetrical observations.

To determine the lactose by the copper solution, we require a standard solution to be made by taking 34·64 grammes of pure copper sulphate and dissolving in 200 c.c. of distilled water. Take also 173 grammes of tartrate of sodium and potassium and dissolve in 480 c.c. of solution of caustic soda or potash. Mix the two solutions slowly, and dilute with distilled water to one litre. One c.c. of this solution is reduced by 5 milligrammes of either glucose or invert-sugar, and by 6·67 milligrammes of lactose.

To estimate the milk-sugar by means of this solution, take 10 c.c. of milk, add a few drops of acetic acid, and warm—this coagulates the casein with the fat; then make up to 100 c.c. with distilled water, filter, and put the filtered whey (which ought to be as clear as possible) into a burette. Take 10 c.c. of standard copper solution, put it in a porcelain dish, and add 50 c.c. of distilled water; boil; as soon as it is in brisk ebullition drop in the whey from the burette; take care that the liquid is boiling all the time; continue the process until the copper is all reduced to red suboxide and no blue colour remains in the supernatant liquid; but stop before any yellow colour appears. Read off the amount of whey used, and divide by 10; the result is the amount of milk which exactly decomposes 10 c.c. of the copper solution. The 10 c.c. of the copper solution are equal to 0·0667 gramme of lactose. The amount of lactose in the 10 c.c. of milk is then known by a simple rule of three; and the amount in 100 c.c. of milk is at once obtained by shifting the decimal point one figure to the right.

Example.—15 c.c. of diluted whey were required to reduce the 10 c.c. of copper solution; $\frac{15}{10}=1·5$, the amount of original milk; $0·0667 \div 1·5 = 0·0445$ gramme of lactose in 1 c.c.; therefore $0·0445 \times 100 = 4·45$ per cent.

Microscopic and Bacteriological Examination of Milk.—It is always advisable to examine a milk sample microscopically. The only strictly normal constituents of milk are the round oil globules of various sizes in an envelope and a little epithelium. The abnormal constituents are epithelium in large amount, pus, conglomerate masses, and casts of the lacteal tubules. The added ingredients may be starch grains, portions of seeds, and chalk (round and often highly refracting bodies, with often a marked double outline, and at once disappearing in acid). Colostrum, occurring for three to eight days after the birth of the calf, is composed of agglomerations of fat vesicles united by a granular matter.

Milk from a healthy cow is secreted free from microbes; but micro-organisms always find their way into the milk from the surface of the udder, from the hands of the milker, from particles of dung, from the milk cans, or from the air of the cow sheds. The average number of micro-organisms found in samples of milk by us is not less than 400,000 per cubic centimetre. Other observers have given the number found in other milk supplies at an even higher figure, but it must be remembered that in any numerical examination the sources of error are very numerous. Owing to its peculiar composition, milk always constitutes a favourable medium for various forms of microbes, which multiply rapidly in it if the milk is not at once exposed to very low temperatures. Repeated examinations have shown that the residues of milk in the excretory ducts of the udder are frequently rich in bacterial life, and that it is the earlier portions of milk drawn off at a milking which are the most common source of infection; for this reason, they should as a rule be rejected. The method of examination of milk is that customary for other liquids. Cover-glass preparations are readily prepared by placing the smeared and dried cover-glasses in a small capsule containing 5 c.c. of chloroform and 1 c.c. of a saturated alcoholic solution of methylene blue. After five minutes, the chloroform is evaporated, the glasses rinsed in water and examined in the usual manner.

Examination of the milk by cultivation is more important; on account of the great number of micro-organisms usually present, free dilution is necessary; of culture media, agar is perhaps the best for milk. The species commonly found in milk are: *B. acidi lactici*, *B. butyricus*, *M. fluorescens liquefaciens*, *B. mesentericus vulgatus*, *B. subtilis*, *B. coli communis*, and various indeterminate cocci. Blue milk contains *B. cyanogenus;* red milk the *B. prodigiosus* or *Sarcina rosea;* yellow milk the *B. synxanthus* of Flügge; while the ropy and slimy milks contain special forms, the identity of which is as yet uncertain. In some bitter tasting milks, the *Proteus vulgaris* has been noted, associated with a coccus and a short thick bacillus whose species is unknown. The presence of the *Oidium lactis*, the *Monilia candida* or *Oidium albicans*, and various other forms of fungi, may be also readily detected in many samples of milk by plate cultures set from them in the usual manner. All these micro-organisms find their way into milk only *during* or *after* milking. Under certain circumstances, pathogenic microbes may be present and even increase in milk.

Milk drawn from diseased cows may contain various pathogenic forms, especially the *bacilli of tuberculosis*, or cocci which produce suppuration. The detection of the tubercle bacillus in milk by direct culture therefrom is difficult; it is much more reliable to inject from 10 to 15 c.c. of the suspected milk, as fresh as possible, into the peritoneal cavity of a guinea-pig. After four weeks, the animal should be killed, when, if the bacilli had been present, there is found the characteristic appearance of peritoneal tuberculosis.

These facts regarding the general bacterial impurity of milk samples suggest the urgent need of reforms in connection with both the milking of cows and of the sale of milk generally. The following suggestions have been formulated by a special commissioner of the British Medical Association, when reporting on the milk supply of London. They are sufficiently to the point as to merit adoption, not only in the metropolis but elsewhere.

1. "That all milking be carried on in the open air, the animals and operators standing on a material which is capable of being thoroughly washed, such as a floor of concrete or cement. Such a floor could be easily laid down in any convenient place which can be found. The site chosen should be removed from inhabited parts as far as possible, and should be provided with a plentiful water supply."

2. "That greater care be expended on the personal cleanliness of the cows. The only too familiar picture of the animal's hind quarters, flanks, and sides being thickly plastered with mud and fæces is one that should be common no longer. It would not be difficult to carry out this change; indeed, in the

better managed of our large dairy companies' farms such a condition no longer prevails, but in the smaller farms it is but too frequently met with."

3. "That the hands of the milker be thoroughly washed before the operation of milking is commenced, and that after once being washed they be not again employed in handling the cow otherwise than in the necessary operation of milking. Any such handling should be succeeded by another washing in fresh water before again commencing to milk."

4. "That all milk vendors' shops should be kept far cleaner than is often the case at present. That all milk retailing shops should be compelled to provide proper storage accommodation, and that the counters, &c., should be tiled."

Formation of an Opinion as to Adulteration of Milk.—It has already been indicated that the favourite sophistications of milk consist, on the one hand, of the more or less complete removal of the cream, and on the other, of the addition of water. If milk is deprived of a large part of its lightest constituents, the fat, it becomes specifically heavier, and a simple determination of its specific gravity reveals the fraud. But if to a milk which, in spite of its fat, is still heavier than water on account of its dissolved solids, water be added, its specific gravity will fall below the normal limits and thus betray the adulteration. It is, however, evident that simultaneous skimming and watering, if carried out under the guidance of the lactometer, may produce a spurious milk of the same specific gravity as the new or original milk.

"Experienced milk sophisticators, however, have other methods more difficult to detect than this crude one of mere dilution. The introduction of cream separators has given them the opportunity of removing very cheaply and quickly almost the whole of the fat from milk, dividing the milk, in fact, into a cream much better than what is produced by ordinary skimming, and a skim milk, beside which ordinary 'skim' is rich indeed."

"The sophisticator has thus the power of either separating his milk in a moderate degree, just taking from it what, from his point of view, is the 'excess' of cream; in other words, reducing its cream to the lowest saleable standard without exposing himself to any such risks of detection as would attend the process of 'watering,' a process by which the total non-fatty solids might be so reduced as to lead to detection of the fraud; or he may take off all the cream, using the 'skim to dilute or standardise other fresh milk; or he may sell the 'skim,' and leaving it to the retailer to produce, by judicious mixture of his two churns, any quality of milk which the character of his district or the carelessness and indifference of his customers may appear to require; or, finally, he may use the skim milk for making cheese, substituting a sufficiency of some other form of fat for the cream he has abstracted."

If carried out judiciously, and kept within the limits imposed by the standard which the magistrates will accept, it is next to impossible to prove this form of sophistication, except one discover the source of the milk, and have an opportunity of milking the cows from which the suspected milk is stated to have been drawn. Given these circumstances, it is possible to be morally certain that a fraud has been committed.

Speaking of this difficulty of detecting watered and skimmed milk, the Report of the Local Government Board for 1892–93 says: "No doubt the chief obstacle in the way of further progress in this matter is to be found in the fact that, in the present state of science, analysis fails to distinguish between the water which is a natural constituent of all milk and that which has been added by the dairyman, and therefore an analyst hesitates to condemn a sample of exceedingly poor milk because it may possibly be the genuine product of an old and ill-fed cow, although it has much more probably received an addition of water. He appreciates the fact that the Acts are intended to prevent the sale not of articles of poor quality, but of those which have been fraudulently tampered with; and it would not be in accordance with their design that a poor man should be subjected to penal proceedings because his cow does not produce as good milk as the better-bred and better-fed herd of his richer neighbours. It is the border cases which create the main difficulty." The case for the owners of poor pastures and the breeders of weedy cows could not be better put. On the other hand, writing on the same subject, Hehner observes as follows: "Owing to the natural variation in the composition of milk, the public analyst is bound to pass as genuine all milks which are at least equal in composition to the poorest genuine milk yet found, although in the great majority of cases thus passed, he has to do with milk artificially and not naturally weak," showing how this interpretation of the statute tends to degrade the average supply to the level of the lowest known milk.

Watering involves the risk that organisms pathogenic to man may pass into the milk with the water and even multiply there. In comparison with watering and skimming all other methods of sophistication are rare in the present day, though, formerly, the addition of chalk, milk of lime, gum, starch, and sugar were not infrequent. As regards the removal of cream, an important distinction must be made between removal by a centrifugal separator and removal by skimming. The former method, beyond reducing the nutritive value of the milk, adds no further disadvantage, as the creaming is effected rapidly, and the milk remains fresh. The other method, or skimming, is slow, and not only deprives the milk of its cream, but also involves the changing of the liquid from the category of a fresh to that of a more or less sour milk.

Watering alone is detected by a lower specific gravity and a diminished quantity of cream. *Creaming* alone is detected by a heightened specific gravity and a diminished quantity of cream. When both are resorted to, the cream will be small in amount, but the specific gravity may be normal. When a quantitative analysis can be made, watering alone is indicated by a general lowering of the constituents, which, however, preserve their normal proportions to each other. Creaming alone is indicated by a lessened amount of fat, but a normal amount of everything else, except total solids. Creaming and watering may be known by a general lowering of all constituents, but the deficiency in fat will be most marked.

The decision as to the addition of water and the removal of cream from milk is notoriously difficult, chiefly owing to the want of knowledge as to what was the original composition of the milk from which the sample was taken. To meet this difficulty, and to prevent adulteration, many efforts have been made to establish a minimum for the composition of normal milk. Standards, proposed some years back, requiring a high proportion of non-fatty solids, were based upon analyses by methods which failed to completely extract all the fat. Since improved methods of analysis have been adopted, it is now generally accepted that the minimum standards for milk should be:—Fat 2·75 per cent., solids not fat 8·5 per cent., and ash 0·7 per cent.

Assuming that the ash of a normal milk is never less than 0·7 per cent., the amount of added water can be calculated as follows:—

Example.—Let a be the observed percentage of ash in a given sample of milk, and A be the normal amount; then $100 - \frac{100a}{A}$ = per cent. of water added. If $a = 0{\cdot}5$, and $A = 0{\cdot}7$, then $100 - \frac{100 \times 0{\cdot}5}{0{\cdot}7} = 28{\cdot}6$ per cent. of water added to the sample.

In a similar way the amount of "solids not fat" may be used as a standard, taking them to be not less than 8·5 per cent.

Example.—Thus, say the total solids found in a milk sample are 12·1 per cent., and the fat is found to be 4·1 per cent.; obviously the solids not fat are 8 per cent. Then $\frac{8 \times 100}{8{\cdot}5} = 94{\cdot}1$ per cent. of the sample is pure milk, or there has been nearly 6 per cent. of water added.

Lescœur has suggested a means of detecting a watered milk and one from which cream has been abstracted by an examination of the milk serum. Coagulation of the milk is readily brought about by adding a trace of rennet, and the serum then separated by filtration.

The density of milk serum thus obtained varies from 1·029 to 1·031 at 15° C. In some samples it has been found as low as 1·027, and this may be taken as the minimum limit.

The extract of this milk serum should be determined also. The amount varies from 6·7 to 7·2 per cent., the mean being 7 per cent. and the minimum 6·7 per cent.

Every milk sample, therefore, which yields a serum having a density lower than 1·027, and the extract of which does not amount to 6·7 per cent., may be looked upon with suspicion, and regarded as having been watered.

The following figures show the effect of added water on the serum of a pure milk:—

	Density at 15° C.	Dry extract per cent.
Pure milk, . .	1·0300	7·0
,, ,, +10 per cent. of water,	1·0275	6·4
,, ,, +20 ,, ,,	1·0251	5·9
,, ,, +30 ,, ,,	1·0230	5·5

In milk which has curdled naturally, the serum, in spite of its different composition, gives almost the same results as does the neutral serum prepared by rennet. Hence no modification of this method is necessary for curdled milk.

Starch, dextrin, or *gum* is at times added to milk to conceal the thinness and bluish colour produced by added water. Add iodine at once for starch; boil with a drop of acetic acid, and add iodine for dextrin, or add lead acetate and then ammonia, when a white precipitate falls.

Cane-sugar.—This carbo-hydrate is not a common addition to milk, being only usually met with in samples of preserved and concentrated milks. The diagnosis of a milk adulterated with cane-sugar depends upon: (1) Any considerable want of agreement between the results from the copper process and the polarimeter. (2) Any considerable rise in the amount of copper reduced, or any increase of rotating power after inversion of the sugar in the whey, by means of citric acid and heat, or by invertase, which reagents only affect the cane-sugar and not the lactose. (3) The separation and preparation of the osazone from the whey by means of sodic acetate and phenyl-hydrazin hydrochlorate. Lactosazone is alone obtained by treatment with phenyl-hydrazin; cane-sugar giving no osazone until inverted, it then gives an osazone not to be distinguished from glucosazone. Lactosazone is freely soluble in hot alcohol, and none separates on cooling, unless the solution be highly concentrated. On the other hand, glucosazone requires repeated boiling in considerable quantities of absolute alcohol before it dissolves. Lactosazone is warty or starch-like in appearance, whereas glucosazone is always in the form of needle crystals.

Glycerin has been sometimes met with. The milk will be sweeter than usual, and there will be a difficulty if not impossibility in drying the solids by evaporation.

Chalk, to neutralise acid, and to give thickness and colour. Let it stand for deposit; collect and wash deposit, then add acetic acid and water; after effervescence, filter, and test with oxalate of ammonium.

Sodium Carbonate.—Very difficult of detection unless the milk be alkaline. Determine the ash, and see if it effervesces; if so, either some carbonate has been added, or, if the sodium have united with lactic acid, this will be converted into carbonate; enough lactic acid to give an effervescing ash does not exist normally in good milk.

Salt has been found added to milk in a case at Glasgow, to the extent of 0·14 to 0·21 per cent., equal to 98 and 147 grains per gallon. This will be detected by the excess of ash which may be dissolved and the chlorine determined in the usual way.

Milk is often *boiled* to preserve it: it may then take up from the vessel lead, copper, or zinc, if these metals are used.

Cream is adulterated or made up with magnesium carbonate, tragacanth, and arrowroot. The microscope detects the latter, and particles of magnesium carbonate (round) can also be seen, and found to disappear with a drop of acid. It is also said that yolk of egg is added both to cream and milk.

Boracic acid may be detected as follows:—The milk should be first well shaken up, as calcium borate is liable to settle; 5 or 6 c.c. are then taken and evaporated in a flat dish to about one-third. A few drops (5 or 6) of strong HCl are added and the evaporation is continued, whilst the flame of a Bunsen burner is directed across the dish. If any appreciable quantity of boron is present, the flame will be tinged green.

Salicylic acid is shown by the deep purple colour produced on the addition of solution of ferric chloride.

The constant addition to milk in the present day of *formalin*, which is a 40 per cent. solution of formaldehyde, as a preservative agent demands a short reference. The formalin used in the trade for preserving milk is a solution of 5 ounces of pure formalin to one gallon of water, corresponding to 2 ounces of formaldehyde in 160 ounces, or 1 in 80. This is used in the proportion of half a pint to the churn of 17 gallons, and does not impart any taste or smell to the milk even after boiling. With the addition of formalin in this strength, the milk keeps fresh for at least three days, and corresponds to one part of formaldehyde in 21,760 parts of milk, or 1 cubic centimetre of formalin in 8,704 cubic centimetres of milk. One gallon of the diluted formalin as used by the milk vendors does the same work as 10 pounds of the preservative powder, also used by them, containing 75 per cent. of boric acid and 25 per cent. of borax.

Though there is no evidence to show that formalin is in any way injurious to health, it is important to bear in mind that the addition of formalin to milk frequently causes an increase in the amount of total solids as subsequently determined on analysis. This effect appears to be due partly to polymerisation of the aldehyde, and conversion into a non-volatile body, and partly to a conversion of the lactose into galactose.

The detection of formalin in milk is conveniently made in the following manner. A solution of diphenylamine in water is made, just sufficient sulphuric acid being added as will effect solution. The liquid to be tested (or, if preferred, a distillate of the milk) is added to this solution and boiled. In the presence of formaldehyde a white flocculent precipitate is deposited, which is often coloured green, if the acid used contain nitrates. It is usually more convenient to distil the milk sample over into the diphenylamine solution, and then to boil.

Tyrotoxicon.—For the detection of this poisonous body, the following procedure is suggested. Add to the milk sodium carbonate to decided alkalinity; shake up with an equal bulk of ether; separate the ethereal layer and allow it to evaporate; dissolve in water; filter, and evaporate the filtrate. A mixture of equal bulks of pure phenol and sulphuric acid strikes an orange-red or purple colour with very small traces of tyrotoxicon.

BUTTER.

As an article of diet, butter supplies to most people the largest amount of fat which they take. Many persons take from 1½ to 2 ounces daily, if the butter used in cooking be included, and the average amount for persons in easy circumstances is 1 ounce daily. Butter appears to be easily digested by most persons, except when it is becoming rancid. It then causes dyspepsia and diarrhœa, but as a rule it may be said that decomposing fats of all kinds disagree.

Composition.—Butter is really the fat of milk clotted together, and consists chiefly of neutral fats mixed with water and small amounts of casein and salts. Average butter may be said to have the following composition per cent.: Fat, 78 to 94; curd, 1 to 3; water, 8 to 12; salt, 0 to 7. The flavour of a good butter is due to butyric and caproic acids, which constitute about 8 per cent. of the fat, the rest being composed of glycerides of oleic, stearic, and palmitic acids.

Water.—The average amount of water varies from 8 to 12 per cent., but may be higher, even in genuine butter, although this is not usual. Hassall has found as much as 15½ per cent. in fresh, and 28½ per cent. in salt butter. Bell records as much as 20·75 per cent. of water in a genuine sample; there was, however, 3·82 of salt present. The retail dealer, by beating up the butter in water, endeavours to increase the amount. This can be detected by evaporation in a water bath; if the quantity of water be very large, melting the butter will show a little water below the oil. An unusually small amount of water is suspicious, as suggestive of the presence of foreign fat. A good butter should not contain more than 12 per cent. of water.

Curd or Casein.—All butter contains some casein, as some milk is taken up with the cream. The best butter contains least. The amount can be told roughly by melting the butter in a test-tube. The casein collecting in the bottom does not exceed one-third of the height of the contents of the tube in the best butter, or between one-third and one-half in fair butter. In bad butter it may reach to more than this. A better plan is dissolving the fat by ether, washing and then weighing the remainder; the casein then weighs from 0·5 to 3 grains in every 100 of very good butter. In bad butter it is much more than this.

The rancidity of butter is owing chiefly to changes in the fat, produced apparently by alterations in the casein, and therefore the greater amount of casein the more the chance of rancidity.

Fat.—The fat amounts to from 84 to 90 per cent. of the butter. Butter oil consists of volatile fatty acids (butyric, caproic, caprylic, and capric) and of non-volatile acids (stearic, palmitic, and oleic), all combined with glycerin. In examining it, the butter should be melted in a beaker-glass placed in hot water, and the fat then poured from off the casein, and allowed to cool. It then forms a solid and usually yellow mass, with the characteristic smell of butter. If transferred, when in a melted state, to a previously weighed beaker and then re-weighed, its percentage amount is readily calculated.

Salt is added to all butter. It preserves it by checking the decomposition of the casein. In fresh butter it should not be more than 0·5 to 2 per cent. (2 to 8 grains per ounce); in salt butter, not more than 8 per cent. (35 grains per ounce). To determine the salt, wash a weighed portion of butter thoroughly with cold distilled water, and determine the chloride of sodium with standard nitrate of silver. An excess of salt is accompanied generally by an excess of water, and frequently by an excess of curd.

Adulterations.—Butter is frequently adulterated with lard, and with beef, mutton, and horse fat, or with vegetable oils. In a process devised by Mége-Mouriès, fresh beef suet is converted into a kind of butter (oleo-margarine). But the original process was so complicated that it would not pay a dishonest tradesman to do it, and it could only be practised on a large scale.

A similar substance from New York was brought into the market under the name of Butterine. Oleo-margarine used to be generally defined as a preparation of animal fats, whereas animal fat beaten up with milk was called Butterine. Large quantities are manufactured in Holland and other countries and sent over to this country. It appears to be a wholesome fat, and as long as it is sold honestly as a substitute for butter, but not as genuine butter, its introduction constitutes a boon to many on account of its cheapness. The Act of 1887 has now decided that the name Butterine shall be no longer used, and that all artificial butter shall be known as *Margarine.* In the United States it is termed oleo-margarine.

Butter is sometimes adulterated by beating up with water: this is frequent in the tropics. It is also sometimes mixed with milk. Potato or other starches are sometimes added. This is a rare adulteration, and is detected by iodine, either at once or after melting. Gypsum and sulphate of barium have been added, it is said; this must be very rare, and can be detected by melting and pouring everything off the insoluble powder, or by incinerating. Annatto is frequently used to colour butter; it is, however, harmless.

Examination of Butter.—As practically the only adulteration of butter is the substitution of foreign fats such as tallow, lard, palm oil, rape-seed oil, or cocoa-nut oil, for milk fat, the examination of butter turns mainly upon the properties and composition of the fat. For the detection of an admixture of foreign fats, several methods have been proposed, the principal being: (1) taking the specific gravity of the fat; (2) determining the melting point of the fat, after separation from the other constituents; (3) determination of the fixed fatty acids; (4) determination of the volatile fatty acids.

The specific gravity of the butter fat can be determined by melting it at 100° F., and then weighing in a specific gravity bottle. That of water being unity, a pure butter fat has usually a specific gravity of 0·911 to 0·913; an adulterated butter one of 0·902 to 0·904, and an artificial butter one as low as 0·859 to 0·861.

Determination of the melting point of butter fat after separation from the casein.—Some of the fat should be put into a wide tube, and placed in an evaporating dish with water; a thermometer should be in the water and another in the fat. Raise the temperature of the water very gradually; remove the lamp from time to time, so that the temperature of the fat may rise slowly. Note the temperature when it begins to melt; when it is completely melted; and when (after removal from the warm water) it begins to recongeal, and becomes quite solid. The melting points are, however, not constant, owing to the variable amounts of stearin and olein and the volatile fatty acids, but still they run within tolerably narrow limits. Butter fat is the most easily melted, and requires the greatest amount of cooling before solidifying; usually there is a difference, often 12° to 15° between the points of commencing and completed melting. The determination of the melting point is, however, certainly more useful in proving that the butter has only slight admixture, than in proving complete purity, *i.e.*, the presence of a small quantity of lard or beef dripping would not raise the melting point sufficiently for detection. In the case of beef dripping, also, the melting point is rather close to that of butter.

Temperature of Melting and Solidifying (Degrees Fahr.).

	Melting.		Solidification.	
	Commencing.	Completed.	Commencing.	Completed.
	Degrees.	Degrees.	Degrees.	Degrees.
Butter fat,	65–68	80–90	70–80	60–82
Lard,	76–80	100–115	90–100	71–75
Beef dripping,	68–85	100–120	90–100	72–76
Mutton dripping,	86–100	140–150	120–130	86–92
Palm oil,	81–92	110	88	69

Determination of the fixed fatty acids.—This, though rather a difficult process to do, is most generally relied upon for giving an opinion as to the genuineness of butter. It is based on the fact that, when saponified with a caustic alkali such as soda or potash, and then decomposed with hydrochloric acid, the individual fatty acids which go to make up butter are obtained. A certain number of these are soluble in water while others are not, and it is owing to the insoluble fatty acids obtainable from butter differing in amount from those obtainable from other animal fats that pure butter can be detected from artificial. The figures being, that if the insoluble fatty acids are over 89 per cent. there is an admixture of foreign fat. In a good butter the volatile fatty acids should not fall below 5 per cent. The process may be thus carried out. Melt some of the butter in a test-tube or small beaker over a water bath, and allow the water and solid particles to subside as much as possible; then pour the melted fat upon a dry filter, care being taken to keep the aqueous solution in the tube or beaker, so as not to contaminate the fat. A double funnel, one with a warm water jacket, is very convenient in order to keep the fat in a state of fusion. After filtering the fat through into a beaker, allow to cool and weigh. Next take out, with a glass rod, 3 or 4 grammes of the fat and put it into a large deep and perfectly dry porcelain evaporating dish. Now re-weigh the beaker and the fat left in it; the loss in weight will represent the amount of butter fat about to be operated upon. The fat which was placed in the evaporating dish is now melted on a water bath, and about 50 to 70 c.c. of pure methylated spirit or absolute alcohol added. A clear yellow solution is formed. Now add from 1 to 2 grammes of caustic soda or potash, or 5 c.c. of a saturated solution of these alkalies in alcohol; agitate by means of the glass rod, heating all the while, but taking care not to heat to boiling point, as loss by spurting would be inevitable. Saponification proceeds rapidly, and is, in the case of butter fat, evinced by the strong smell of butyric ether, resembling the odour of pine-apples.

After 2 or 3 minutes, add a few drops of distilled water: if turbidity, caused by undecomposed fat, ensues, continue the heating a little longer, the turbidity usually dissolving in the excess of alcohol. Keep on adding small quantities of water from time to time, until a considerable addition of it to the solution of soap no longer causes any precipitate of fat. Saponification is complete when any amount of dilution does not affect the transparency of the liquid. Should it happen that the water has been added too quickly, fat separates in the form of oily droplets, which now no longer dissolve in the too dilute alcohol. In this case, an additional quantity of alcohol may effect the solution, but it is preferable to begin the experiment afresh with a new quantity of butter fat.

The alcoholic solution of soap is continuously heated over the water bath until all smell of alcohol has passed off; if all the alcohol is not removed some of the fatty acids still remain in solution. When this has been done, the dish is nearly filled with water, in which the gelatinous soap, which has separated out on evaporating the liquid, readily dissolves. Dilute hydrochloric acid is now added, until strong acid reaction results, to liberate the fatty acids. These rise quickly to the surface as a white or creamy scum, with the evolution of a strong and disagreeable smell of butyric acid. The separated fatty acids are heated for half an hour on the water bath, until they are perfectly fused into a clear oil, and the acid liquid below is also clear. Care should be taken that the water does not evaporate much.

Meanwhile, dry and weigh a filter of about five inches in diameter. Moisten the filter and fill the jacket with boiling water; then transfer every trace of oil from the dish and glass rod to the filter. Carefully wash out all the fatty acids from the dish to the filter by means of boiling water, and continue washing the filter well, until the filtrate gives no reaction with litmus paper. Usually about a litre of water is required. After all the water has run through the filter, the funnel in which it has been is emptied of its contained hot water, and the whole plunged into a beaker filled with cold water, so that the levels of the fat inside and the water outside the funnel are the same. When the fatty acids are quite solidified, the filter is carefully taken out of the funnel, placed in a small weighed beaker and dried for two hours. It is now re-weighed, and the amount of insoluble fatty acids calculated as a percentage of the butter fat.

Example.—The following may be taken as an illustration of this determination:—

Beaker and butter fat,	40·4337	grammes.
Beaker,	37·1506	,,
Butter fat taken,	3·2831	,,
Filter,	0·5830	,,
Beaker,	20·9967	,,
Beaker and filter,	21·5797	,,
Beaker, filter, and fatty acids,	24·4505	,,
Insoluble fatty acids,	2·8708	,, or 87·42 per cent. of the butter fat.

The percentage of insoluble fatty acids in butter fat, made from the milk of cows of the most varied breed, varies usually between 86·6 and 87·5, though in some rare instances it falls as low as 86·3, and rises as high as 88·5 per cent. A fair average is represented by the figure 87·3 per cent. All other animal fats furnish, on an average, 95·3 per cent. of insoluble fatty acids, or, in other words, there is a standard difference of 8 between the percentage of insoluble fatty acids in normal butter fat and that in other animal fats. From the percentage of the insoluble fatty acids found, it is, therefore, easy to draw conclusions as to the genuineness or otherwise of any given sample of butter. If the quantity of insoluble fatty acid be lower than 88 per cent., the butter must be declared genuine; if, however, the fatty acids are higher than 88·5 per cent., we may conclude that adulteration with foreign fat has taken place. This statement will be perhaps clearer if applied to an actual example.

Example.—Say a sample of butter has been examined, and found to have the following percentage composition:—Water 12, Curd 1·5, Salts 2, Fat 84·5. The fixed or insoluble fatty acids have been estimated, by the foregoing method, and found to constitute 92·3 per cent. of the butter fat. Assuming that there is a standard difference of 8 per cent. between the fixed fatty acids yielded by a pure butter fat, and that in foreign or other animal fats; and taking the observed difference between the fatty acids found in the sample and that yielded by pure butter fat to be 5, or 92·3 – 87·3 = 5, we get the following equation to represent the percentage of foreign fat, or adulteration, in the sample. As the constant difference, between the fixed fatty acids in normal butter and that in foreign fat is to the observed difference, between the fatty acids found in the sample and those yielded by pure butter fat, so is the percentage of fat in the sample to the percentage of foreign fat in the sample; or, 8 : 5 : : 84·5 : x, which equals 52·81 parts of foreign fat in 100 parts of the sample, that is, there is but 31·69 per cent. of true butter fat in the sample.

Determination of the Volatile Fatty Acids.—As an alternative to the foregoing determination, the following process, originally proposed by Reichert, and modified by Meissl and Wollny, affords a fairly reliable method of butter analysis. It is carried out as follows:—

Five grammes of the clear filtered butter fat are saponified on a water bath in a flask, capable of holding 300 to 350 c.c., with 10 c.c. of a solution of pure caustic potash in 70 per cent. alcohol (20 grammes KHO in 100 c.c. alcohol). When the fat has completely dissolved, the alcohol is driven off slowly by gentle evaporation. The soap is then dissolved in 100 c.c. of water, decomposed with 40 c.c. of dilute sulphuric acid (1 in 10), and 110 c.c. distilled off, a few small pieces of pumice stone having been added. 100 c.c. of this distillate are filtered and titrated with deci-normal alkali, rosolic acid or phenolphthalein being used as an indicator. The number of c.c. used is increased by $\frac{1}{10}$ corresponding to the total quantity of the distillate. The two chief sources of error in this method are a loss of butyric ether, and a gain by absorption of carbonic acid, hence it is advisable to carry out the saponification under a reflux condenser, and both distil off the alcohol and dissolve the soap in water in a closed flask.

Five grammes of genuine butter yield a distillate requiring from 28 to 31 c.c. of deci-normal alkali. Similar amounts of artificial butters, such as margarine, yield distillates requiring less than 1 c.c. of the alkali, and various butter mixtures demand intermediate quantities.

CHEESE.

This is made from milk by the action of rennet, and consists of coagulated casein, with varying proportions of fat and salts. The different qualities of cheese depend mainly upon whether they are made from pure milk, from skimmed milk, or from a mixture of skim and whole milk. Thus, Cheddar, double Gloucester, Cheshire, and some American cheeses are made from whole milk, while Stilton is made from whole milk to which cream is added. Dutch, Parmesan, Suffolk, and Somersetshire cheeses are made from skimmed milk. Cream cheese consists of the fresh curd which has been moderately pressed; it is eaten without being allowed to ripen. When a cheese is kept, it undergoes a change known as "ripening," which is essentially a decomposition, whereby the casein undergoes a fatty change, including the formation of lime salts of the fatty acids and the production of a soluble compound of phosphoric acid with casein, from the phosphate of lime usually present in milk.

As an article of diet, cheese is very valuable, being particularly rich in both proteid and fat: about $\frac{1}{2}$ ℔ contains as much proteid as 1 ℔ of meat, and $\frac{1}{3}$ ℔ as much fat. It does not, however, keep well in warm climates, and is occasionally very indigestible.

The percentage composition of some of the more common varieties is as follows:—

	Water.	Proteids.	Fat.	Free Acid as Lactic Acid.	Salts.
Cheddar,	35·60	28·16	31·57	0·45	4·22
Cheshire,	37·11	26·93	30·68	0·86	4·42
Single Gloucester,	35·75	31·10	28·35	0·31	4·49
Dutch,	41·30	28·25	22·78	0·57	7·10
American Red,	28·63	29·64	38·24	...	3·49
Gorgonzola,	32·50	32·80	31·20	...	3·50
Gruyere,	32·00	35·10	28·00	...	4·80
Roquefort,	26·50	32·90	32·30	...	4·40
Camembert,	51·90	18·90	21·00	...	4·70

The quality is known by the taste. The only adulteration is from substances added to give weight. Starch is chiefly employed, and can be detected by iodine. There is usually about 5 or 6 per cent. of salt.

Sulphate of copper and arsenious acid are sometimes used to destroy insects; the rind is then the most poisonous part. Copper is detected by ammonia or potassium ferrocyanide. Arsenic by any test (Reinsch's or Marsh's). Sometimes cheese becomes sour, particularly if made from sheep's milk, and may cause diarrhœa. The occasional production of the ptomaine tyrotoxicon should be remembered when poisonous symptoms arise.

Acarus domesticus, *Aspergillus glaucus* (blue and green mould), and *Sporendonema casei* (red mould) occur during decay. During decay, also, the fat augments at the expense of the casein; leucin is produced, with valerianic and butyric acids. Lactic acid is also often produced, from the lactose of the milk contained in the cheese. The aroma of cheese partly arises from this decomposition, and the production of volatile acids.

The maggots or larvæ of a fly (*Piophila casei*) are well known, and are frequently present in cheese undergoing decomposition.

WHEAT.

As an article of diet, wheat is poor in water but rich in solids, therefore very nutritious in small bulk: the whole grain is somewhat indigestible, but when its outer coats are removed, is readily digested. The proteids in wheat are large and varied, consisting chiefly of a globulin and an albumose which, under the action of water, give rise to what is known as glutin. Whether all the globulin and albumose is transformed into glutin is uncertain, but the weight of evidence is in favour of the view that some escapes in a soluble form. The starchy substances are large, 60 to 70 per cent., are very digestible, and consist mainly of starch, sugar and dextrin. A nitrogenous ferment, called cerealin, is also contained in wheat, being closely associated with the internal coat of the grain. This body, like diastase, acts energetically in transforming starch into dextrin, sugar and even lactic acid. There is also present a small amount of fat, while the salts are chiefly phosphates of potash and magnesia. The chief defect in wheat, as an article of diet, is its poverty in fats and in vegetable salts which may form carbonates in the system. The average percentage composition of a wheat grain is as follows:—

Water,	13·37	
Proteids,	12·04	
Fat,	1·85	
Carbo-hydrate,	68·65	
Cellulose,	2·31	
Ash,	1·78	Phosphates of Potash, Magnesia, and Lime. Iron. Soda. Chlorine. Silica. Carbonic acid.

As usually prepared, the grain is separated into flour and bran; the mean being 80 parts of flour, 16 of bran, and 4 of loss. The flour is itself divided into best or superfine, seconds or middlings, pollards or thirds or bran flour. In different districts different names are used. The wheats of commerce are named from colour or consistence (hard or soft, white or red); the hard wheat contains less water, less starch, and more glutin than the soft wheat.

The medical officer will seldom be called on to examine wheat grains, but if so, the following points should be attended to. The grains should be well filled out, of not too dark a colour; the furrow should not be too deep; there should be no smell, no discoloration, and no evidence of insects or *fungi*. The heavier the weight the better.

In examining wheat, or any other cereal grains, it is necessary to prepare them beforehand by soaking for some time in water. It will then be found easy to demonstrate the different structures. By means of a needle and a pair of fine forceps the different coats can be removed *seriatim*, sometimes quite separately, but generally more or less in combination. After examining the separate coats, sections may be made of the whole grain, so as to see the structures *in situ*. The hairs are generally found in a bunch at the end of the grain. The starch grains are best demonstrated by picking out a little from the centre of the grain; water mixed with a little glycerin forms the best medium for demonstration.

To each wheat grain there are four envelopes, surrounding a fine and very loose areolar tissue of cellulose filled with starch grains. The outer coat is made up of two or three layers of long cells, with slightly beaded walls, running in the direction of the axis of the grain. The hairs are attached to this coat, and are prolongations, in fact, of the cells. In the finest flour, the hairs and bits of this and the other coats may be found.

The second coat, counting from without, is composed of a layer of shorter cells, more regular in size, with slightly rounded ends and beaded walls, and lying at right angles to the first coat, or across the axis of the grain. It is impossible to mistake it. The third coat is a delicate diaphanous, almost hyaline membrane, so fine that its existence was formerly doubted. Maddox, however, has distinctly shown it to have faint lines crossing each other diagonally, which may be cells. With a little care, it is very easily demonstrated. In the transverse section of the envelope it appears as a thin white line. Internal, again, to this coat what appears to be another coat can sometimes be made out; it is a very fine membrane, marked with widely separated curved lines, which look like the outlines of large round or oval cells. The internal or fourth coat, as it is usually called, is composed of one or two layers (in places) of rounded or squarish cells filled with a dark substance which can be emptied from the cells. When the cells are empty, they have a remote resemblance to the areolar tissue of the leguminosæ, and there is little doubt that from this cause adulteration with pea or bean has been sometimes improperly asserted.

The starch grains of wheat (fig. 36) are very variable in size, the smallest being almost mere points, the largest $\frac{1}{1000}$th of an inch in diameter or larger. In shape the smallest are round, the largest round, oval, or lenticular. It has been well noticed by Hassall that there is often a singular want of intermediate-sized grains. The hilum, when it can be seen, is central, the concentric lines are perceived with difficulty, and only in a small number; the edge of the grain is sometimes turned over so as to cause the appearance of a slight furrow or line along the grain. Very weak liquor potassæ causes little swellings; strong liquor potassæ bulges them out, and eventually destroys them.

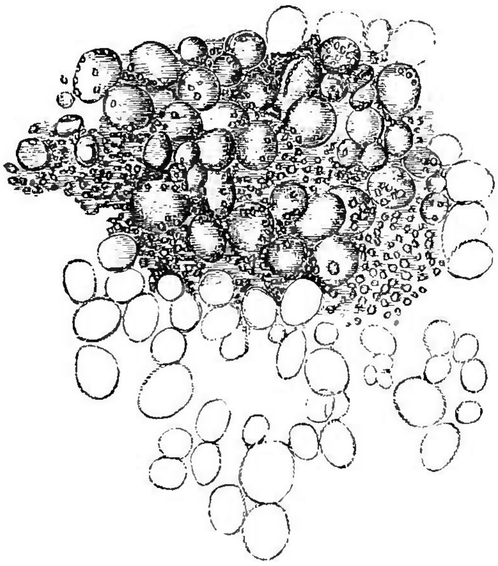


Fig. 36.

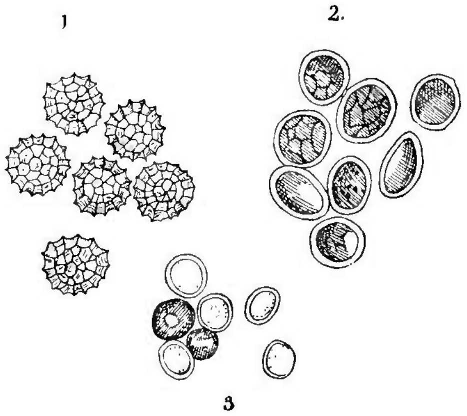


Fig. 37.

The wheat grains should be carefully examined for any diseased forms. Frequently small, short, thick and blackish grains are found. If these characteristically modified grains be steeped in water for some hours, the microscope will reveal inside them briskly mobile worms from 0·6 to 1 mm. in length. These are known as the *Anguillulæ tritici*, and the disease they give rise to is called gout or cockle disease, from the slight resemblance of the grains to the seeds of Agrostemma.

A number of fungi of the family of the Ustilagineæ frequently destroy corn grains. The chief of these are *Ustilago carbo*, *Tilletia caries*, and *Tilletia lævis*. *Ustilago carbo* or smut forms a black dusty powder, occupying the glume in place of the grain, which is entirely destroyed. The spores are almost regularly globular, light brown and smooth (fig. 37 [3]). *Tilletia caries* and *T. lævis*, sometimes called the canker or stinking disease of wheat, are fungi which, microscopically, are very similar to each other, and fill the grains with a moist, smeary, black powder. Microscopically, the spores of Tilletia are larger than those of Ustilago. In *T. caries*, they are globular or roundish with net-like ridges; in *T. lævis*, they are more irregular and smooth (fig. 37 [2]).

If flour be adulterated with rye, it may contain the mycelium of a fungus called the *Claviceps purpurea* or ergot of rye (page 343). At present, however, it is rare to find ergot in flour, as it is carefully sought out on account of its value as a drug.

Wheaten flour is of two kinds, the one ordinarily used being white, the other, whole meal, being of a dark colour, owing to the admixture of bran. In the market there are several varieties, according to the completeness of the milling. The most highly milled flours are the whitest, and contain least bran and cellulose; they lose in the process some proteid and some salts, but this loss is largely compensated by the fineness of the bread prepared from it. The chief flours in the market are in the order of their excellence, Vienna whites, best whites, best households, second households, and others much inferior in quality. There are also brown meal and whole meal. The percentage composition of three typical wheat flours may be thus stated:—

	Water.	Proteid.	Fat.	Carbo-hydrate.	Cellulose.	Salts.	Proportion of nitrogenous to non-nitrogenous food-stuff.
Fine flour,	13·37	10·21	0·94	74·71	0·29	0·48	1 is to 7·4
Coarse flour,	12·81	12·06	1·36	71·83	0·98	0·96	1 ,, 5·3
Whole meal,	13·00	11·70	1·70	69·90	1·90	1·80	1 ,, 6·3

Of the carbo-hydrates in flour, 66·28 per cent. is starch, 4·09 is dextrin, and 1·86 per cent. is sugar. It is an open question whether the separation of the bran from the finest flour is altogether desirable, as the bran contains often as much as 15 per cent. of nitrogenous matter, with 3·5 per cent. of fat, and 5·7 per cent. of salts. On the other hand, if the bran is used, it seems probable that much is left undigested, and all the nutriment which is contained in it is not extracted. A plan was suggested by Mége-Mouriès, which seems to save all the most valuable parts of the bran; the two or three outer and more or less siliceous envelopes of the wheat are detached, and the fourth or internal envelope is left. Several plans of decorticating wheat have been proposed, but none of them at present have superseded the old system of grinding.

If the whole wheat is used, it should be ground very fine, as the harder envelopes are irritating, and it is well to remember that for sick persons with any bowel complaints bread must be used entirely without bran. Dysenteries have been found most intractable, merely from attention not being directed to this simple point. It is all the more necessary to insist upon this, as whole-meal bread has been much recommended and used of late. At the same time there is no doubt that whole-meal bread, well made, is more nutritious than the fine white bread now so generally used. The principal constituents lost with the bran are fat and salts, the analysis of whole meal showing a marked excess of these over best sifted flour. There is also a certain loss of nitrogenous matter, some of which is believed to aid digestion. But for the irritating qualities of the outer envelopes (which have, however, been much diminished by modern processes), whole-meal bread would be a more valuable nutrient.

Several fungi are found in wheat flour. The most common are the Ustilagineæ already mentioned and an Uredinaceous species called the *Puccinia graminis* (fig. 38). It is easily recognised by its round dark sporangia, which are either contoured with a double line, or are covered with little projections. The accompanying drawing shows a section through part of a grain of wheat attacked by puccinia; the sprouting teleutospores are clearly seen growing on the surface of the grain. The symptoms which this fungus may give rise to have not been well described, there being some doubt as to whether it really is injurious to man at all.

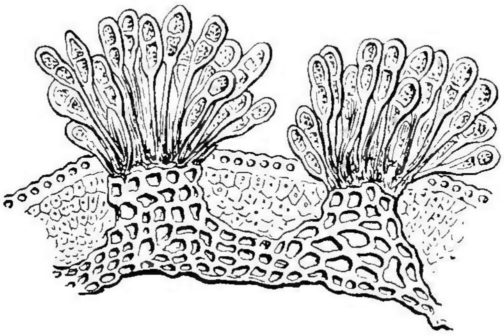


Fig. 38.

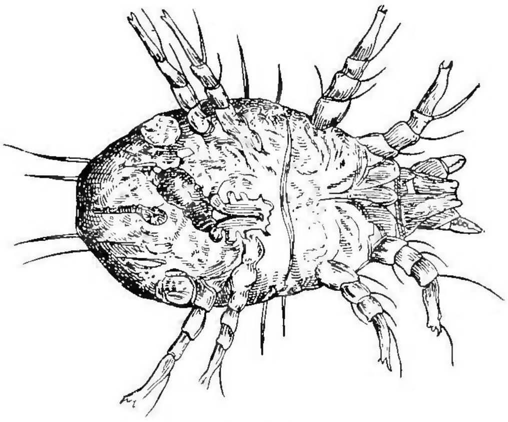


Fig. 39.

The *Acarus farinæ* (fig. 39) is by no means uncommon in inferior flour, especially if it is damp. It does not necessarily indicate that leguminous seeds are present, as stated. It is no doubt introduced from the grain in the mill, as it has been found adhering to the grain itself. It is at once recognised. Portions of the skin are also sometimes found.

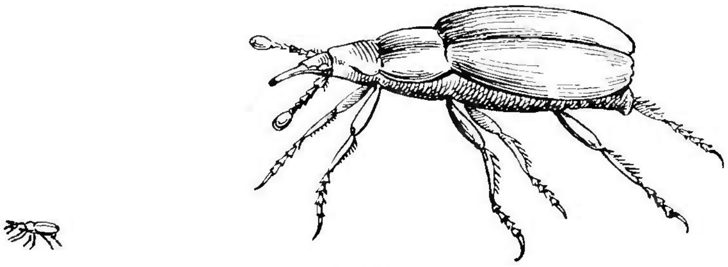


Fig. 40.

The presence of *acari* always show that the flour is beginning to change. A single acarus may occasionally be found in good flour, but even one should be looked on with suspicion, and the flour should be afterwards frequently examined to see if they are increasing in numbers. In flour which has gone to extreme decomposition, and is moist and becoming discoloured, vibrios and other forms of bacterial life are frequently seen. They cannot be mistaken.

Another organism occasionally met with in flour is the *Calandra granaria* or weevil (fig. 40), while somewhat rarer are the larvæ of various kinds of moth, more particularly *Ephestia elutella* and *Ephestia kuehniella* belonging to the micro-lepidoptera.

Adulterations of Flour.—At present there is very little adulteration of wheat flour in this country, but with rising prices the case might be different. Abroad, adulteration is probably more common, and the medical officer must be prepared to investigate the point.

The chief adulterations are by the flour of other grains, viz.:—

Barley,
Potato,
Beans and peas,
Maize,
Oat,
Rye,
Rice.

The greater number of these are easily recognised by the microscope, and will be considered in more detail under their respective headings.

Other adulterations are by mineral substances, viz.:—

Alum,
Gypsum,
Clay,
Powdered flint,
Calcium and magnesium carbonates.

These are best detected by chemical examination.

Among the rarer adulterations of flour are Linseed, Buckwheat, Millet, Melampyrum, Lolium temulentum, and some other grains: they can be conveniently discussed in this place.

Linseed is not a common adulterant. Its envelopes are peculiar: the external is made up of hexagonal cells containing oil: the second of round cells: the third of fibres: and the fourth of angular cells containing a dark reddish colouring matter.

Buckwheat, like rye, is sometimes found in wheat coming from the Baltic. Its starch grains are small and round and adhere together in masses. Under a high power there are indications of concentric rings. Bread made from flour prepared from this grain has a darkish, somewhat violet colour.

Millet is a frequent adulterant of flour in India, China, Egypt, and Western Africa. The starch grains are very small, round, and tolerably uniform in size.

Melampyrum arvense, or purple cow-wheat, has been occasionally mixed with flour: it is not injurious, but gives the bread made from the flour which contains it a peculiar smoky-violet or bluish-violet tint. This appears to be due to a colouring matter in the seed, which, when warmed with an acid, gives the violet tint.

Lolium temulentum, or Darnel seeds, occasionally have been found in flour. They do not affect the colour of the bread, but produce vertigo, hallucinations, delirium, and narcotic symptoms. The detection of *lolium* is best effected by means of alcohol, which gives a greenish solution with a disagreeable repulsive taste, and on evaporation a resinous, yellow-green and unpleasant extract is left. Pure flour gives with alcohol only a clear straw-coloured solution, with a more or less agreeable taste.

Of the preparations of flour, bread is the most important: while of less importance are biscuits, macaroni, and vermicelli.

Examination of Flour.—Every sample of flour should be examined microscopically, physically, chemically, and practically by making bread. While adulterations are best determined by the microscope on the lines already indicated, the quality is best demonstrated by attention to the following points.

Sight.—The flour should be quite white, or with the very slightest tinge of yellow; any decided yellow indicates commencing changes; the amount of bran should not be great.

Touch.—There should be no lumps, or, if there are, they should at once break down on slight pressure; there must be no grittiness, which shows that the starch grains are changing, and adhering too strongly to each other, and will give an acid bread. There should, however, be a certain amount of cohesion when a handful of flour is compressed, and if thrown against a wall or board some of the flour should adhere. When made into a paste with water, the dough must be coherent, and draw out easily into strings.

Taste.—The taste must not be acid, though the best flour is slightly acid to test-paper. An acid taste, showing lactic or acetic acid, is sure to give an acid bread.

Smell.—There must be no smell of fermentation or mouldiness.

Age of flour is shown by colour, grittiness, and acidity.

Amount of Water.—Weigh 1 gramme, spread it out on a dish, and dry either by a water bath or in a hot-air bath or oven, the temperature not being allowed to go above 212°. The flour must not be at all burnt or much darkened in colour. Weigh directly the flour is cold; the loss multiplied by a hundred is the percentage of water.

The range of water is from 10 per cent. in the best dried flours to 18 per cent. in the worst. The more water the greater liability of change in the flour, and, of course, the less is the amount of nutriment purchased in a given weight. If, then, the water be over 18 per cent., the flour should be rejected; if over 16, it should be unfavourably spoken of.

Amount of Glutin.—Weigh 10 grammes and mix by means of a glass rod with a little water, so as to make a well-mixed dough, adding the water slowly from a burette: usually for 10 grammes of flour not more than 4·2 c.c. of water are needed. When made, let the dough stand for a quarter of an hour in an evaporating dish; then pour a little water on it; work it about with the rod, and carefully wash off the starch; pour off, from time to time, the starch water into another vessel. After a time, the glutin becomes so coherent that it may be taken in the fingers and worked about in water, the water being from time to time poured off till it comes off quite clear. If there is not time to dry the glutin, then weigh; the dry glutin is rather more than one-third the weight of the moist; 1 to 2·9 is the usual proportion; therefore divide the weight of the moist glutin by 2·9. If there be time, dry the glutin thoroughly, and weigh it. This is best done by spreading it out on a crucible lid and drying it in the bath. The dry glutin ranges from 8 to 12 per cent.; flour should be rejected in which it falls below 8. If there is much bran, it often apparently increases the amount of glutin by adhering to it, and should be separated if possible; in fact, the glutin, as thus obtained, is never pure, but always contains some bran, starch, and fat. The glutin should be able to be drawn out into long threads; the more extensible it is the better. It is always well to make two determinations of glutin, especially if there is any disputed question of quality.

Amount of Ash.—Take 2 grammes; put into a porcelain or platinum crucible, and incinerate to a white ash. Weigh. The ash should not be more than 2 per cent., or probably some mineral substances have been added; it should not be less than 0·5, or the flour is too poor in salts: it generally ranges between 0·7 and 0·9 per cent.

If the ash be more than 2 per cent., add hydrochloric acid, and see if there be effervescence (magnesium or calcium carbonate). Dissolve, and test for lime with oxalate of ammonium, and then for magnesia, in the same way as in water. As flour contains both lime and magnesia, to prove adulteration the precise amount of lime and magnesia must be determined by weighing the incinerated calcium oxalate, or the magnesium pyrophosphate.

If there is no effervescence add water, and test for sulphuric acid and lime, to see if calcium sulphate (plaster of Paris) has been added. In normal flour the amount of sulphuric acid is very small.

Notice, also, if the ash be red (from iron). If clay has been added, it will be left undissolved by acids and water.

If magnesium carbonate has been added, the ash is light and porous and bulky.

An easy mode of detecting large quantities of added mineral substances is given by Redtenbacher; the flour is strongly shaken with chloroform; the flour floats, while all foreign mineral substances fall. This is a very useful test.

If the water be small, the glutin large, and the salts in good quantity, the flour is good, supposing nothing is detected on microscopical examination. But in all cases it is well, if time can be spared, to have a loaf made.

Practical Test by Baking.—Make a loaf, and see if it is acid when fresh, and how soon it becomes so; if the colour is good; and the rising satisfactory. Old and changing flour does not rise well, gives a yellowish colour to the bread, and speedily becomes acid. Excess of acidity can be detected by holding a piece of bread in the mouth for some time, as well as by test-paper.

Test for Ergot.—There is no very good test for ergot when it is ground up with the flour. Laneau's plan is to make a paste with a weak alkaline solution; to add dilute nitric acid to slight excess, and then alkali to neutralisation; a violet-red colour is said to be given if ergot is present, which becomes rosy-red when more nitric acid is added, and violet when alkali is added.

Wittstein considers this method imperfect, and prefers trusting to the peculiar odour of propylamine (herring-like smell) developed by liquor potassæ in ergoted flour.

BREAD.

If carbon dioxide gas is, in any way, formed within or forced into the interior of dough, so as to divide the dough into a number of little cavities, bread is made. There are practically two kinds of bread, namely, that made by means of yeast, and that aërated by chemical means or the non-fermented bread. The ordinary process of bread-making consists really of three stages; namely, the preparation of the leaven or ferment, the preparation of the "sponge," and the making of the dough.

One sack of flour, weighing 280 lb, is usually reckoned to yield from 376 to 384 lb of bread, or from 94 to 96 quartern loaves, and in making bread from this amount of flour the following procedure is usually adopted.

First, the ferment or leaven is made with 8 to 12 lb of boiled potatoes mashed into a thin paste. After cooling to about 80° F., or 27° C., a quart of brewer's yeast and 2 lb of flour are added. In this mixture of potato starch, flour, and yeast, the yeast decomposes the proteids of the flour and the starch, forming maltose, dextrin, and peptone-like bodies. At the same time the yeast becomes very active. The process is allowed to go on for five hours.

To the ferment when ready, one-third of the sack of flour, 48 ounces of salt, and 30 quarts of water are added. If the flour is very good, the salt is not necessary: and even with the inferior flours, if at all in excess, will check the fermentation. The resulting mixture constitutes the "sponge," in which very active fermentation goes on: after about five hours, the sponge breaks, owing to the development of large quantities of carbonic acid and alcohol from the maltose and dextrin. When the sponge has broken twice, the dough is formed by adding to the sponge the remainder of the sack of flour and some 30 quarts of water. This rises in an hour or so, and is then transferred to an oven for an hour and a half. Though the temperature of the oven varies from 400° to 450° F., or from 204° to 232° C., the actual temperature of the dough does not rise much over 212° F., or 100° C. In this stage the chemical processes are not very active, but the bread gradually becomes well aërated, and its constituents, undergoing a kind of automatic digestion, improve both in flavour and aroma.

In the non-fermented breads, the carbon dioxide is disengaged by mixing sodium or ammonium carbonate with the dough, and adding hydrochloric, tartaric, phosphoric, or citric acids. Baking powders are compounds of these substances. In what is called Dauglish's patent aërated bread, the carbonic acid is forced through the dough by pressure. About 20 cubic feet of CO_2, derived from chalk and sulphuric acid, are used for 280 ℔ of flour, and about 11 cubic feet are actually incorporated with the flour. It is claimed for unfermented breads that they do not contain alcohol, acetic acid, and other products of excessive fermentation, but the advantage is a doubtful one, as the action of yeast partially digests the starch, changing it into maltose and dextrin; while the proteids of flour are also largely converted into albumoses or other peptone-like bodies.

Chemical Composition of Bread.—From what has been said about the making of bread, it is obvious that bread differs in composition from flour. The percentage composition of some ordinary breads is given in the following table:—

	Water.	Proteids.	Fats.	Starch.	Sugar.	Cellulose.	Salt.	Ratio of nitrogenous to non-nitrogenous food-stuffs.
White bread, average quality,	40·10	8·00	1·50	49·20	...	...	1·30	1 is to 6·3
White bread, fine quality,	35·59	7·06	0·46	52·56	4·02	0·32	1·09	1 ,, 7·5
White bread, coarse quality,	40·45	6·15	0·44	49·04	2·05	0·62	1·22	1 ,, 8·1
Whole-meal bread,	43·40	11·10	0·40	41·90	...	1·70	1·50	1 ,, 4·0

As an article of diet, bread has very similar advantages and disadvantages as flour. It is rich in proteid and starch, but poor in fat and salts. Roughly speaking, its nitrogen is to the carbon as 1 is to 21. To make it a perfect food, it therefore requires more nitrogen. Its poverty in fat is curiously exemplified by the constant practice of using fat with it, butter for the rich and dripping or fat bacon for the poor. As to the relative advantages of the various methods of making bread, it must not be overlooked that yeast bread is nothing more nor less than a partially digested flour, and as such holds a superior dietetic position to the non-fermented forms of bread.

Special Points about making of Bread.—It may be of bad colour from old flour: from grown flour (in which case the changes in the starch have generally gone on to a considerable extent, and the bread contains more sugar than usual, and does not rise well), and perhaps from bad yeast. The colour given by admixture of bran must not be confounded with yellowness of this kind.

Bread is also dark coloured from admixture of other grains, as already noticed under flour (rye, buckwheat, melampyrum, sainfoin, &c.). Bread may be acid, from bad flour giving rise to an excess of lactic and perhaps acetic acids, or, it is said, from bad yeast. In finding the cause of acidity in bread, look first to the flour, which may be old and a little discoloured, and too acid; if nothing can be made out, examine the yeast, and change the source of supply; then look to the vessels in which the dough is kneaded, and to the water. Enforce great cleanliness on the part of the men who make up the dough.

Bread is frequently heavy and sodden from bad yeast fermenting too rapidly, or when the fermentation has not taken place (cold weather, bad water, or some other cause will sometimes hinder it), or when the wheat is grown; when too little or too much heat has been employed. It is said also that if the flour has been dried at too great a heat (above 200° F.) the glutin is altered and the bread does not rise well. It is bitter from bitter yeast.

Bread becomes mouldy rapidly when it contains an excess of water.

Rice is used as an addition because it is cheaper; it retains water, and therefore the bread is heavier. Rice bread (if 25 per cent. of rice be added) is heavier, of closer texture, and less filled with cavities. Potatoes are sometimes added, but are generally used only in small quantity with the yeast.

Alum is added to stop an excess of fermentation, when the altering glutin or cerealin acts too much on the starch, and it also whitens the bread; it does not increase the amount of water; it enables bread to be made from flour which otherwise could not be used. Sulphates of copper and of zinc, in very small amount, are sometimes employed for the same purpose.

For acid flour, lime-water is used instead of pure water; lime-water has this advantage, that, while it does not check the fermentation of yeast, it hinders the action of diastase on starch. It must be caustic lime-water, and not chalk and water, as sometimes is the case.

Loaves are generally weighed when hot, and that is considered to be their weight. After being taken from the oven bread begins to lose weight. The loss of weight depends upon size, amount of crust, temperature, and movement of air. In a sheltered place, at ordinary temperature, a 2-℔ loaf, baked with crust all over, loses about $\frac{3}{4}$ per cent. in cooling, and from 1 to $1\frac{1}{4}$ in five hours. A similar loaf, with only top and bottom crust, loses 3 per cent. in cooling, and about 4 per cent. in five or six hours. A loaf with four sides crust loses 2 per cent. in cooling, and retains its weight without much further loss for five hours. For each of six sides that is not crust there is a loss of weight of about 1 per cent. in the first five hours. At the end of twenty-four hours the proportion is about one-half more, and the total loss is doubled at the end of seventy-two hours (three days). If the bread is baked in larger loaves (4 ℔, for instance) the loss will be proportionately less, the ratio of the evaporating surface to the bulk of the loaf being diminished.

When loaves become stale they can be dipped in water and rebaked, they will then taste quite fresh for twenty-four hours; after that they rapidly change.

Diseases connected with the Quality of Flour and Bread.—Frequently the flour is originally bad: it may be ergoted, or grown and fermenting, or affected with fungi. Fermenting flour produces dyspepsia and diarrhœa:

the heat and moisture of the stomach doubtless excite at once very rapid fermentation : the proteids, already metamorphosing, act energetically on the starch, and carbon dioxide is rapidly developed ; hence uncomfortable feelings, flatulence, imperfect digestion, and diarrhœa. It is to remedy this condition of flour that alum is added, and some of the effects ascribed to alum may be really owing to the flour.

The most important disease connected with flour is, however, ergotism ; this is less common in wheat than in rye flour, but yet is occasionally seen. Sometimes ergoted meal produces at once violent stomach and intestinal symptoms, at other times primary digestion is well performed, and the early symptoms are great general depression and feverishness, ushering in the local symptoms of acrodynia.

The flour may have been originally good, but altered either from age or imperfect drying. The bread made from such flour is often acid, and sometimes highly so, sufficient to produce diarrhœa, though such bread has sometimes been used for a long time without this effect ; usually persons will not eat much of it, and thus the supply of nutriment is lessened. If the bread be too moist, *fungi* form, and *Oïdium aurantiacum*, in particular, has been known to give rise to little endemics of diarrhœa. *Mucor mucedo* either does not produce this, or does so but rarely. It is not known that *Acarus*, so common in flour, has any bad effects when eaten.

Of the various substances added from time to time to flour, alum is the chief : there has been much difference of opinion as to its effects. It has been asserted to produce dyspepsia ; to lessen the nutritive value of bread by rendering the phosphoric acid insoluble, and to be also a falsification, inasmuch as it permits an inferior flour to be sold for a good one. The last allegation is no doubt correct ; the second probably so, as there is little doubt of the formation, and none of the insolubility, of aluminum phosphate. The first point is more doubtful, though several physicians of great authority have considered its action very deleterious, and that it causes dyspepsia and constipation. Pereira considered that whatever may have been the effect in the case of healthy persons, sick persons did really suffer in that way. A question like this is obviously difficult of that strict proof we now demand in medicine. Seeing, indeed, that the usual effect of bad flour is flatulence and diarrhœa, if constipation were decidedly produced by bread, it would be more likely to proceed from alum than from any other ingredient of the bread. Looking again to the fact that sometimes bread has contained large quantities of alum,—sometimes as much as 40 grains in a 4-℔ loaf, and probably more,—we get an amount in an ordinary meal which (if the aluminum phosphate is an astringent) might very well cause constipation. Looking, then, to the positive evidence, and the reasonableness of that evidence, it seems extremely likely that strongly alumed bread does produce the injurious effects ascribed to it.

Sulphuric acid is said to be added, before grinding, to flour instead of alum, it having the same power of restraining decay. For the same reason sulphate of copper is added. The amount is so small that it seldom produces any symptoms : still it is possible that some anomalous cases of stomach irritation may be owing to this.

Lead poisoning is extremely rare as a consequence of the eating of bread. Alford records a case in which it occurred, owing to holes in some millstones having been repaired with the molten metal, and where old wood which had been painted was used for heating the baking oven.

The symptoms produced by bread containing *Lolium temulentum* have already been described : while as to the effect of flour from grains other than wheat, it is not known whether the addition of potatoes, rice, barley, peas, &c., in any way injures health, except as it may affect nutrition or digestion. Occasionally, in times of famine, other substances are mixed—chestnuts, acorns, &c. In 1835, during famine, fatal dysentery appeared in Königsberg owing to the people mixing their flour with the pollen of the male catkin of the hazel bush. In India the use of a vetch, *Lathyrus sativus* (kisārī-dāl), with barley or wheat, gives rise to a special paralysis of the legs when it exceeds one-twelfth part of the flour; *L. cicera* has the same effect. During the siege of Paris, straw, to the extent of one-eighth, was introduced into the bread; this had a very irritating effect.

EXAMINATION OF BREAD.

There should be a due proportion—not less than 30 per cent.—of crust, which should be yellowish-brown, firm, and not aërated; the external surface should not be burnt. The amount of crust can be readily estimated by carefully paring it off with a sharp knife, weighing, and then calculating it as a percentage of the weight of the whole loaf. The crumb should be permeated with small regular cavities; no parts should be heavy, nor without these little cells; the partitions between the cavities should not be tough; the colour should be white or brownish from admixture of bran; the taste not acid, even when held in the mouth. If the bread is acid the flour is bad, or leaven has been used; if the colour changes soon, and *fungi* form, the bread is too moist; if sodden and heavy, the flour is bad, or the baking is in fault; the heat may have been too great, or the sponge badly set.

The purely chemical examination of bread should be directed chiefly to the determination of the water and acidity, and of the presence of alum or sulphate of copper.

Amount of Water.—This should be calculated on the whole loaf, and determined separately in both the crust and crumb. Usually it amounts to about 16 per cent. in the crust, and from 35 to 45 per cent. in the crumb. On the whole loaf it should not be more than 45 per cent.; if more, the bread is *pro tanto* less nutritious, and liable to become mouldy sooner. The determination is readily made by taking a weighed quantity of the powdered bread, drying in a hot-air bath or oven, re-weighing, and calculating out as a percentage. If a loaf be found to have 24 per cent. of crust and 76 per cent. of crumb, with 16 per cent. of water in the crust and 40 in the crumb, the statement for the moisture in the whole loaf will, therefore, stand as follows:—

$$\frac{16}{100} \times 24 = 3{\cdot}84$$

$$\frac{40}{100} \times 76 = 30{\cdot}40$$

34·24 percentage of water in the whole loaf.

Degree of Acidity.—This is a somewhat important determination, and can be readily made by means of a standard alkaline solution, prepared by taking liquor sodæ or liquor potassæ of pharmacopœial strength, and diluting with 8 or 9 parts of distilled water, so that 10 c.c. exactly neutralises 10 c.c. of a deci-normal solution of oxalic acid. If so prepared, 1 c.c. of the alkaline solution equals 6 milligrammes of glacial acetic acid, in terms of which the acidity of bread is usually expressed. The acidity of bread is conveniently determined by soaking, for an hour, 10 grammes in 100 c.c. of distilled water, macerating, and then titrating with the standard alkaline solution; either litmus and turmeric papers or phenolphthalein may be used as indicators. As in the case of the moisture, so the acidity should be separately estimated for the crust and crumb, and then calculated on the whole loaf. The actual acidity found will vary; even the best bread is slightly acid. It generally averages from 4·5 to 6 grains per pound, or from 0·064 to 0·086 per cent. Eight grains per pound, or 0·114 per cent., of glacial acetic acid ought certainly to be the limit.

Amount of Alum.—The determination of the presence of alum is not difficult, but a quantitative analysis is necessary, as even unalumed bread may contain an appreciable amount. As a qualitative test, a decoction of logwood may be used; a piece of pure bread and a piece of suspected bread are put into a glass containing freshly prepared decoction, and left for twenty-four hours; the pure bread is simply stained, the alumed bread is dark purplish, as the alum acts like a mordant.

For a quantitative estimation, the following process suggested by Dupré, and modified by Wanklyn, is the best.

Take the ash of a quarter of a pound of bread, place in a porcelain dish and moisten with 3 c.c. of pure hydrochloric acid to separate silica; add 30 to 50 c.c. of distilled water, boil, filter, wash the filter well with boiling water; add to the filtrate, which contains the phosphates of calcium, magnesium, aluminum, and iron, 5 c.c. of liquor ammoniæ (sp. gr. 0·880), which causes a precipitate of these phosphates; then add gradually 20 c.c. of strong acetic acid, which partially clears the fluid by dissolving the phosphates of calcium and magnesium; boil and filter. The undissolved part is a mixture of phosphate of aluminum and phosphate of iron; wash precipitate well with boiling water, dry, ignite, and weigh.

The iron must now be determined in this precipitate. This may be done by the permanganate, but Wanklyn's colorimetric test is probably better; it is as follows:—Dissolve 1 gramme of pure iron wire in nitro-hydrochloric acid, precipitate the ferric oxide with ammonia; wash the precipitate, dissolve it in a little hydrochloric acid, and dilute to 1 litre: 1 c.c. therefore equals 1 milligramme of metallic iron; when used it is diluted 1 in 100 so as to make a solution of which each c.c. contains $\frac{1}{100}$th milligramme ($=0·01$ of a milligramme) of metallic iron. To use this, dissolve the phosphates of aluminum and iron (obtained by the above described process) in 3 c.c. of pure hydrochloric acid, and dilute to 100 c.c. with distilled water. Test the solution to see if it give a deep colour with a ten per cent. solution of ferrocyanide of potassium; if the colour is not too deep take 50 c.c. of the solution, and dilute up to 100 c.c. with distilled water: but if it be deep take a smaller quantity, still diluting up to 100 c.c. with distilled water. Put it into a cylindrical glass and add 1·5 c.c. of the solution of ferrocyanide of potassium, and 1 c.c. of strong hydrochloric acid: a blue colour is given. Into another glass as much of the standard iron solution is dropped in as will produce a similar colour. The bulk being made up to 100 c.c. with distilled water and 1·5 c.c. of ferrocyanide solution and 1 c.c. of strong hydrochloric acid being added. This procedure of "Wanklynising" is analogous to that of "Nesslerising" for ammonia. The amount of iron is then read off and calculated as phosphate (1 of iron $= 2·696$ $FePO_4$). Deduct the weight from the total weight of phosphate of aluminum and iron; the remainder is phosphate of aluminum ($= AlPO_4$), of which 1 part equals 0·42 alumina, or 2·1 dry or 3·9 crystallised potassium alum; or 1·9 dry or 3·7 of crystallised ammonium alum, which last is almost the only kind now in the market. Calculate as crystallised ammonium alum, $AlNH_4(SO_4)_2\ 12H_2O$, and express as grains per pound.

Example.—Weight of capsule + phosphatic ash = 19·155 grammes.
,, ,, alone = 19·060 ,,

0·095
Weight of ash of filter paper = 0·005 ,,

Nett weight of phosphatic ash = 0·090 ,, ($FePO_4 + AlPO_4$).

After solution and dilution of the ash to 100 c.c., 5 c.c. of it required 12 c.c. of the standard iron solution: then, $\frac{100 \times 12}{5} = 240$ c.c. for the whole 100 c.c.

240 × 0·01 = 2·4 mgm. of Fe in ¼ ℔ of bread.
2·4 × 2·696 = 6·46 mgm. $FePO_4$, or 0·00646 gramme in ¼ ℔ of bread.

Then, 0·090 or total phosphates of iron and alum *less* 0·00646 or phosphate of iron gives 0·08354 gramme of phosphate of alum in ¼ ℔ of bread:

and 0·08354 × 3·7 = 0·3091 gramme $AlNH_4(SO_4)_2 12H_2O$ in ¼ ℔ of bread.
0·3091 × 4 × 15·5 = 19·16 grains ,, ,, per ℔ of bread.

Alum is not much used, except with inferior bread: the object of its addition is to arrest the change in the glutin. The amount of alum in bread is said to be, on an average, 3 ounces to a sack or 280 ℔ of flour; if the sack gives 105 4-℔ loaves, there will be 3 grains in a pound of bread; but if crystallised alum is meant by this, there will only be about 1½ grain of dry alum. This amount must, therefore, be deducted from the alum found in the bread examined, the result then giving the amount of the salt added: or in other words, any excess over 12 grains in a 4-℔ loaf must be regarded as an adulteration. A very good witness, in the inquiry into the grievances of the journeymen bakers, gave the quantity in alumed bread to be 41·6 grains per 4-℔ loaf, or 10·4 grains per pound. When mixed with flour and baked the alum is decomposed: part of the alumina combines most strongly with phosphoric acid; and either this or the alum itself is presumed to be in combination with the glutin; potassium disulphate is probably formed.

Cupric Sulphate.—Cut a smooth slice of bread, and draw over it a glass rod dipped in potassium ferrocyanide. If copper be present, a brick-red colour is given by the formation of ferrocyanide of copper. The test is very delicate. This is believed to be a very rare adulteration in England. It has been said that cobalt is used instead of copper, but it is also probably very rare; it can be detected by the blueness of the ash.

Potatoes.—If potatoes in any quantity have been added, the ash of the bread, instead of being neutral, is alkaline; this can only occur from sodium carbonate having been added, or from the presence of some salts of organic acids,—citrates, lactates, tartrates, which form carbonates on incineration. But if it be from sodium carbonate, the solution of bread will be alkaline, so that it can be known if the alkalinity is produced during incineration. If so, it is almost certain to be from potato.

The *ash* of bread ought never to be over 3 per cent.

BISCUITS.

The simplest biscuits are merely flour and water, but the majority have slight additions of butter, sugar, and flavouring substances, with milk, eggs, &c. What are known as diet or digestive biscuits contain some bran. Abernethy biscuits contain caraway seeds. Cracknels are glazed with white of egg, while macaroons and ratafias are flavoured with sweet and bitter almonds. Ginger, lemon, orange-peel, and many other flavours and spices are used as ingredients in fancy biscuits and cakes.

Biscuits should be well baked, but not burnt: of a light yellow colour, should float and partially dissolve in water. When struck, they should give a ringing sound, and when put into the mouth should thoroughly soften down. All biscuits should be free from weevils. All the plainer varieties of biscuit may be considered as more nutritious than bread, in the proportion of 5 to 3. They are more digestible when not very dense, and when they have been browned by baking, so as to turn much of their starch into dextrin. Like flour, biscuit is deficient in fat, and after a time seems difficult of digestion. Perhaps the want of variety is objectionable, but it is quite certain that men do not thrive well upon it for long periods.

The essential differences between biscuits and bread are that they are not vesiculated, and they are baked until they contain scarcely any water, sometimes not even 5 per cent. There are, of course, some exceptions to this rule, especially in the case of the fancy biscuits. Strictly speaking, a biscuit is that which has been twice cooked or baked, but this definition will not apply to the generality of biscuits now made. A few kinds are really put twice into the oven; such are rusks, which are made from flour, milk, butter, and sugar, first lightly baked as a kind of bread, then cut into slices and again put into a sharp oven so as to scorch both sides. They are afterwards thoroughly dried by a lower degree of heat continued for some hours.

The percentage composition of two varieties of plain biscuit may be taken to be as follows:—

	Water.	Proteids.	Fat.	Starch.	Sugar.	Cellulose.	Salt.	Ratio of nitrogenous to non-nitrogenous food-stuffs.
Navy biscuit,	10·20	10·90	1·60	75·00	...	1·20	1·10	1 is to 7
Milk biscuit,	9·45	7·18	9·28	57·18	15·92	0·16	0·83	1 ,, 1·4

From the foregoing, it will be readily seen that biscuits contain a much smaller quantity of water and a larger proportion of proteid and carbohydrate than bread. Weight for weight, they are therefore more nutritious than bread, and being easily transported are useful as a substitute for bread, when this cannot be obtained.

Besides biscuits and bread, other preparations from flour are macaroni and vermicelli. *Macaroni* is made from the "hard" wheats of Italy and France. These wheats yield large quantities of glutin, which readily permit of the manufacture of the macaroni of commerce. Macaroni is a valuable food, little appreciated in these islands, and of a fairly constant composition. It contains, on an average, 13 per cent. of water, 9 of proteids, 0·4 of fat, 76·7 of carbo-hydrates, and 0·9 per cent. of salts. *Vermicelli* closely resembles macaroni in both its composition and nutritive properties.

BARLEY.

As an article of diet, barley has the same advantages and disadvantages as wheat. It is said to be rather laxative. The barley grain contains about as much proteid as wheat, but these do not, on the action of water, form glutin, but remain in a soluble form as globulin, albumin, and albumose. It is difficult to say how far this affects its nutritive value, but it undoubtedly affects the capability of barley being made into bread, and as such being largely used as an article of diet.

The envelopes of barley are the same in number as those of wheat, but they are more delicate. The outer coat is described usually as having three layers of cells; the walls of the external layer are beautifully waved, but not beaded; the individual cells are smaller than those of the outer coat of wheat. The second coat, disposed at right angles to the first, as in wheat, is like the second coat of wheat, except in being more delicate and not beaded. The third is hyaline and transparent, with faint cross-lines, as in wheat. The fourth has the cells similar in shape to the corresponding wheat coat, but they are very much smaller, and often arranged in two or three layers.

The starch grains of barley are very like the wheat, with a central hilum and obscure marking, but are on the whole smaller; some have thickened edges, instead of the thin edges of the wheat starch grains, but it is very difficult and sometimes impossible to distinguish them. It is therefore specially to the envelopes that we must attend.

When the whole barley grain is ground, it forms *barley-meal;* when deprived of its husk, and roughly ground, it constitutes *Scotch*, *milled*, or *pot barley*. *Pearl barley* is the grain deprived of the husk, rounded and polished by rubbing. So-called *patent barley* is merely pearl barley crushed to the state of flour. Barley-water is prepared from pearl barley, and forms a slightly nutritive liquid for infants and the sick. *Malt* is the product yielded when barley has been allowed to germinate, and the germination stopped at a certain point by exposure to heat on a kiln. As a result of this process, the starch of the grain is largely converted into sugar by the development within the barley grain of a peculiar active nitrogenous ferment called diastase. There being little or no glutin in barley, it cannot be made into ordinary bread; when barley bread is made, it is usually from a mixture of barley-meal with wheaten flour. Barley cakes are eaten in some places on the score of economy; but, as compared with those made from wheat, are less palatable and less digestible.

The diseases which may arise from altered quality of barley are the same as those from wheat, namely, indigestion, flatulence, and diarrhœa. There appears to be nothing peculiar in the action of diseased barley as distinguished from diseased wheat.

RYE.

Although little used in this country except for malting, rye in the northern countries of Europe is largely used for making bread. In its percentage composition, rye closely resembles wheat, its proteids forming, on the addition of water, a kind of glutin. Rye bread is dark in colour, somewhat heavy and very acid; but falling little short of wheaten bread in nutritive value.

Rye bread is indigestible and apt to cause diarrhœa. If mixed with two parts of wheat flour, rye flour makes an excellent bread.

Percentage Composition of Rye Bread.

	Water.	Proteid.	Fat.	Starch.	Sugar.	Cellulose.	Salts.
German rye bread,	42·26	6·11	0·43	46·94	2·31	0·49	1·46
,, black bread,	43·42	7·59	1·51	41·87	3·25	0·94	1·42

The envelopes of rye are very like those of wheat, and can perhaps hardly be distinguished from them. The recent starch grains (fig. 41) are also like those of wheat, but they are much more distinctly spherical. They have also sometimes a peculiar rayed hilum, which used to be thought peculiar to the older and drier grains. It is, however, to be seen even in the starch of fresh soft grains. In the starch of wheat, this rayed hilum is only met with occasionally, when the grain is very old or dry. If rye is mixed in any quantity with ordinary wheat flour it is readily discoverable by baking, as it makes a dark, acid bread.

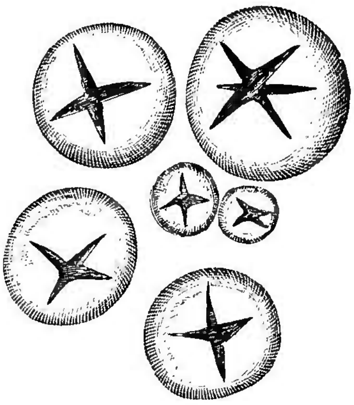


Fig. 41.

Rye is subject to a very peculiar fungus disease due to the permanent mycelium of the *Secale cornutum*, which grows at the expense and in place of a grain of the corn, producing what is called an ergot of rye. If we take a spike of ergotised rye, we see one or more of the rye grains replaced by blackish horn-like growths, twice or three times as long and stout as the normal rye grains (fig. 42). This is the ergot, and when fresh has a faint sickly odour, with a bitter and nauseous taste; from it ergotine is produced. This black grain or ergot is not a perfect fungus, but is really a sclerotium or permanent mycelium of the *Secale cornutum*. If this sclerotium or ergot be placed in a clean, moist, shady place it will germinate (fig. 43), producing on its surface several club-shaped growths. Each little white stemmed offshoot from the ergot has a small spherical head of a beautiful purplish colour. This growth is now the perfect condition of the ergot, and is termed *Claviceps purpurea*. The claviceps derives its nourishment from the ergot, and after it has appeared the ergot collapses and perishes. If one of the heads or clubbed ends of the claviceps be cut through longitudinally, it will be found to have the structure as shown in fig. 44. Its outer surface is seen to be packed all round with small flasks, conceptacles or *perithecia*, with their mouths all opening to the outside. Each single perithecium is closely packed with fine long transparent bladders, each of which again contains some eight or ten fine, long, attenuated bodies which are sporidia or spores. When ripe, these needle-like spores are ejected into the air, whence they ultimately find attachment to the base of the pistil of a flower of rye. Here it germinates to form, in course of time, a sclerotium or ergot, with a subsequent development of the claviceps stage.

When the ergot gets mixed with rye grains, it becomes ground down with them, and the resulting bread gives rise to a disease in men called ergotism, the symptoms of which are vomiting, diarrhœa, followed in severe cases by either loss of sensibility,

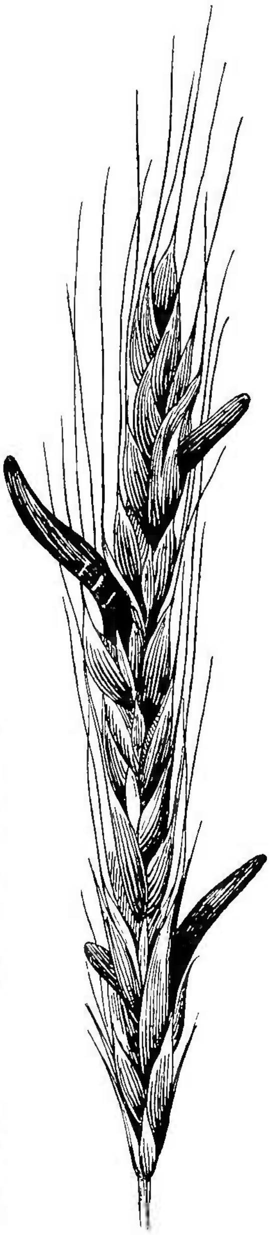


Fig. 42.

gangrene or paralysis. The disease is practically unknown in this country, and much less prevalent now than formerly abroad. On account of their size, the ergots can be readily sifted from the unaffected grains: as already stated, the ergot is carefully sought out, owing to its value as a drug, and for this reason is rarely found in flour.

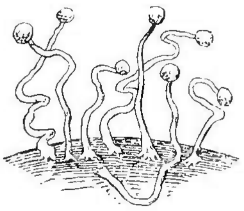


Fig. 43.

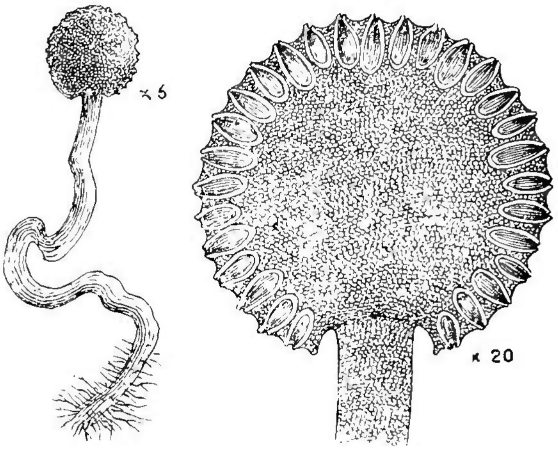


Fig. 44.

OATS.

As met with in commerce, oats consist of the seeds of the *Avena sativa* enclosed in their husks. When deprived of this integument, the grain goes by the name of *groats* or *grits*, used in making porridge: and these groats, when ground down fine, constitute *oat-meal*, from which gruel is made. Of all the cereals, oats rank next to wheat as articles of food, being noticeable for containing large amounts of proteid and fat — particularly the latter. Oats resemble barley rather than wheat, in that their proteids do not form glutin on the addition of water: on this account oat-meal cannot be vesiculated and made into bread like wheaten flour. It is, however, made into thin cakes by mixing into a paste with water, and then baking on an iron plate. Owing to the large amount of cellulose which they contain, this is apt to irritate the intestines, and more or less interfere with digestion.

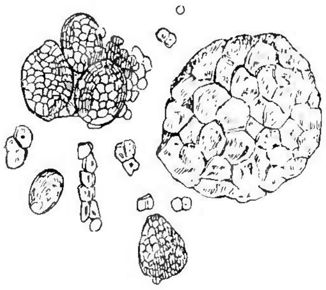


Fig. 45.

In oats, there are two or three envelopes: the outer coat contains longitudinal cells; the second contains obliquely transverse cells, which are not very clearly seen; the cells are wanting in parts, or pass into the cells of the third coat; the third a layer, usually single, of cells like the fourth coat of wheat. The husk must be detached before the envelopes are looked for, for lining it is a layer of wavy cells, like the external envelope of barley, which might mislead. The starch-cells are small, many-sided, and cohere into composite round bodies, which (fig. 45) are very characteristic, and which can be broken down into the separate grains by pressure. A high power is necessary for the examination of these grains. The oat starch does not polarise light, and there is usually no difficulty in their detection by means of the microscope.

In the form of oat-meal, oats can be taken for long periods without distaste, and in this form constitute a material part of the dietary of the Scotch peasantry. The chief adulterations of oat-meal are barley meal and the husks of barley, of wheat and of the oat itself. A single look through the microscope usually detects the round and smooth barley starch, while the envelopes are recognised with very little more trouble. Occasionally rice and maize are added. In a good oat-meal there should be a fair proportion of envelope, but the meal should be devoid of any branny character, which usually arises from barley husks. The starch should not be discoloured, and the whole sample free from *acari*.

RICE.

The whole grain (paddy) deprived of the husk is sold as rice. There are many varieties, of different colours and composition. The amount of nitrogenous matter varies greatly, from 3 to 7·5 per cent. As an article of diet it has the advantage of an extremely digestible starch grain, and, like the other *Cerealia*, there is a great admixture of substances; it is, however, poorer in nitrogenous substances than wheat, and is much poorer in fat. Consequently, among rice-feeding nations, leguminous seeds are taken to supply the first, and animal or vegetable fats to remedy the latter defect. Rice is also poor in salts. It is essentially a carbo-hydrate food, and, if properly and sufficiently cooked, is very digestible. It is best cooked by thoroughly steaming; if boiled in water, it loses some of its already small quantity of proteid and saline matter. It cannot be made into bread, but is much used in France for mixing with wheaten flour to make the very white bread which is in request in that country.

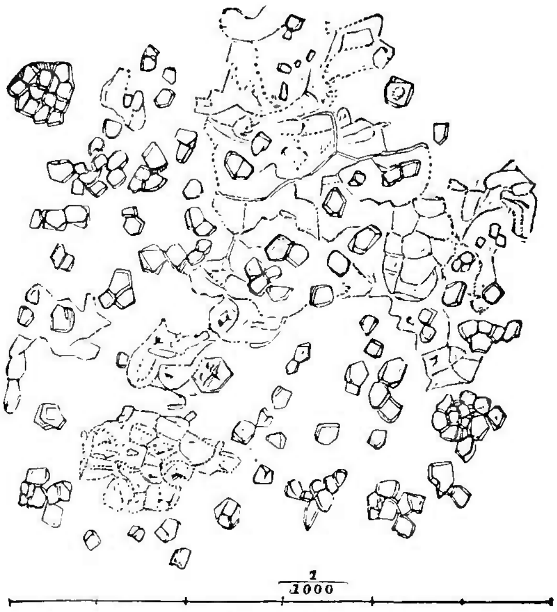


Fig. 46.

The husk of rice is very peculiar; on the outer coat are numerous siliceous granules, arranged in longitudinal and transverse ridges; there are also numerous hairs, some of which are seated over stomata. Below this, there is a membrane of transverse and longitudinal rough edged fibres, while below these again is a fine membrane of transverse angular cells, covering a further delicate membrane of large cells. The starch grains (fig. 46) are very small, angular under low power, but faceted and compressed under high powers. They cannot be mistaken for the round cells of wheat, but may be confounded with oat starch, from which, however, they are distinguished by the absence of the compound cells or glomeruli. Their shape is also a little like maize, but they are very much smaller.

MAIZE.

Though not much used in England, maize or Indian corn is an important food in America and in Italy, where it is called *polenta*. In its nutritive value, maize resembles oats, containing a large quantity of fat. When made either into cakes or porridge, it affords a valuable food. Maize, being deficient in glutin, does not make good bread; it is, moreover, harsh in flavour. This defect is largely removed by treating it with caustic potash, a procedure which is the foundation of the process for making it into the common commercial articles extensively sold under the names of oswego corn-flour and hominy. If imperfectly cooked, or at all decomposed, maize may give rise to very disturbing symptoms. The grain, too, is liable to a peculiar disease due to a fungus called *Sporisorium maidis*, which gives rise to a disease in man known as "pellagra," and closely resembling scurvy. This affection is not uncommon in Lombardy, where much maize is eaten as food.

The coats of maize are two, the outer being made up of many strata of cells; there is no transverse second coat as in wheat; the internal coat consists of a single stratum of cells like the fourth of wheat, but less regular in shape and size. The cellulose, through the seed holding the starch in its meshes, forms a very characteristic structure, which on section looks like a pavement made of triangular, square, or polygonal pieces; the cells are filled with the starch grains, which are very small, and compressed, so as to have facets (fig. 47). They are very different from the smooth, uncompressed round cells of wheat. The starch grains of oats, rice, and maize somewhat resemble each other, in being all faceted. The maize starch grains are much larger than the other two, with a distinct hilum; oat and rice starch grains are smaller than those of maize, and are usually without a hilum, while both the oat and rice grains have a tendency to collect together into clumps.

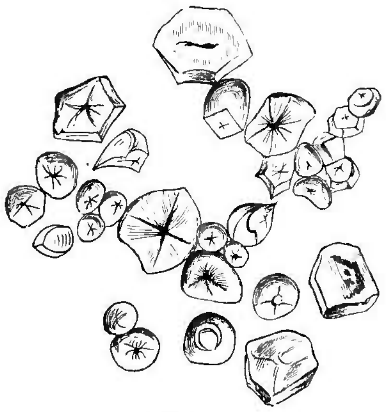


Fig. 47.

MILLET AND BUCKWHEAT.

Various grains belonging to the Cerealia or to other natural orders, and having similar properties, are used as food in different countries. Of these the chief are the different millets, used largely in Africa, Italy, Spain, Portugal, and some parts of India and China.

English Names.	Botanical Names.	Indian Names.
Common millet,	*Panicum miliaceum*,	Sanwā Chenawāri (Hindustani). Varagū (Tamul).
Small millet,	*Sorghum* or *Panicum vulgare*,	Dharrā (Arabic). Cholam (Tamul). Joār or Joārī (Hind.).
Spiked millet,	*Pencillaria spicata*,	Bājrā or Bājrī (Hind.). Kambū (Tamul).
Golden-coloured millet,	*Sorghum saccharatum*.	

English Names.	Botanical Names.	Indian Names.
Italian millet,	*Setaria Italica,*	Kālā kangnī (Hind.). Tenay (Tamul).
German millet,	*Setaria Germanica.*	
	Eleusine corocana,	Rāgī or Raggy (Hind., Canarese, and Tamul). Murha and Maud in the N. Prov. of Hindustan.

The millets are very similar in composition, their ash being particularly rich in silica and phosphates.

	Water.	Proteids.	Fats.	Carbo-hydrates.	Cellu-lose.	Salts.	Ratio of nitrogenous to non-nitrogenous food-stuffs.
Common millet,	11·79	10·51	4·26	68·16	2·48	2·80	1 is to 6·89
Small millet,	11·46	8·96	3·79	70·25	3·59	1·95	1 ,, 8·26
Spiked millet,	11·72	8·61	3·54	71·31	3·40	1·42	1 ,, 8·69
Golden-coloured millet,	15·17	9·26	3·36	67·99	2·51	1·71	1 ,, 7·70
Italian millet,	12·04	7·40	3·87	74·21	1·37	1·11	1 ,, 10·55
German millet,	11·92	8·41	3·62	71·50	3·25	1·30	1 ,, 8·93
Raggy or Rāgī,	13·2	7·30	1·50	73·20	2·50	2·30	1 ,, 10·23
Buckwheat,	12·68	10·18	1·90	71·73	1·65	1·86	1 ,, 7·22

Millet bread is very good, and some was issued to the troops in the last China Expedition. This should always be done in a millet country, if wheat or barley cannot be got. In Northern China millet is almost exclusively used.

Raggy or Rāgī (*Eleusine corocana*) is largely used in Southern India and in some parts of Northern Hindustan, and is considered even more nutritive than wheat. It is capable of being preserved for many years in dry grain pits.

Buckwheat (*Fagopyrum esculentum*) is not so likely to be used. It is poor in nitrogenous substances and fat, and contains a good deal of indigestible cellulose, but it makes fairly palatable cakes.

PEAS AND BEANS.

These belong to the Leguminosæ, and in respect of dietetic properties are broadly distinguished from other vegetable foods by their large amount of nitrogenous substance, called legumin or vegetable casein, which is probably largely derived, during extraction, from certain globulins and albumoses present in these seeds. The character of the proteids in the leguminous plants has not been very well investigated; our fullest knowledge relates to the kidney bean, *Phaseolus vulgaris*, which contains two globulins and legumin. The two globulins, known respectively as *phaseolin* and *phaselin*, are both very soluble in dilute saline solutions, from which they are precipitated by acids, the precipitates being soluble in common salt solution. By prolonged dialysis of their solutions, they separate out and thereby become partially insoluble in brine. The following analysis of those globulins by Osborne is interesting as typical of the proteids of this group of seeds.

	Phaseolin.	Phaselin.
Carbon,	52·58	51·60
Hydrogen,	6·84	7·02
Nitrogen,	16·47	14·65
Oxygen,	23·55	26·24
Sulphur,	0·56	0·49
	100·00	100·00

The advantages of peas and beans as articles of diet are the great amount of legumin and salts, especially those of potash and lime. Their disadvantages lie in their great indigestibility and poorness in fat and sodium chloride. Rubner has shown that from about 21 to 30 per cent. of the nitrogen of peas passes out undigested in the fæces as compared with 13 to 14 per cent. of the nitrogen of white bread, and about 17 per cent. of black bread. The existence of sulphur frequently causes flatus from the production of hydrogen sulphide. Still they are a most valuable article of food, and always ought to be used when much exercise is taken, as they constitute an excellent addition to meat and the other cereals. Both men and beasts can be nourished on them alone for some time; in fact, added to rice, they form the staple food of large populations in India.

Closely allied to peas and beans are Lentils (*Ervum lens*), Gram (*Phaseolus Mungo*), Soja beans (*Soja hispida*), Lablab beans (*Dolichos lablab*), and Dal (*Lathyrus sativus*). Lentils contain a large amount of proteid, are rich in iron and phosphate of lime, and have the advantage over peas of containing no sulphur. "Revalenta" is prepared from lentils. Gram, although chiefly used for horses and cattle, is sometimes employed as food for men in India, making palatable and nutritious cakes. Soja or Soy beans, from the large amount of fat they contain, approximate in composition to the oily seeds such as linseed, pea-nuts, walnuts, hazel-nuts, and almonds. Lablab beans are obtained from a pulse grown in India not only for its ripe seeds, but also for its green pods, which are used as a vegetable. The Dal is a vetch used occasionally in Europe and constantly in India, when mixed with wheat or barley flour, for bread. When used in too great quantities, it produces constipation, colic, and some form of indigestion, and, if eaten in excess, paraplegia. It is also injurious to horses, but less so to oxen. To this group belong also the seeds of the Peruvian food, the *Chenopodium Quinoa*. The starch grains of the Quinoa are said to be the smallest known. It may be worth remarking that this seed is very rich in salts (2·4 per cent.), and particularly so in iron (0·75 per cent.); indeed, it is the richest in iron of any vegetable. It is possible that it might be a useful food in some cases of illness. It is fairly nutritious and digestible. The following table shows the percentage composition of some of the more common leguminous seeds:—

	Water.	Proteid.	Fat.	Carbo-hydrate.	Cellu-lose.	Salts.	Ratio of nitrogenous to non-nitrogenous food-stuffs.
Pea flour,	11·41	25·20	2·01	57·17	1·32	2·89	1 is to 2·3
Green peas,	78·44	6·35	0·53	12·00	1·87	0·81	1 ,, 1·8
Dried peas,	13·92	23·15	1·89	52·68	5·68	2·68	1 ,, 2·2
Bean flour,	10·29	23·19	2·13	59·37	1·67	3·35	1 ,, 2·6
Dried beans, .	13·49	25·31	1·68	48·33	8·06	3·13	1 ,, 1·9
Fresh French beans,	88·75	2·72	0·14	6·60	1·18	0·61	1 ,, 2·4
Haricot beans,	11·24	23·66	1·96	55·60	3·88	3·66	1 ,, 2·4
Lentil flour,	10·73	25·46	1·83	57·35	2·01	2·67	1 ,, 2·3
Gram,	10·80	22·20	2·70	54·10	5·80	4·40	1 ,, 2·7
Soja beans,	15·70	33·40	17·70	26·00	3·10	4·10	1 ,, 1·2
Lablab beans, .	12·10	24·40	1·50	57·80	1·20	3·00	1 ,, 2·5
Lathyrus sativus,	12·74	24·08	2·38	51·38	6·60	2·82	1 ,, 2·2
Yellow lupin seeds,	13·98	38·25	4·38	25·46	14·12	3·81	1 ,, 0·8

It will be noticed how great is the difference between the composition of fresh and dried peas; roughly, 1 part of the dried pea equals, by weight, 4 parts of the green in proteids and carbo-hydrates.

The starch grains of peas and beans (fig. 48) are characteristic, being oval or kidney shaped: they have no clear hilum, but usually a deep central longitudinal cleft, or at times an irregularly shaped depression. The addition of hot water to pea or bean flour causes the emission of the typical beany smell. Pea flour is sometimes met with as an adulterant of wheat flour, but rarely to a greater extent than 4 per cent., as it makes the bread heavy and dark.

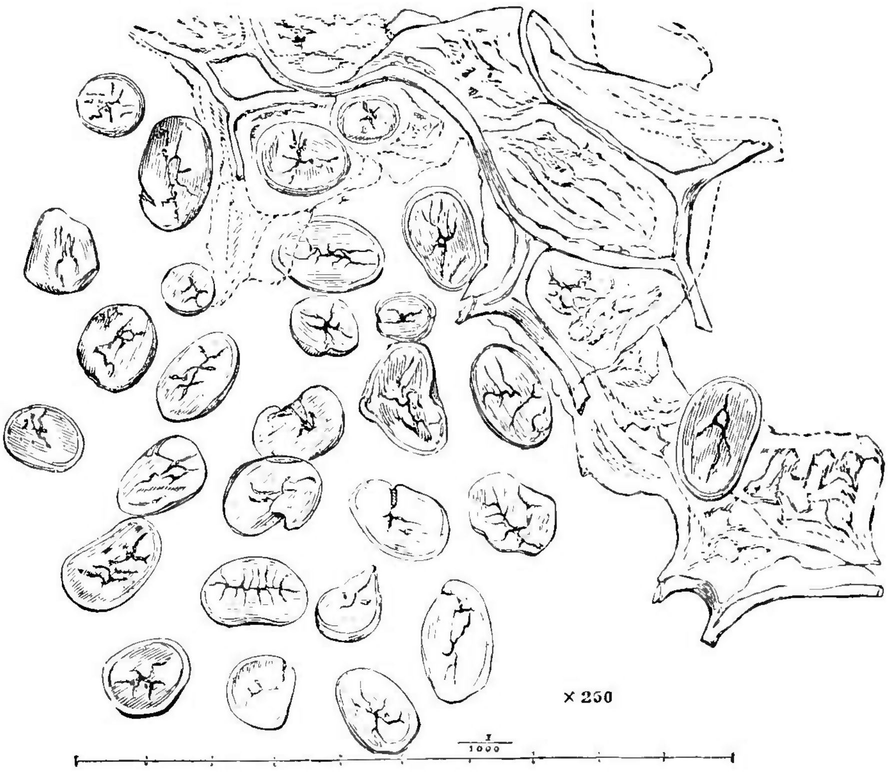


Fig. 48.

POTATOES.

These may be considered as occupying a place next in importance to the seeds of the cereals as articles of vegetable food. The potato, used as food, constitutes the tuber or exuberant growth of a portion of the underground stem of the *Solanum tuberosum*. The tuber develops into a thick fleshy mass, retaining its buds under the name of "eyes," each of which eyes or buds is capable of independent growth when in a detached or isolated state. In its chemical composition the potato shows a large proportion of starch with a very small quantity of proteid. The juice of the potato is acid, due to the presence of a certain amount of free citric acid with citrates of potassium, sodium, and calcium. In its dietetic value, the potato is both a carbo-hydrate and an anti-scorbutic. As the amount of salts is small, and that of water large, at least 8 to 12 ounces of potatoes should be taken daily, if no other vegetables are eaten.

The starch grains of the potato (fig. 49) are characterised by being large oyster-shaped granules with well-marked concentric rings, and a clear though small hilum at the narrow end. Weak liquor potassæ (1 in 10) swells them out greatly after a time, while wheat starch is little affected by this strength. Potato starch is largely used for adulterating the more expensive farinaceous dietetic preparations: though cheaper, there is nothing to show that potato starch is less nutritious than other starches.

Potatoes require to be cooked before being eaten: this may be done by either steaming, boiling, baking, or frying. The heat coagulates the albuminous juices, and the absorbed water swells up and distends the starch grains. When these changes are complete, the potato is said to be mealy or floury: when these changes are only partially completed, and the starch cells imperfectly broken up and separated, the potato remains more or less firm, and is spoken of as being close, waxy, or watery. The potato plant is sometimes affected with a fungus—the *Phytophera infestans*—which causes the disease known as potato murrain. This can be readily detected by the microscope. The disease commences in the leaves of the plant, and thence extends to the stem and on to the tubers. On the surface of the latter, brown spots make their appearance, penetrate the potato, and eventually cause it to rot and decay.

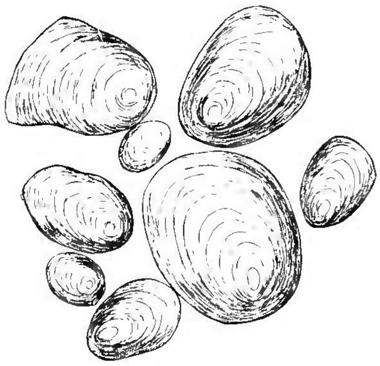


Fig. 49.

The quality of the potato is usually judged by its size, firmness, and absence of fungus disease.

A still better judgment may be formed by taking the specific gravity, and using the following tables:—Multiply the specific gravity by the factor opposite it, and divide by 1000: the result is the percentage of solids:—

Specific gravity, between	Factor.	Specific gravity, between	Factor.
1061–1068	16	1105–1109	24
1069–1074	18	1110–1114	26
1075–1082	20	1115–1119	27
1083–1104	22	1120–1129	28

If the starch alone is to be determined, deduct 7 from the factor, and proceed as before; the result is the percentage of starch.

If the specific gravity of the potato is—

Below	1068	The quality is very bad.
Between	1068–1082	,, inferior.
Between	1082–1105	,, rather poor.
Above	1105	,, good.
Above	1110	,, best.

As, however, the medical officer will seldom have an hydrometer which will give so high a specific gravity, and must work, therefore, with a common urinometer, the following plan must be adopted:—Take a sufficient quantity of water, and dissolve in it ½ an ounce or an ounce of salt, and take the specific gravity; then add another ½ ounce or ounce, and take again the specific gravity; do this two or three times, so as to get the increase of specific gravity for each addition of a known quantity of salt; then add salt enough to bring up the specific gravity to the desired amount. This is, of course, not quite accurate, but in the absence of proper instruments it is the only plan that seems feasible.

For the preservation of potatoes, sugar, in the form of molasses, is the best plan on a large scale; a cask is filled with alternate strata of molasses and peeled and sliced potatoes. On a small scale, boiling the potatoes for a few minutes will keep them for some time. Free exposure to air, turning the potatoes over and at once removing those that are bad, are useful plans.

The preserved potatoes are sliced, dried, and granulated, and when well prepared are extremely useful.

The Sweet Potato and the Yam are somewhat similar to the ordinary potato, and form good substitutes when potatoes cannot be obtained. They are very rich in salts, and are therefore excellent anti-scorbutics.

As judged by their composition, *Beetroot* and *Jerusalem artichoke* are closely allied to the potato, but as foods they are of very subsidiary importance. The relative percentage composition of these vegetable foods is shown below.

	Proteid.	Fat.	Carbo-hydrate.	Salts.	Cellu-lose.	Water.	Ratio of nitrogenous to non-nitrogenous food-stuffs.
Potatoes,	2·00	0·16	21·00	1·00	0·70	75·14	1 is to 10·6
Beetroot,	1·15	0·10	14·35	0·73	0·91	82·76	1 ,, 12·5
Jerusalem artichoke,	1·76	0·14	16·29	1·08	1·49	79·24	1 ,, 9·3

Young unripe potatoes, and also those which have been kept too long and are sprouting, contain solanine, especially in the skin and in the shoots. Ripe potatoes which have reached their full size are either very poor in solanine, or totally free from this alkaloid. There is reason to believe that the poisonous character of solanine in potatoes is largely exaggerated, and that the diseases of cattle ascribed to the consumption of solaniferous potato waste from distilleries have been partly infectious diseases and partly poisonings from ptomaines. Potatoes are further said to lose the chief part of their solanine by boiling. On keeping, there ensues in the potato a slow decrease of the starch, which passes temporarily into dextrin, and in small quantities into sugar. Kramer has recently described a bacillus, nearly allied to the *B. butyricus*, as the cause of the wet-rot in potatoes. If the spoiled parts are cut away, the remainder may be eaten without injury: the decayed part tastes and smells badly. Frozen potatoes are often destroyed by putrefaction after thawing, but before they putrefy they are not hurtful to health. Tubers bared of soil become dark coloured next the stem; their pungent taste is said to be due to solanine.

ARROWROOTS, TAPIOCA, AND SAGO.

The arrowroots are obtained from various sources. Originally, the term arrowroot was applied to the starch from the tuber or rhizome of the *Maranta arundinacea*, because that root was supposed to have the power of counteracting the effects of poisoned arrows. The term is now applied to a great variety of starches, but, strictly speaking, should be limited to those known in commerce as Canna, Curcuma, Maranta, and Tacca arrowroots. The roots of the plants are dug up when about a year old, washed, and reduced to a pulp. This is repeatedly washed, passed through coarse sieves to separate the fibres, and the starch allowed to settle, which again is washed and dried. When finished ready for exportation, arrowroot is a white, tasteless, odourless substance, firm to the feel, and producing, on pressure, a slight crackling noise. Arrowroot, being a pure starch, has no dietetic value beyond that peculiar to this substance. It is chiefly used as a bland article of food for invalids, or, in an ordinary way, as blancmange, puddings, and biscuits.

Maranta arrowroot, sometimes spoken of as Bermuda arrowroot (fig. 50), is derived from the *Maranta arundinacea*, a plant growing in Jamaica and Bermuda. It is judged by its whiteness, by its grains being aggregated into little lumps, and by the jelly being readily made, and being firm, colourless, transparent, and good tasted. The jelly remains firm for three or four days without turning thin or sour, whereas potato flour jelly in twelve hours may become thin and acescent. Under the microscope the starch grains are easily identified. They are slightly ovoid, like potato starch, but have a mark or line at the larger end (the hilum of the potato starch is at the smaller end); the concentric lines are well marked. The most common adulterations are sago, tapioca, and potato starch. All these starch grains are readily detected by the microscope.

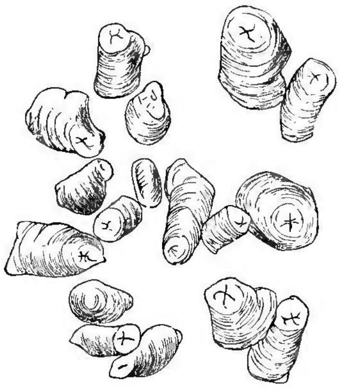


Fig. 50.

The starch grains of *St Vincent* arrowroot have the same character as those of Bermuda arrowroot, and it is almost impossible to distinguish them.

Curcuma arrowroot is furnished from the *Curcuma angustifolia*, a species of turmeric plant. Its starch grains under the microscope are large and oblong (fig. 51), marked with very distinct concentric lines, which, however, in the majority of cases, are not complete circles. The hilum is often indistinct and always at the smaller end.

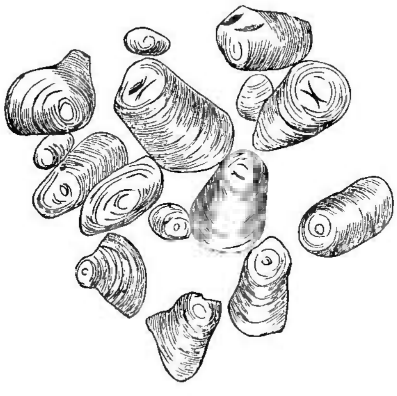


Fig. 51.

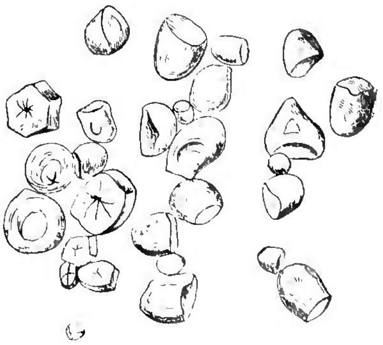


Fig. 52.

Tacca arrowroot is obtained from the *Tacca oceanica*, growing in Tahiti. Its granules are truncated, or wedge-shaped at one end. Their striation is indistinct with a more or less circular hilum. These starch grains are practically indistinguishable from those of Rio arrowroot (fig. 52) obtained from *Jatropha manihot* or *Cassava* growing in the Brazils. It is from the finest part of the pith of this plant that commercial **tapioca** is made. Tapioca is often adulterated with potato starch and sago, both of which are easily detected by the microscope.

Canna arrowroot or "Tous les Mois" (fig. 53) is furnished by the *Canna edulis*, a native of the West Indies. Its starch grains are very like those of potato, but they are much larger, flatter, and have more definite striæ. The hilum is at the smaller end of the grain.

Sago is derived from the sago palm, *Sagus farinifera*, but some inferior kinds are obtained from the *Cycas circinalis*. The starch grains are very similar to those of tapioca, but larger (fig. 54).

Granulated sago is either "common" or "pearl"; the latter is chiefly used in hospitals. The starch is soluble in cold as well as in hot water. The starch grains are elongated, rounded at the larger end, and compressed at the other; and hence their shape is quite different from the potato starch. The hilum is a point, or more often a cross, slit, or star, and is seated at the smaller end, whereas in Maranta arrowroot the hilum is at the larger end. Rings are more or less clearly seen.

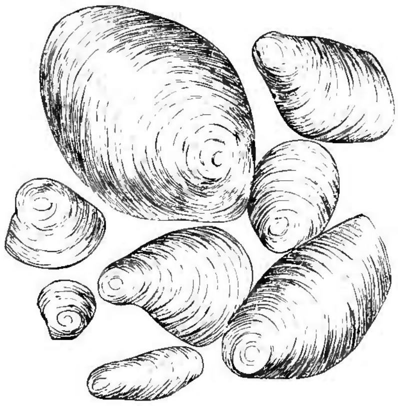


Fig. 53.

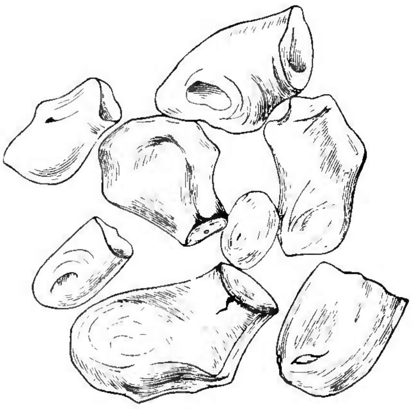


Fig. 54.

In the market is a factitious sago made of potato flour. This is sometimes coloured red or brownish, either from cochineal or sugar. In thirty specimens Hassall found five to be factitious. The microscope easily detects potato starch.

Under the name of British Arrowroot or "Farina," potato starch is sold in the market, so white and crackling, and making so good a jelly, that it is not always easy to distinguish it from *Manihot*. The microscope at once detects it. The pear-shaped grains, marked hilum towards the smaller end, and the swelling with weak liquor potassæ, render a mistake impossible. In making the jelly a much larger quantity is required than of Maranta arrowroot. *Maranta arundinacea*, mixed with twice its weight of hydrochloric acid, produces a white opaque paste, whereas potato starch treated similarly produces a transparent acid jelly-like paste.

As it is sometimes difficult to remember the characters of the different forms of starch, their microscopical differentiation may, to a certain extent, be facilitated by a tabulated arrangement such as the following:—

I. *Starches* with isolated smooth or unfacetted grains, being originally free in the cell cavity.

	General Characters.		Particular Characters.		Name.
	Form.	*Hilum.*	*Form.*	*Hilum.*	
Unfaceted.	A.—Contour ovoid. *Hilum* eccentric.	Grains large. *Hilum* at the small end.	Outline even. Continuous rings, oblique, including more than half the grain.	*Hilum* distinct.	Potato; British arrowroot.
			Outline even. Continuous rings, nearly transverse, including less than half the grain.	*Hilum* distinct.	Tous-les-Mois (*Canna*) arrowroot.
				Hilum indistinct.	*Curcuma* arrowroot.
		Grains medium sized. *Hilum* at the larger end.	Outline uneven, often with beak-like projections.	*Hilum* slit-like, triradial or crucial.	Bermuda (*Maranta*) arrowroot.
			Outline more even, beak less frequently seen.	*Hilum* similar, but less apparent.	St Vincent arrowroot.
	B.—Contour oval.	*Hilum* longitudinal, linear lateral.	Grains often broad and reniform.	*Hilum* cleft-like, puckered, irregular.	Bean starch.
			Grains narrower and more uniform.	*Hilum* less puckered and more regular.	Pea starch.
	C.—Contour round.	*Hilum* central.	Form lenticular.	Surface convex at the *hilum*. Grains large and minute only.	Wheat starch.
				Surface depressed at the *hilum*. Grains large, medium-sized, and minute.	Barley starch.
			Form spherical.	*Hilum* often deeply fissured, star-like.	Rye starch.

II. *Starches* with the grains faceted by original juxtaposition in the cell cavity. *Hilum* central.

Faceted.	A.—Often presenting the rounded free surface of grains originally superficial in the cluster.	*Hilum* often cavernous.	Grains very large, with a central sinus or cavernous antrum. (Rings, sinuous, irregular.)		Sago.
			Grains small. (Sago in miniature.)		Tapioca.
		Hilum stellate.	Grains small. (Like Tapioca without preparation.)		Rio arrowroot.
	B.—Altogether faceted.	*Hilum* stellate.	Grains small. (Discoidal with faceted margin.)		Maize.
		Hilum inconspicuous.	Grains minute.	In rounded glomeruli or compound grains, and free in the cells.	Oats.
				Closely packed in the cells and fixed.	Rice.

SUGAR.

There are two chief varieties of sugar now found in the market, namely, sugar from the sugar-cane, *Saccharum officinarum*, and beet-sugar from the *Beta vulgaris*.

Cane-sugar is either white or brown. The white cane-sugar contains, per cent., 93·33 of saccharose, 1·78 of dextrose, 0·35 of proteid, 0·30 of gum, 0·91 of so-called extractives, 0·76 of salts, and 2·16 of water. Brown sugar contains more water than the white, the amount varying from 4 per cent. in the better kinds to 10 per cent. in the coarser varieties. Its colour is due to invert sugar, of which there is 4 or 5 per cent. present.

Beet-sugar contains, in 100 parts, 94·5 of saccharose, 0·18 of invert sugar, 1·93 of water, and 3·37 of extractives, gums, and vegetable acids.

Honey differs from ordinary sugar in containing more dextrose and lævulose than saccharose. Its precise composition varies very much, but, as an average, it may be said to have, in 100 parts, 72·88 of invert sugar (lævulose 38·65, dextrose 34·23), 0·22 of dextrine, 1·76 of saccharose, 0·71 of wax, 0·76 of proteid, 2·82 of non-saccharine substances, 0·25 of ash, 0·028 of phosphoric acid, and 20·6 parts of water. Honey is often adulterated with cane-sugar, or with sugar made from starch and with inert matter (Martin). The total invert sugar may be as high as 80 per cent., or as low as 64, but the lævulose is always in greater proportion than the dextrose.

Examination of Sugar.—Sugar should be more or less white, crystalline, not evidently moist to the touch, and should dissolve entirely in water, or leave merely small fragments, which, on examination with the microscope, will often be found to be bits of cane. The whiter the sample, the less usually is the percentage of water. The unpurified sugars contain nitrogenous matters which decompose, and a sort of fermentation occurs. The sugar-mite is often found in such sugar, while fungi are very frequently present. The actual amount of sugar present in a sample may be conveniently estimated by dissolving 5 grammes in distilled water and making up to 100 c.c. Of this solution, 10 c.c. are diluted to 100 c.c. with water and from 1 to 2 c.c. of hydrochloric acid added. Boil away one-third of the volume, cool, neutralise with sodium carbonate, and then make up to original bulk of 100 c.c. Titrate some of the copper solution, as used for lactose (page 316), with this solution of inverted sugar and calculate out as a percentage of cane-sugar: each c.c. of the copper solution equalling 5 milligrammes of inverted sugar.

Saccharin.—In this place it is convenient to mention saccharin (orthobenzoic sulphinide) which has appeared in the trade as a white inodorous powder, three hundred times as sweet as cane-sugar. Pure saccharin is sparingly soluble (1 in 260) with a faint acid reaction, but lately an alkaline salt has been introduced which is more readily dissolved. Its taste is slightly aromatic, and its after-taste irritating only when the powder itself, or a concentrated solution, is tasted: dilute solutions have a purely sweet flavour. Saccharin is recommended as a substitute for cane-sugar. As 2 grains of saccharin suffice to give 1000 grains of starch sugar the same sweetening power as that of 1000 grains of cane-sugar, it is likely that substitutions of a cheaper for a more expensive material will be attempted in this direction.

The detection of saccharin may be effected by extracting the dried substance with anhydrous ether: if the evaporated residue have a sweet taste, saccharin is present, all sugars and also glycerin being insoluble in ether.

According to the experiments of all observers, saccharin is non-poisonous, even in continuously large doses; but since it has no nutritive value, its substitution for a carbo-hydrate reduces nutritive value. A substitution of pure starch-sugar, sweetened up with saccharin for an equal weight of cane-sugar, cannot be regarded, physiologically speaking, as an injury. If the use of saccharin is thus hygienically unobjectionable, a declaration of its presence should be unconditionally demanded. The antiseptic and anti-zymotic properties of saccharin have no practical value.

SUCCULENT VEGETABLES AND FRUITS.

This class of vegetable foods contains articles of diet which supply water, vegetable acids, and salts to the body. Their chief value depends upon their anti-scorbutic properties, as their absence for any lengthened period from a diet leads to the production of scurvy. To all succulent vegetables, common salt is added in cooking; and to some, butter is a valuable addition. The fruits are rich in water, vegetable acids, and salts of the organic acids: they are eminently anti-scorbutic, especially the lemon. Some, like the cocoa-nut, are rich in oil, while others, like the banana, contain large quantities of sugar. Except for their anti-scorbutic properties, and their pleasant taste, the fruits are quite subsidiary as articles of diet. The percentage composition of some ordinary vegetables and fruits is given in the following table:—

	Water.	Pro-teids.	Fat.	Starch.	Glucose.	Cellu-lose.	Salts.	Malic Acid.	Oxalic Acid.	Pectose and Gum.	Citric Acid.
Cabbage,	85·50	5·00	0·50	7·80	...	...	1·20	...	...	...	...
Carrots,	87·80	1·00	0·20	9·60	0·40	...	1·00	...	...	...	...
Cauliflower,	90·89	2·48	0·34	3·34	1·21	0·91	0·83	...	...	...	...
Celery,	93·30	1·20	...	1·60	2·20	0·90	0·80	...	...	...	...
Lettuce,	96·00	0·70	0·20	1·00	...	0·50	1·00	...	...	...	...
Spinach,	88·47	3·49	0·58	4·34	0·10	0·93	2·09	...	...	...	...
Turnips,	90·78	1·18	0·22	5·89	...	1·13	0·80	...	...	...	...
Rhubarb,	95·10	0·90	...	...	2·10	1·10	0·50	...	0·30	...	...
Apples,	83·00	0·40	...	...	6·80	3·20	0·40	1·00	...	5·20	...
Dates,	20·80	6·60	0·20	...	54·00	5·50	1·60	...	...	12·30	...
Gooseberries,	86·00	0·40	...	...	7·00	2·70	0·50	...	...	1·90	1·50
Figs,	17·50	6·10	0·90	3·00	57·50	7·30	2·30	...	...	5·40	...

Vegetables scarcely require any very critical hygienic examination: if they have become too old and woody, they are inferior in nutritive value, and are imperfectly digested: stale vegetables are equally inferior in value and far from appetising. If vegetables are watered with sewage or drainage containing the ova of the Tæniæ, the latter may find their way into man, and grow up to cysticerci: pathogenic bacteria may possibly be introduced in the same way; in fact, there is reason to believe that in this manner watercress, growing in sewage-polluted streams, has been on several occasions the source of enteric fever outbreaks.

According to Lominsky, various bacteria penetrate into the roots of young plants but do not increase there. Some pathogenic species, if inoculated into living leaves, are said not merely to maintain themselves, but even to multiply. These observations, however, require verification. De Loos has recorded a remarkable instance of lead poisoning from vegetables being grown upon soil over some disused white-lead works. He states that 650 grammes of turnips had absorbed 10 milligrammes of lead, six carrots 17 milligrammes; and four lettuces had taken up as much as 130 milligrammes of lead.

Frequently cases of poisoning arise from mistakes as to the identity of vegetable species. Thus fool's parsley (*Æthusa cynapium*) is mistaken for true parsley, water hemlock (*Cicuta virosa*) for celery, and *Œnanthe crocata* for carrot.

Dried vegetables are now produced of excellent quality, and when properly prepared taste as if fresh. They appear to present no special points for hygienic criticism.

Unripe fruit, rich in cellulose, acids, and in tannin, but poor in sugar, often occasions intestinal catarrh. The popular characteristics of ripeness should suffice for an experienced observer. For stone fruits and berries, the colour, consistence, and taste should be noted: in the case of seed fruits, such as apples and pears, it is advisable to examine whether the pips have taken a brown colour. Mouldy fruit should invariably be rejected. Dried fruits often require examining for dirt, sand, mould, and mites. In some specimens of American tinned fruit a small proportion of zinc has been detected.

Among the fruit juices, currant and cherry juice are of less interest than raspberry. The juices are attempted to be obtained from the pressed and sweetened fruits partly by boiling, and partly by fermentation. Frequently the colour suffers by unsuitable preparation or preservation, and is artificially heightened by vegetable colours, such as that from infusions of the field poppy or more commonly by means of aniline dyes. There is no objection to the use of these latter if employed in small quantities and provided they are free from arsenic and other impurities.

Mushrooms and the fungi generally, in spite of the high percentage of nitrogen in their solids, do not rank higher in nutritive value than the majority of vegetables. Like the latter, they yield an edible food only in presence of much water; their nitrogen is largely referable to worthless amido-compounds, while the utilisation of their albumin is imperfect.

There are no general characters for the recognition of edible fungi. It must be borne in mind that the virulence of many poisonous kinds varies according to the year and locality. It is obvious that of the kinds known as wholesome, only such specimens must be gathered as are fresh, not decayed or damaged by rain. All mushrooms must be carefully cleaned before use. It is not advisable to preserve portions of dishes of mushrooms which have not been consumed. The use of dried mushrooms is as far as possible to be avoided: they are seldom correctly determined, often imperfectly cleaned, dusty and perforated by insects.

PREPARED CONCENTRATED AND PRESERVED FOODS.

This is a very important subject, but one upon which considerable misconception exists, owing to a confusion of ideas between concentration and preservation. It is obvious how important it must be in time of war to have a food which may be at once nutritious, portable, easily cooked, and not liable to deterioration. In this connection, however, it must be remembered that a man must get his 260 to 300 or even 350 grains of nitrogen, and 8 to 12 ounces of carbon, in each twenty-four hours, besides some hydrogen and salts. The work of the body when in activity cannot be carried on with less; and at present these elements cannot be presented to us in a digestible form in a smaller bulk than 22 or 23 water-free ounces. Concentration at present cannot be carried beyond this, and practically has not really been carried to this point. Life, however, and vigour may for some days be preserved with a much less amount; and the total amount of food has been reduced to 11 water-free ounces daily, with full retention of strength for seven days, though the body was constantly losing weight. For expeditions of three or four days, if transport were a matter of great difficulty, soldiers might be kept on from 10 to 12 ounces of water-free food daily, provided they had been fully fed beforehand, and subsequently had time and food to make up the tissues of their own bodies, which would be expended in the time, and would not have been replaced by the insufficient food.

When we inquire into the concentrated foods now in the market, some of which profess to supply all the substances necessary for nutrition, we find many of them not very satisfactory. They are often not so concentrated as they might be, or are deficient in important principles, or are disagreeable to the taste. The truth is, we cannot so concentrate food-stuffs down to a portable or convenient size, and at the same time obtain from them the full nutritive value of the original or fresh articles. Recognising this fact, it is better to divide all the so-called concentrated and preserved foods into (1) those which are really prepared as emergency rations, aiming at supplying more or less of the daily needs of the body in a minimum bulk, and (2) those which are essentially preserved food-stuffs.

Prepared Emergency Foods or Rations.—These naturally afford the greatest interest to the soldier, sailor, hunter, and explorer, or other persons engaged upon expeditions where ordinary articles of food are difficult to obtain, and when circumstances of transport render the use of easily cooked, compact and portable substances absolutely necessary. Foods of this kind constitute the so-called "iron" or "eiserne" ration of the Germans and other armies; by which allowance is understood those aliments given to each soldier in the field for emergencies. Many different preparations have been recommended for this purpose, and among them we may include the various Erbswursts and pea-sausages, the meat powders, meat biscuits, concentrated soups, meat extracts, and different compound rations made up of two or more preserved food-stuffs.

The original Erbswurst of the Germans was a sausage of pease with bacon fat. Numerous preparations of this kind are now in the market; they consist in the main of powdered pease with bacon or beef fat and condiments, the whole being enclosed in a waterproof cover, and then issued as a sausage or packet. Some few also contain powdered beef. The nutritive value of the several kinds is given in the table which follows. Erbswurst soon becomes distasteful, causing digestive derangements from its excess of fat; it at the same time lacks the sustaining qualities of fresh meat.

The pea-soup tablets of Neumann are made of meat juice with pea flour. Their relatively high amount of salts is said to be due to sodium chloride. It would be necessary to take 21 ounces of this preparation to get the proper quantity of proteid, yet with that one would obtain only 0·6 ounce of fat, which is absolutely insufficient. A similar defect is present in the pease and haricot cakes of Schorke, and the meat cakes of König of Mayence.

Rumford's ration contains pieces of meat with flour, pearl barley, and salt. Like Schorke's preparations, it does not constitute a complete aliment. Edward's desiccated soup was well spoken of in our own army during several campaigns. It consists of a mixture of beef and vegetables, and is easily prepared by boiling an ounce in a pint of water.

Allusion may here be made to "panole," which is a preparation made of ground parched Indian corn 3 parts, and sugar 1 part. It has been largely used in the expeditions on the south-west frontier of the United States, and has a high reputation in the American army.

An English and at the same time a very good preparation is Morel's field ration, sold as a sausage, weighing 18 ounces. Equally good articles are Moir's sausage and Corbin's pea and lentil pastes. In all this class of prepared or emergency rations, we find a marked excess of fats and carbohydrates. The salts are variable, though in all cases much in excess of the meat quantities. Although these preparations yield the alimentary elements of a complete food, yet they are in such proportion as only to serve as food for a limited time. Further, in most of them the albumin is vegetable, being derived from peas and beans. It is true the chemical values of animal and vegetable albumin are the same, yet experience shows the former to be very much more easily and completely assimilable than the latter.

Another class of preparations are the various meat cakes and meat biscuits; in them the proteids are mainly derived from animal sources and not from the legumes. The meat is dried and finely powdered, and represents in nutritive value about four times its weight of ordinary meat with bone. In England, the chief meat powder is Johnson's, which makes an excellent soup. In Germany, Hoffmann's meat powder is well spoken of, especially when made up into different kinds of cake or biscuit, with either beans, rice, barley meal, wheat flour, or potatoes. In 100 parts this meat powder contains 73 of albumin, 7 of salts, 10 of water, and 1 of hydrochloric acid. Hoffmann's meat cakes are agreeable, portable, and very easily cooked. If consumed for many days together, the digestion becomes disturbed and the appetite fails. Taken with biscuits, they have been largely used and tried in the United States army, but not received with sufficient favour to warrant their regular issue. Erdmann's meat powder is similar to other preparations of this kind.

The majority of meat biscuits now in the market are as a rule nothing more than meat powders mixed with flour and water. Owing to the extreme heat to which they are exposed in baking, the meat in them is usually rendered valueless. A large number of them, from time to time, have come under notice at Netley, but the greater number have failed to present any very distinctive points of merit. The French speak highly of a meat cake prepared by Scherer-Kestner who, by the admixture of pepsin, really obtains the formation of a digestible biscuit. Analogous to this of Kestner's, there exists in Germany a biscuit made by Schill, in which the water is replaced by defibrinated blood. According to Heidlesheim and Voit, this contains 26 per cent. of proteid and only 2·5 per cent. of fats; but beyond being highly assimilable, it is not of much use as a prepared food. Another food is "Courousa" made by Jacquier of Nantes, and which has been tried in the Russian army. Each ration of it weighs 12·75 ounces, and is supposed to contain elements for a day's nourishment. Experience shows its qualities to be indifferent. The Russian Government prepares and issues to its troops a variety of prepared foods or rations similar to the meat cakes of Hoffmann, already noticed. They consist mainly of finely powdered meat mixed with barley or peas, or oat-meal, or cabbage, or potatoes and mushrooms. Their use in the Russian army is highly extolled, being issued in daily rations of 25 ounces. They are, however, admitted to be difficult of digestion and probably very unsuited for Western nations. A special preparation, made by Grouvel of Paris, was largely tried by the French War Office a few years ago; 11 ounces being said to afford a day's aliment. Its composition was roughly 20 parts of beef, 48 parts of pea-flour, 20 parts of fat, and 12 parts of condiment. Although it appeared to be considerably superior to the Erbswursts and German pea-sausage, its general utility was not manifest.

The concentrated soups and meat extracts date from the introduction of Liebig's well-known preparation. Numerous articles of this kind are now in the market, notably those of Brand, Kemmerich, and others, which exist chiefly in the form of fluid meats, essences, extracts, &c. These, from their composition, are not capable of replacing a true alimentary substance, nor even are they the representation of the least quantity of meat, either roast or boiled. They are merely the juices of meat, not the meat itself. An extraordinary large number of these meat extracts are now in the market, but it is only too probable that many of them are not true meat extracts, but artificial substitutes. A good meat extract should have less than 20 per cent. of water: it should contain almost 25 per cent. of its weight of mineral meat salts, one quarter of which should be phosphoric acid in combination with potash, not with lime: it should, when dissolved in warm water, yield but an insignificant precipitate on the addition of double the amount of alcohol: it should be solid or nearly so, free from all excrementitious odour and from a burnt flavour. Experiments indicate that diets composed exclusively of meat extracts kill animals more quickly than total deprivation of food: these preparations are not, however, quite without alimentary value. They act as stimulants, food regulators, and digestive agents, rather than as providers of nitrogenous matter. It would be a fatal mistake to use these extracts, deluded by their portability, and with the idea that they in small compass contained considerable reparative materials: they are essentially alimentary aids and not true foods. If used solely in that sense, they can be turned to very good account as stimulants during and after very great exertion. A number of condensed soups are now made mixed with vegetables; these, if used with biscuits or bread, constitute articles of considerable value for use in times of emergency, and when the more ordinary aliments are not available.

Of all the prepared foods, the army rations made by Moir, Maconochie, and other makers appear best to conform to the ideal type of an emergent ration. They exist in several varieties, consisting of mixtures of either beef or mutton with potatoes, carrots, onions, beans, gravy, and pickles. Some also contain bacon fat and brawn, the whole being cooked and contained in hermetically sealed tins of small size, and may be eaten either cold or warmed up. In a sample recently examined by us, were found 7·2 ounces beef and fat, exclusive of bone, 6·7 ounces of mixed vegetables, and 6·1 ounces of gravy, or 20 ounces of fresh and wholesome food. In another tin, were found 9·2 ounces of mutton, without bone, 6·8 ounces of vegetables, and 3 ounces of gravy, or 19 ounces of fresh and palatable food-substances, presenting all the qualities of fresh meat and fresh vegetables. In some other examples of these prepared foods, cocoa constitutes one of the elements, being placed in a separate section of the tin.

The accompanying table gives the percentage composition of some of the prepared foods just considered; but it must be borne in mind, when judging the merits or demerits of this class of aliment, that not only must their nutritive value be taken into account, but also their portability, durability, palatableness, and readiness for cooking. On the whole, it must be confessed that this question of preparing emergent foods has not been yet satisfactorily solved; much remains still to be accomplished.

Percentage Composition of some Preserved and Prepared Foods.

	Water.	Total Proteids.	Indigestible Proteids.	Digestible Proteids.	Peptones.	Meat Extract.	Fat.	Carbo-hydrates.	Salts.
Erbswurst (German),	7·03	21·00	4·12	8·14	4·37	4·37	22·20	45·76	4·00
,, (Knorr's),	10·86	17·50	2·62	9·64	2·62	2·62	23·96	35·74	11·94
,, (Moir's), .	8·51	15·75	3·50	9·62	2·19	0·44	23·38	47·91	4·44
Pease sausage (Moir's),	11·40	21·00	4·75	9·26	5·68	1·31	32·30	27·40	7·90
Hoffmann's meat cake,	6·45	24·24	...	...	...	...	24·76	39·73	4·82
Neumann's pease cake,	9·51	20·53	...	...	...	...	3·66	53·10	13·20
Schorke's bean cake,	7·98	16·72	...	...	...	...	17·20	42·10	16·00
Rumford's soup cake,	13·40	16·20	...	...	...	...	1·80	56·30	12·30
König's meat biscuit,	5·10	8·30	...	...	...	...	6·10	76·70	3·80
Schill's ,,	14·50	24·70	...	...	...	...	2·50	56·70	1·60
Dunmore's ,,	11·89	10·81	...	...	...	...	8·06	67·94	1·30
Armebis ,, .	8·51	15·75	...	...	...	...	15·80	58·04	1·90
Cheese biscuits (Dunmore's),	11·35	11·37	...	...	...	...	15·84	59·63	1·80
Emergency ration (Woolwich),	6·94	8·00	...	...	...	...	18·11	65·58	1·37
Grouvel's army ration,	14·71	30·57	...	...	...	..	18·77	31·45	4·50
Moir's soldier's ration,	53·91	23·44	2·62	10·16	2·43	8·23	14·72	6·12	1·80
Morel's field ration,	27·45	32·94	...	...	...	...	23·60	10·54	5·47
Pemmican (Australian),	2·39	51·70	3·64	41·86	5·46	0·74	42·08	...	3·65
Maconochie's service ration,	76·59	9·72	...	...	...	...	5·48	5·88	2·33
Courousa,	21·03	24·10	...	...	...	...	21·22	27·35	6·30
Panole, . .	7·83	7·50	...	...	...	...	4·50	72·67	7·50
Meat extract (Queensland),	16·31	57·61	..	6·44	2·59	48·58	2·25	...	22·21
Concentrated beef-tea (Mason's),	47·74	47·78	0·22	20·15	10·00	17·41	...	...	5·38
Essence of mutton ,,	90·23	9·33	0·11	2·08	1·31	5·83	...	...	1·15
Meat extract (Armour Co.),	19·44	47·00	...	7·00	3·06	36·94	1·62	...	29·00
Johnston's fluid beef, .	38·93	45·90	10·01	7·00	4·37	24·51	1·64	...	13·53
Beef extract (Armour Co.),	15·22	55·77	2·67	6·95	3·50	42·65	2·17	...	26·80
Pea-soup (Lazenby),	14·16	22·75	4·37	10·50	3·50	4·37	1·60	53·58	7·90
Meat peptone (Koch), .	40·60	49·69	1·45	17·50	12·78	17·96	2·87	...	6·84
,, ,, (Kemmerich),	38·29	50·26	1·05	14·26	17·85	17·10	...	2·54	8·90
Bovril lozenges,	18·30	61·20	3·02	27·38	13·76	17·04	0·78	10·93	8·78
Bovinine (Bush's), .	81·44	16·16	...	9·48	1·29	5·39	0·18	1·45	0·77
Corned beef (M'Neill's), .	59·16	24·92	...	...	...	...	12·59	...	3·32
Compressed beef (Queensland),	61·28	31·05	...	...	...	...	5·83	...	1·83
Kreochyle Co.'s liquid meat,	81·22	15·37	4·45	3·70	0·81	6·35	1·22	...	2·19
Liebig's extract,	19·33	46·48	0·84	7·64	2·95	35·05	1·92	...	32·26

Preserved Foods.—Speaking generally, the methods employed to preserve food-stuffs are based upon one or more of the following plans:—1. Freezing or refrigerating. 2. Salting, and the use of various chemical agents. 3. Drying. 4. The exclusion of air, and hermetically sealing in tin cases.

The employment of freezing and refrigerating is now extensively applied to the preservation of meat during long voyages from the Colonies and South America, the carcasses reaching this country in excellent condition; but the method is hardly applicable for the preservation of meat in the sense in which meat is understood to be preserved in this section.

Salting of meat is a well-known form of preserving. Owing to the great loss of the nutritive qualities, which meat suffers in the process, the use of salted meat to any extent is not to be recommended. Besides salt, all kinds of chemical agents have been tried as food preservers, more particularly boracic and salicylic acids, together with coatings of fat, glucose, and gelatin.

Meat is also preserved in tin cases, either simply by the complete exclusion of air (Appert's process) or by partly excluding air and destroying the oxygen of the remaining part by sodium sulphite (M'Call's process). It is not necessary to raise the heat so high in this case, but the meat is less sapid. Meat prepared in either way has, it is said, given rise to diarrhœa, but this is simply from bad preparation: when well manufactured it has not this effect.

Meat is also preserved by drawing off the air from the case, and substituting nitrogen and a little sulphur dioxide (Jones and Trevithick's patent), or the air can be heated to 400° or 500°, so as to kill all germs (Pasteur), and then allowed to flow into an exhausted flask.

Various other plans have been proposed, such as the use of antiseptics, borax, boric acid, salicylic acid, glycerin, &c., and various preparations such as glacialin, boro-glyceride, and the like, consisting of mixtures of two or more. Of these preparations, boric acid and glycerin appear to be the least hurtful; but food to which these substances have been added is liable to cause gastric derangement, and they are not to be recommended.

To dried food, its unattractive appearance and insipidity afford many objections. In this category we may consider such forms of dried meat as the *tassajos* and *charqui* of South America, the *biltong* of the Kaffirs, the *kelea* of the Arabs, and the *dauer fleisch* of the Germans.

Dried Cerealia.—Many flours, if well dried, will keep for a long time. There are now in the market different kinds of malt biscuit and granulated malt food. Liebig's food for infants is composed of equal parts of wheaten flour and malt flour mixed with a little potassium carbonate and cooked with 10 parts of milk. The wheat and malt flour are usually cooked and sold in powder ready to be boiled with the milk.

Dried Bread.—In addition to biscuit already described, bread has been partially dried by being pressed in an hydraulic press (Laignel's method). Much water flows out, but when taken out the bread still feels moist. In a day or two, however, it becomes as hard as a stone, and in a year's time will be found good and agreeable. Placed in water, it slowly swells. The "pain biscuité" of the French army is bread dried by heat.

Dried Potatoes are sold in two forms—sliced and granulated. In either case the potato is easily cooked, and is very palatable. It should be soaked in cold water first for some time, then slowly boiled, or, what is much better, steamed. The directions for cooking Edward's preserved potato (which is granulated) are: "To three-quarters of a pound add about one quart of boiling water, stirring it at the same time; cover it closely; the basin or vessel used should be kept hot; let it stand for ten minutes; then well mash, adding butter, salt, &c., at discretion." It is stated to be equal to six times its bulk of the fresh vegetable, but this is hardly borne out by analysis: four times is as high as it would be safe to allow. The analysis shows that a pound of preserved potato contains the solid matter of only 3½ pounds of ordinary fresh potatoes.

Dried Vegetables (*other than Potatoes*).—Dried and compressed vegetables of all kinds (peas, cauliflowers, carrots, &c.) are now prepared, especially by Messrs Masson and Challot, so perfectly that, if properly cooked, they furnish a dish almost equal to fresh vegetables. Analysis shows that dried compressed cabbage contains the solids of *seven* times its weight of fresh cabbage, whilst the mixed vegetables contain *five and a half* times the solids of the fresh vegetables. They must be cooked very slowly. If there is any disagreeable taste from commencing putrefaction, which is very rare, a little chloride of lime removes it at once. Potassium permanganate can be also used for this purpose.

As anti-scorbutics, dried are said to be inferior to fresh vegetables, but are still much better than nothing.

Dried Apples in slices are now imported largely from America: they are palatable when cooked, and would be a useful article in the field.

Dried Milk is also met with in the form of a powder, but is less preferable to preserved milk sold in the liquid form, as during the process of manufacture very considerable loss of casein takes place.

Dried Eggs.—The yolk is not easily kept after drying, but the white can be so; it is cut into thin scales, and forty-four eggs make about one pound. The yolk and white are also mixed with flour, ground rice, &c., and are then dried.

The tinned foods stand out pre-eminently as the best of all kinds of preserved food. Not only meats, but nearly every variety of aliment has been and can be preserved by means of hermetically sealing. The potted and preserved meats, such as the Chicago and Australian kinds, speak for themselves. From analysis, their nutritive qualities appear to be nearly identical with fresh meat, while the absence of bone renders them, weight for weight, of increased value, to say nothing of their compactness, durability, and portability. Their saltish taste renders their prolonged use distasteful, but a greater employment of pickles and condiments will in great measure meet this defect.

Among this class of preparations, *Pemmican* deserves to take a high place. It has been extensively used in Arctic voyages, and is made of the best beef and fat rolled and dried together: sugar, with raisins and currants, are sometimes added to it, and with these latter it is of undoubted high anti-scorbutic value. Its analysis shows that, in itself, it offers all the elements of a true food. In regard to other organic products, the processes of preservation by tinning have reached considerable perfection, notably in the case of milk, fruit, and vegetables.

Concentrated Milk.—Milk is evaporated at low steam heat to the consistence of a thick syrup, and white sugar is added. After opening the tins the samples remain good for over a month. The amount of sugar, however, is very large; in one sample it was found to be as much as 16·7 lactose and 60·7 cane-sugar. Other samples, such as the Swiss and Bavarian (Lœflund's), are preserved without extra sugar, and are reduced in bulk to a half or a quarter of the original: these, however, must be used as soon as possible after the tin is opened, for they do not keep like the sweetened preparations. The general composition and nutritive value of some of these preserved milks has been already mentioned.

Preserved Fruits and *Vegetables*, that is, those preserved in tins in their natural condition, are much to be preferred, both as being more palatable, and as being more nutritious, and better anti-scorbutics than the dried varieties. They occupy, however, much greater bulk, and are liable to be contaminated by metallic poisons (copper, lead, tin, zinc) from a solution of these metals by acids formed during fermentation or preservation. Green vegetables, especially beans and peas, when preserved in tins, are frequently coloured by sulphate of copper. The amount found varies from none to as much as 3 grains per tin. This addition is quite unnecessary, as the public would soon become accustomed to yellowish or pale green vegetables, provided they were assured that such colours were the natural result of preservation processes.

How far various preservative and colouring chemical agents should be allowed to be added to foods, and to what extent, when so added, they influence health, has been a matter of some discussion. Practically, boracic acid, sulphurous acid, and salicylic acid are the only chemical preservative, and salts of copper the only colouring agents in general use: and although we are unable to fix any precise quantity, or any exact limit of time at which these several substances act harmfully, we are justified in demanding at least:—1. That the kind and quantity of the preservative or colouring agent added be always stated on the label. 2. That milk and other articles specially used by children should not contain any preservative addition whatever. 3. That the minimum quantity of the agent required for the preservation or colouring of the fresh article should not be exceeded.

Even admitting that preservative and colouring agents are relatively harmless, their general use should be discouraged, as they facilitate an uncleanly and slovenly treatment of food, rendering it possible to preserve articles of diet, often in incipient decomposition, for some time with an appearance of freshness which is altogether false, besides favouring trade frauds and possible dangers to health.

BIBLIOGRAPHY AND REFERENCES.

ADAMETZ, "Die Bakterien normaler und abnormaler Milch," *Centralblatt f. Bakter.*, viii. p. 109. ARUSTAMOFF, "On the Presence of Pathogenic Bacteria in Sturgeons," *Centralblatt f. Bakter.*, x. p. 114.

BAGINSKY, "Zur biologie der normaler Milchkothbacterien," *Zeit. f. phys. Chemie*, Bd. xii. p. 443. BEAUMONT, *Experiments and Observations on the Gastric Juice and the Phys. of Digestion*, Edin., 1838. BELL, Sir J., *Analyses and Adulterations of Foods*, Lond., 1883. BLYTH, *Foods, Composition and Analyses*, Lond., 1882; also *The Chemistry of Foods*, 2 vols., Lond., 1889. BUNGE, *Physiol. and Patholog. Chemistry*, trans. by Wooldridge, Lond., 1890.

CHURCH, *Food, its Sources, Constituents, and Uses*, Lond., 1882; also *Food Grains of India*, Lond., 1886. CREIGHTON, *Bovine Tuberculosis in Man*, Lond., 1881.

DANILEWSKI, Pflüger's *Archiv*, xxxvi., 1885, p. 237. DE CHAUMONT, "The Soldier's Ration," *Sanitary Record*, Feb. 5th, 1876. DE LOOS, "On the Production of Plumbism by Vegetables," *Jahresberichte für Pharmakologie*, 1877, p. 536. DRECHSEL, "Eiweisskörper," in Ladenburg's *Handwörterbuch der Chemie*; also *Journ. f. praktische Chemie*, N.F. xix., 1879. DUCLAUX, *Le Lait*, Paris, 1887. DUFOUR and CONSTANTIN, *Nouvelle flore des Champignons*, Paris, 1891.

FISCHER, *Handbuch der Kohlenhydrate*, Berlin, 1891; also various papers in *Berichte der Chem. Gesellsch.*, xxvi. p. 2400. FLEISCHMANN, Article "Milch," in Dammer's *Lexikon der Verfälschungen*. FÖRSTER, Article "Ernährung," in Ziemssen's *Handbuch der Hygiene*, 1882. FRANKLAND, *Phil. Mag.*, Sept. 1866, vol. xxxii. p. 182.

GAMGEE, *Physiological Chemistry*, Lond., 1893. GRAHAM, *Chemistry of Breadmaking*, Lond., 1880. GRAY, "Report on Two Cases of Fatal Poisoning of Children apparently due to the Milk Supply," *Practitioner*, Jan. 1894.

HAMMARSTEN, *Zeitsch. f. Phys. Chemie*, Bd. xix. p. 19. HARVEY, *Report to Local Govern. Board on Fever at Swanage in* 1886, *apparently due to watered Milk*. HASSALL, *Food, its Adulterations, and the Methods for their Detection*, Lond., 1876. HEHNER and ANGELL, *Butter, its Analysis and Adulterations*, Lond., 1877.

JAGO, *The Science and Art of Breadmaking*, Lond., 1895. JESSEN and LEHMANN, "Uber Saccharin," *Archiv. f. Hyg.*, x. p. 61. JOHNE, *Der Trichinenschauer*, Berlin, 1889.

KASTNER, "On Tuberculous Meat," *Münch. Medicin Wochenschr.*, May 17, 1893. KAYSER, "Etudes sur la fermentation lactique," *Ann. de l'Institut Pasteur*, No.

vi., 1894. Knieriem, "Uber die Verwerthung der Cellulose im thierischen Organismus," *Zeit. f. Biol.*, xxi. p. 67. Koch, A., "Vergleichende bakteriologische Untersuchungen über die Haltbarkeit der Norweger und Nordsee-Schellfische," *Mittheil. der Sektion f. Küsten u. Hochseefischerei*, No. 8, August 1894. König, *Procent Zusammensetzung der menschl. Nahrungs-Mittel.*, Berlin, 1888; also *Chemie der menschlichen Nahrungs und Genussmittel*, Berlin, 1882; also Article "Mehle," in Dammer's *Lexikon der Verfälschungen.* Kossel, *Untersuch. über die Nucleine*, Strassburg, 1881; also papers in *Zeitschrift f. physiolog. Chemie*, vol. vi. p. 422, and vol. vii. p. 7, 1882.

Landois and Stirling, *Human Physiology*, 3rd Edit., Lond., 1888. Lawes and Gilbert, "On the Sources of the Fat in the Animal Body," *Phil. Mag.*, 1866. Leffmann and Beam, *Analysis of Milk and Milk Products*, Philadelphia, 1893. Lehmann, *Methods of Practical Hygiene*, trans. by Crookes, Lond., 1893. Leichmann, "Uber die freiwillige Säuerung der Milch," *Milch Zeitung*, 1894, No. 33, pp. 523–525. Lescœur, "The Detection of Watered Milk by the Examination of the Milk Serum," *Analyst*, Sept. 1895, p. 200. Levy, *Traité d'Hygiene*, Paris, 1879. Lominsky, "On the Presence of Bacteria in Plants," *Centr. f. Bakt.*, viii. p. 325.

Macfarlane, "On the Fluctuating Composition of Cow's Milk," *Deutsch. Molkerei Zeitung*, 1891, p. 5. Martin, Article on "Food," in Stevenson and Murphy's *Treatise on Hygiene*, Lond., 1892. Meinert, *Armée u. Volks Ernährung*, Berlin, 1880; also *Massen-Ernährung*, Berlin, 1885. Mott, *Effects of Alum on the Human System when used in Baking Powders*, New York, 1880. Munk and Uffelmann, *Die Ernährung des Gesunden und Kranken Menschen*, Vienna and Leipzig, 2nd Ed., 1891.

Noorden, *Pathologie des Stoffwechsels*, Berlin, 1892.

Oliver, "The Diet of Toil," *Lancet*, 1895, i. p. 1629.

Paton, "Physiology of the Carbohydrates," *Edin. Med. Journ.*, Dec. 1894. Pavy, *Treatise on Food and Dietetics*, Lond., 1875; also *Physiology of the Carbohydrates*, Lond., 1894. Pfeiffer, *Die Analyse der Milch*, Wiesbaden, 1887. Playfair, *On the Food of Man in Relation to his Useful Work*, Lond., 1865. Polit and Labit, *Etude sur les Empoisonnements Alimentaires*, Paris, 1890. Prausnitz, "On the Absorbability of Milk," *Zeitschrift f. Biol.*, vol. xxv., 1889, p. 533.

Ralfe, *An Enquiry into the general Pathology of Scurvy*, London, 1877. Ranke, *Physiologie des Menschen*, Berlin, 1868. Rechenberg, *Journ. f. prakt. Chem.*, N.F. xxii., 1880, pp. 1 and 223. "Report on the Milk Supply of London," *Brit. Med. Journ.*, 1895, vol. ii. pp. 41, 159, 230, and 321. *Report of Committee on Scurvy in the Arctic Expedition of* 1875–76, Lond., 1877. Richet, *Du Suc Gastrique chez l'homme et les animaux*, Paris, 1878. Roth, "Uber das Vorkommen von Tuberkelbacillen in der Butter," *Korrespondenz-blatt f. Schweizer Aerzte*, 1894, No. 17, p. 521. Rubner, Various papers on the "Digestibility of Proteids," in *Zeitsch. f. Biologie*, more particularly in xv. p. 115, xvi. p. 119, xix. p. 45, and xxi. pp. 250 and 337; also *Lehrbuch der Hygiene*, Leipzig, 1889.

Senckpiehl, *Uber Massener Krankung nach Fleischgenuss, namentlich durch Wurst und Fischgift*, Dissertation, Berlin, 1887. Simpson, "On the Spread of Cholera by Milk," *Practitioner*, 1887. Smith, *Annual Report to Privy Council*, 1863–4. Spooner, "Dietary Scales in connection with the Health of Seamen," *Transac. 7th Internat. Congr. of Hygiene*, Lond., 1891, Section viii. p. 41. Stiles and Hassall, *A Revision of the Adult Cestodes of Cattle, Sheep, and allied Animals*, U. S. Department of Agriculture, Bureau of Animal Industry, No. 4, Washington, 1893. Stohmann, *Journ. f. prakt. Chemie*, N.F. xix. p. 236, 1879; also in *Landwirthschaftl. Jahrb.*, 1884, pp. 531–581. Stone, "On the Carbohydrates," *Chemical News*, Aug. 31, Sept. 7 and 21, 1894. Strumpell, "Digestibility of Proteids," *Deutsch. Archiv. f. Klin. Med.*, 1876, vol. xvii. p. 108. Stutzer, "On Meat Extracts," *Analyst*, 1885.

Tiemann, *Comptes Rendus*, cxvii., Sept. 25th, 1893. Tollens, *Handbuch der Kohlenhydrate*, Breslau, 1888; also various papers in *Berichte der Chem. Gesellsch.*, especially xxvi. p. 1799.

Uffelmann, "Uber den Eiweissgehalt und die Verdaulichkeit der Essbaren Pilze," *Archiv. d. Hygiene*, vi.; also *Das Brot und dessen diätetischer Werth*, Berlin, 1884.

VALLIN, "Rapport sur l'Emploi de l'Acide Salicylique," *Bulletin de l'Academie*, 1887. VOGEL, Article "Milch," in the *Vereinbarungen der Bayer Chemiker*, Berlin, 1885. VOIT, VON, *Physiologie des allgemeinen Stoffwechsels und der Ernährung*, vol. vi. of Hermann's *Handbuch der Physiologie*, Leipzig, 1881; also "Die Verköstigung der Gefangenen in dem Arbeitshause Rebdorf," *Münch. Med. Wochenschrift*, 1886, Nos. 1 to 4.

WALLEY, *Practical Guide to Meat Inspection*, Lond., 1890. WEISKE, "On the Digestibility of Cellulose," *Zeitsch. f. Biol.*, vol. vi., 1870, p. 456. WELPLY, "Creameries and Infectious Diseases," *Lancet*, April 21, 1894. WILCKENS, "Uber die Vertheilung der Bakterien in Milch durch die Wirkung des Centrifugierens," *Oesterr. Molkereizeitung*, 1894, No. 14. WILEY, *Foods and Food Adulterants*, Washington Government Printing Office, 1892. WILLIAMS, *Chemistry of Cooking*, Lond., 1892. WOLLNY, "On the Reichert-Meissl Method of Butter Analysis," *Analyst*, Nov. 1887. WYLDE, *The Inspection of Meat*, London, 1890.

CHAPTER V

BEVERAGES AND CONDIMENTS.

Almost as important to civilised man as the food-stuffs, which are absolutely necessary for existence, are substances which enable food to be taken with pleasure or relish: such substances have been appropriately called food accessories. The Germans call them "means of enjoyment," as distinguished from the true foods or "means of nourishment." They include substances varying from the simplest aromatic principles, such as one smells when meat is cooking, or condiments and spices, to the more complex alcoholic and non-alcoholic drinks which so largely enter into the daily dietaries of both civilised and uncivilised peoples. The general action of the food accessories seems to be to stimulate digestion, either directly by affecting the digestive organs, or indirectly through the central nervous system. The condiments are mainly added to food as flavouring agents; they include such articles as mustard, pepper, onions, cloves, nutmeg, cinnamon, salt, and vinegar. Excepting the two last, all these owe their value as food accessories to aromatic oils which they contain. These essential oils are all stimulants directly of the muscular movements of the digestive organs and of the secretion of their juices; but if taken in excess, easily induce gastric catarrh and exhaustion of the mucous lining of the stomach. The influence of common salt has already been discussed.

The food accessories taken in as beverages may be divided into three groups:—(1) The liquids containing alcohol, such as beer, wine, &c.; (2) the liquids containing the active principles caffeine or theobromine, such as tea, coffee, Paraguay tea, cocoa, &c.; (3) the liquids containing large quantities of the organic acids and their salts, such as lime or lemon juice and vinegar. The alcoholic beverages owe their action as food accessories chiefly to the ethylic alcohol they contain; and the effect of the different alcoholic drinks is, broadly speaking, proportional to the amount of alcohol present in them, but not entirely so, since many of them owe part of their effect to the action of certain aromatic substances and other principles. For these reasons, therefore, the presence of these other principles must be considered as well as the alcohol in deciding the utility or otherwise of any given alcoholic drink.

For the sake of convenience, and also according to the amount of alcohol they contain, the alcoholic beverages may be divided into beers, light wines, sweet wines, and spirits.

BEER.

The usual definition of beer was, that it is a fermented infusion of malt flavoured with hops. This, however, is not quite correct, at the present day, as sugar largely takes the place of malt, and other vegetable bitters that of hops; so that probably a more accurate definition would be, to call it a fermented saccharine infusion to which has been added any wholesome bitter. Formerly the substitution of quassia, gentian, calumba, or any other bitter in place of hops was illegal, but now it is not the case, with the result that all kinds of bitters may be used, provided they are wholesome. As a matter of fact, however, in the best beers even now, the only bitter used is hops.

Modern beers may be divided into two great groups, namely, the non-malt beers and the malt beers. What are called non-malt beers are those made by a yeast fermentation of an infusion of sugar, mainly derived from starch chemically or artificially converted, as by the action of sulphuric acid. Malt beers are the result of a similar yeast fermentation of an infusion of sugar, only in this case the sugar is derived from the natural conversion of grain starch by means of germination or malting. In both instances, the resulting liquor is an alcoholic one in which a portion of the alcohol becomes transformed into aldehyde and subsequently by a further oxidation changed into acetic acid.

The actual preparation of malt and the subsequent brewing of beer is practically as follows. The maltster first soaks his barley in a cistern for some fifty hours: he then transfers it to the "couch" and twenty-four hours later spreads it out on floors in a malting. Here he leaves it for ten or fourteen days, during which time germination takes place and the grain sprouts. After this sprouting has taken place sufficiently, all germination action is arrested by drying the grain over a kiln. It is now malt, and if tasted is distinctly sweet, owing to the conversion of the grain starch into sugar by the action of the diastase ferment. After the dried malt has been sifted or screened so as to break off all the sproutings, it passes into the hands of the brewer, who, after crushing it, places it in his mash tub with water warmed to about 160° F. This water completes the transformation of the starch into grape-sugar and dissolves it, causing the resulting liquor, or *wort* as it is called, to have a decidedly sweet taste.

In the case of a brewer using chemically converted starch (saccharum) or a mixture of it with malt, a similar treatment with warm water would be followed by the production of a sweet liquor or wort. When the conversion of the starch into sugar is sufficiently complete, all chance of further conversion is stopped by boiling the wort, which also acts in coagulating the albumin which the water has dissolved out of the grain; advantage is also taken of the boiling to add hops which aid further in clearing the wort by coagulating the remaining albuminous matters, besides imparting to it their characteristic bitterness. Both the length of the boiling and the quantity of hops added vary, according to the richness of the wort in sugar, and with the quality of beer it is intended to make.

The next step in brewing is to run off the boiled liquid into shallow vessels, in which they are cooled to the best temperature for fermentation. If "top" yeast is intended to be used, this temperature is 60° F., but if what is called "bottom" or sedimentary yeast, as used in Bavaria, a much lower temperature is preferable. When at the required heat, the liquid is run into the fermenting tun and a sufficient quantity of yeast is added. It is usual to use a yeast obtained from a kind of beer different from that which it is proposed to make; the whole is allowed to ferment slowly for six or eight days. During this time, the sugar splits up into alcohol which remains in the beer, and into carbonic acid gas which, for the most part, escapes into the air. The most essential points in brewing are the facts that the quantity of yeast to be added and the temperature at which fermentation is allowed to take place, vary with different kinds of beer; also that yeast works better when transferred from one kind of beer to another; and that the fermentation must be so regulated that the whole of the sugar contained in the wort is not transformed into alcohol, as if it is all so transformed the beer has no keeping power; that is, it would turn sour in the casks. This turning sour is due mainly to the passage of the alcohol into aldehyde and the subsequent oxidation of this into acetic acid.

There are many varieties of ales and beers, the chief being: *Pale* and *Mild Ales*, made from the finest dried malt and the best hops; the mild ale is usually sweeter, stronger, and less bitter than the pale. *Porter* is nothing more than a weak mild ale, coloured and flavoured with roasted malt. *Stout* is a richer and stronger kind of porter. The *German Beers* are fermented by means of sedimentary yeast as distinguished from the surface yeast used in England. Their fermentation is carried on at a lower temperature than in the case of British beers. They contain also less alcohol than the English, but are richer in carbonic acid gas, and keep better. *Lager* and *Bock* beer is made from a stronger wort, and is proportionately richer in alcohol and malt extract. The *Belgian beers* are made with unmalted wheat and barley; they take long periods to ferment, doing so spontaneously, no yeast being added; as a rule, they are hard from the presence of much acid. *Bottled beers* are all bottled while fermentation is going on, and owe their sparkling and frothing to the excess of carbonic acid in them. German *White beer* is an acidulous beverage chiefly obtained from barley and wheat malt by rapid top fermentation, the properties of which differ much at different places. It is mostly sold in bottles. When required in bottles in a briskly effervescing state and clear, an addition of an enlivening material is necessary in the form of cane-sugar. Only by this means can a productive secondary fermentation be kept up in the bottles, as the main fermentation almost entirely consumes the fermentable material. The *Vienna beers*, like the German lighter beers, are remarkable for producing neither intoxication nor drowsiness, due principally to the small quantity of alcohol they contain.

The German or Bavarian process of brewing differs in several important points from that practised in England, and we may refer to these points for an explanation of the qualities—especially in regard to flavour, alcoholic strength, and the quantity of malt and hop extractives which sharply distinguish German from English beers. Thus the peculiar qualities, especially the flavour, of German or Austrian beers are doubtless to be ascribed, in a large measure, first to the fermentation being very slow, and carefully restricted to a low temperature; secondly, the employment of sedimentary yeast tends to render the products of a simpler, and doubtless more wholesome, nature than those which are evolved when a more rapid fermentation is allowed to proceed, such as occurs when a comparatively high temperature and top-growing yeast are adopted. Again, the quantity of hops used in the brewing of German beers is much less than is employed in this country, while in Bohemia and Bavaria the hops are gathered earlier, so as to exclude much of the narcotic principles which longer growth fosters. Since, as is well known, the constituents of the hop are distinctly narcotic, this, in addition to the decreased percentage of spirit, would account for the comparative absence of drowsy symptoms when Bavarian, German or Austrian beer is drunk, but which so frequently follow the consumption of English beers.

It has already been mentioned that a yeast that is formed by a violent or racy fermentation and at a higher temperature, as employed in English brewing, has more active qualities than yeast formed at a lower temperature and by slow fermentation. The first spreads itself rapidly over the surface of the fluid and is termed "superficial" yeast, while the second sinks to the bottom of the vessel and there continues its action; it is, therefore, termed "sedimentary" or bottom yeast, and is what is employed in German breweries. The important advantage of the use of a yeast growing at a low temperature in brewing is that while the normal functions of the yeast are free to act, yet the same cold discourages the growth of disease ferments, and a healthier beer is ensured.

Composition of Beer.—The specific gravity varies from 1006 to 1030, or even more. The average in English ales and porters is from 1010 to 1014. The percentage of extract is from 4 to 15 per cent. in ale, and from 4 to 9 per cent. in porter. It is least in the bitter, and highest in the sweet ales. The alcohol varies from 1 to 10 per cent. in volume. The free acidity which arises from lactic, acetic, gallic, and malic acids ranges (if reckoned as glacial acetic acid) from 18 to 45 grains per pint. The fermentation produces, besides alcohol and carbonic acid, a little glycerin and succinic acid. There is a small quantity of albuminous matter in most beers, but not averaging more than 0·5 per cent. The salts average 0·1 to 0·2 per cent., and consist of alkaline chlorides and phosphates, and some earthy phosphates. There is a small amount of ammoniacal salt. The dark beers, or porters, contain caramel and assamar. Free carbon dioxide is always more or less present; the average is 0·1 to 0·2 part by weight per cent., or about 1¾ cubic inch per ounce. Volatile and essential oils are also present.

A more exact statement of the percentage composition of various beers is presented in the following table:—

	Specific Gravity.	Malt Extract.	Alcohol.	Free or Total Acidity as Acetic Acid.	CO_2.	Ash.	Water.
Burton ale,	1032	14·50	5·90	...	...	...	79·60
Scotch ale,	1030	10·90	8·50	...	0·15	...	80·45
Bass's XX,	1014	5·10	4·43	0·180	...	...	...
Cheap draught ale,	1006	2·75	3·00	0·203	...	...	...
,, ,, ,,	1009	3·50	3·00	0·203	...	...	...
London porter,	1021	6·80	6·90	...	...	0·212	86·30
,, ,,	1022	7·16	4·21	0·168	...	...	...
Cheap draught porter,	1011	4·00	3·00	0·156	...	...	...
,, ,, ,,	1014	5·00	3·50	0·162	...	...	...
Berlin ale,	1019	6·30	7·60	...	0·17	0·188	85·93
Belgian faro ale,	1008	2·90	4·90	...	0·20	0·142	92·00
Bock beer,	1027	9·20	4·20	...	0·17	0·263	86·49
Lager beer,	1016	5·79	3·90	...	0·19	0·228	90·08
Bavarian beer,	1022	5·40	3·50	...	0·22	0·290	91·10
Vienna beer,	1021	6·10	3·50	...	0·19	0·210	...

Of the constituents of beer it is necessary to specially notice the water, the malt extract, the bitters, and the ash.

The water used in brewing should, of course, be free from all injurious impurities, and especially from any organic matters undergoing change. It is well known that variations in the mineral constituents of the water used in brewing exert an important influence on the character of the finished beer. Hard and somewhat saline water, for instance, is preferred in the brewing of pale and bitter ales in this country, since it extracts less colouring matter and, what is more important, less albuminous matter from the malt.

It is the latter substances which, when present in excess, are fatal to the prime condition of English brewed ales. Thus in England hard waters are in general use for brewing. On the other hand, the German brewer uses a softer and practically non-saline water, which extracts a greater amount of albuminous principles. How much common salt is present, is mainly interesting because in prosecutions for the addition of salt to beer, the defence frequently is, that the latter is a natural component of the beer from the water used in the brewing. As brewers, commonly, use hard waters, it is obvious that the waters in particular localities may contain varying quantities of salt. Generally speaking, the water used in different breweries gives quantities from 10 to 15 grains per gallon.

The malt extract is really the sum of the non-volatile constituents, and represents the residue of the extractive substances of the wort which have not been volatilised as carbonic acid during fermentation. In reality it consists of dextrin, sugar, cellulose, albuminous substances, and some fat from the malt or "saccharum" used, with lupulite and hop resin.

Formerly, beer bitters were, by law, compelled to be derived solely from hops; but since the repeal of the hop duty in 1862, any bitter may be used, provided it is harmless. From time to time various objectionable bitters, such as picric acid, picrotoxin or colchicine, have been identified in beers, but only very rarely; in fact so rarely, that they may be practically said to be now never used for the purpose. In the same way, quassiin, gentianin, absynthin, aloin, and some other more or less doubtful bitters have been found in beers, but extremely rarely. The chief bitter employed in beer to give it the characteristic flavour is that derived from hops. Hops are the cones or strobiles of the *Humulus Lupulus*. They contain about 4 per cent. of the astringent substance tannin, 1·5 per cent. of a fragrant essential oil, and much resin. These substances are chiefly found in the yellow glandular secretion of the hop cones, called *lupulin* or *lupulite*.

The ash of beer contains the mineral constituents that previously existed partly in the water, partly in the hops, and partly in the malt used. The ferric oxide, some phosphoric acid, a little lime and magnesia, with much of the silica remains undissolved and does not pass into the beer, the remainder is dissolved. The following table, from Wynter-Blyth, gives the average composition of the beer ash of commerce :—

	Beer Ash.
Potash,	37·22
Soda,	8·04
Lime, .	1·93
Magnesia,	5·51
Iron oxide, .	traces
Sulphuric acid,	1·44
Phosphoric acid,	32·09
Chlorine,	2·91
Silica,	10·82

Nutritive Value of Beer.—The action of beer upon tissue change, so far as is known, is supposed to be one of lessened excretion, the urea and pulmonary carbon dioxide being both decreased. If this be the case, it is not owing to the alcohol, at least in moderate dietetic doses, but of some of the other ingredients; but the experiments require repetition. On the nervous system the action is probably the same as that of alcohol. The peculiar exhausting or depressing action of beer taken in large amount has been ascribed by Ranke to the large amount of potash salts, but probably the other constituents (especially the hop) are also concerned.

When beer is taken in daily excess, it produces gradually a state of fulness and plethora of the system, which probably arises from a continual, though slight, interference with elimination both of fat and nitrogenous tissues. When this reaches a certain point appetite lessens, and the formative power of the body is impaired. The imperfect oxidation leads to excess of partially oxidised products, such as oxalic and uric acids. Hence many of the anomalous affections, classed as gouty and bilious disorders, which are evidently connected with defects in the regressive metamorphosis. Sir Wm. Roberts states that malt liquors hamper salivary digestion in exact proportion to their acidity, and retard peptic digestion altogether out of proportion to their percentage of alcohol; but digestion is assisted by a moderate quantity of light beer, especially when it contains free carbon dioxide.

The question, What is excess? is not easy to answer, and will depend both on the composition of the beer and on the habits of life of those who take it; but, judging from the amount of alcohol which is allowable, from one pint to two pints, according to the strength of the beer, is a sufficient amount for a healthy man.

In consequence of the abundant proportion of sugar and dextrin, and the appreciable amount of albumin, beer has decidedly a nutritive value which is not insignificant. Even the alcohol, setting aside its toxic properties, must be viewed in a limited sense as a nutritive substance. Hitherto, no attempt has been made in this country to lay down any standards of composition for beer, with a view to control the nutritive value of this important means of popular enjoyment and nutrition. Beers or porters containing less than 3 per cent. of alcohol and 4 per cent. of extract, must be pronounced weak, of inferior value, and not calculated to keep. While for ordinary ales, professing to be of fair or ordinary quality, the extract and alcohol may not unreasonably be expected to be each 4 per cent.: porters of the same class should yield at least 5 per cent. of extract and from 4 to 5 per cent. of alcohol. This is equivalent to expecting that the beer be brewed from an original wort having a specific gravity of from 1042 to 1054. Beers which, instead of being made from malt alone, receive additions of starch, maltose, potato sugar, &c., are relatively poorer in nitrogenous substances, ash and especially phosphoric acid. These non-malt beers retain their carbonic acid very imperfectly, hence readily get flat. Many of the German and Austrian beers, which contain small quantities of alcohol and large extracts, are to be more regarded as food and drink than are the average British ales. In the former there is a lessened change by fermentation of the extract into alcohol and carbonic acid, whereby a greater nutritive residue in the form of malt extract is present, whereas in the British beers the reverse is generally the case.

What is known as "small beer" is a thin beer often drawn for workmen and servants, containing only 1 to 2 per cent. of extract, about 1 per cent. of alcohol, and from 0·06 to 0·08 of ash. This beer is obtained by a repeated extraction of the malt which has been once used for ordinary beer, and then treating the resulting thin wort as for beer. The keeping properties of this liquid are very low, it readily becomes yeasty and sour, and has, practically, no nutritive value at all.

Adulterations of Beer.—The chief and simplest adulteration of beer is by the addition of water. Another very common adulteration is salt, the object of this addition being not so much to develop the flavour and to preserve the liquor, as to produce a craving for more drink. The use of gypsum, of which we have before spoken, can hardly be regarded as an adulteration. Sulphuric acid is occasionally added to clarify beer, and to give it the hard flavour of age; alum has been known to be used for the same purpose. To lessen excessive acidity sodium bicarbonate may be added: while sometimes publicans seek to give flat beer the semblance of freshness by means of effervescing powders containing tartaric acid along with sodium bicarbonate, which develop carbonic acid in the beer. Liquorice and sugar are both known to be added, occasionally, to give body to thin and watery beers and to improve their colour. A mixture of alum, salt, and sulphate of iron is also sometimes added to beer to give it a "head" when flat.

Inasmuch as we are not able now to limit our conception of ideal beer to its being a beverage consisting purely of barley malt, water and hops, we are unable to consider the various substitutes for barley malt, such as wheat, rice, maize, potato starch, maltose, glucose, &c., as in any way adulterants. Our position is somewhat similar in regard to the various substitutes for hops; these are not adulterants unless hurtful bitters. Mention has been already made of the fact that, at times, wormwood, marsh-rosemary, bitter-clover, box tree, holy thistle, centaury, gentian, quassia, and various other bitters of a more or less harmless nature may be added to beer, while occasionally others of a more objectionable character, such as colchicum, picrotoxin and aloin, have been used; still the employment of these is so exceptional, and the use of genuine hops so general, that the serious consideration of beer adulteration or sophistication by these means is unnecessary.

EXAMINATION OF BEER.

The most important points to be observed in the examination of beer are:—1. Its physical characters. 2. Specific gravity at 15° C. or 60° F. 3. Determination of the proportion of alcohol. 4. Determination of the extract. 5. Determination of the degree of acidity. 6. Determination of possible adulterations.

1. **Physical Characters.**—The beer should be transparent, not turbid. Turbidity arises from imperfect brewing or clarifying, or from commencing changes. If the latter, the acidity will probably be found to be increased. The amount of carbon dioxide disengaged should neither be excessive nor deficient.

The taste should be pleasant. If bitter, the bitterness should not be persistent. It should not taste too acid.

Smell gives no indication till the changes have gone on to some extent. If there is any turbidity, microscopic examination will usually detect the cause.

2. **Determination of the Specific Gravity.**—The beer, after it has been brought to the required temperature of 15° C. or 60° F., is well shaken in a flask, half filled, to expel carbonic acid, and filtered through wadding to remove froth; the specific gravity is then determined by means of an accurate hydrometer. The specific gravity should be taken both before and after driving off the alcohol. From the reading, after de-alcoholisation, an approximate conclusion can be formed of the amount of solids or extract present, by dividing by 4 the excess of the gravity reading over 1000, or by 0·004 the excess of the gravity over unity. Of course the more extract, the greater is the body of the beer. Before de-alcoholisation, in the better class of beers the specific gravity will vary from 1010 to 1025, and in the inferior kinds from 1006 to 1014.

3. **Determination of the Alcohol.**—There are various ways of determin-

ing the amount of alcohol in beer, wine and spirits: for the medical officer, one of the two following will be sufficient.

Measure a certain quantity of the alcoholic fluid, and take the specific gravity at 60° F. *1st.* Place in a retort and distil at least two-thirds. Take the distillate, dilute to original volume with distilled water, determine the specific gravity at 60° F. by a proper instrument, and then refer to the annexed table of specific gravities—opposite the found specific gravity the percentage of alcohol is given in *volume* and in *weight.*

2nd. Then, to check this, a plan recommended by Mulder may be used. Take the residue of the liquid in the retort, dilute with water to the original volume, and take the specific gravity at 60° F.

Then deduct the specific gravity before the evaporation from the specific gravity after it, take the difference, and deduct this from unity (the specific gravity of water), and look in the table of specific gravities for the number thus obtained; opposite will be found the percentage of alcohol. The results of these two methods should be identical.

Table of Percentages of Absolute Alcohol at 60° *Fahrenheit.*

Vols. per cent.	Weight per cent.	Specific gravity at 60° F.	Vols. per cent.	Weight per cent.	Specific gravity at 60° F.	Vols. per cent.	Weight per cent.	Specific gravity at 60° F.	Vols. per cent.	Weight per cent.	Specific gravity at 60° F.
0	0	1·0000	26	21·30	·9689	51	43·47	·9315	76	69·05	·8739
1	0·80	·9976	27	22·14	·9679	52	44·42	·9295	77	70·18	·8712
2	1·60	·9961	28	22·99	·9668	53	45·36	·9275	78	71·31	·8685
3	2·40	·9947	29	23·84	·9657	54	46·32	·9254	79	72·45	·8658
4	3·20	·9933	30	24·69	·9646	55	47·29	·9234	80	73·59	·8631
5	4·00	·9919	31	25·55	·9634	56	48·26	·9213	81	74·74	·8603
6	4·81	·9906	32	26·41	·9622	57	49·23	·9192	82	75·91	·8575
7	5·62	·9893	33	27·27	·9609	58	50·21	·9170	83	77·09	·8547
8	6·43	·9881	34	28·13	·9596	59	51·20	·9148	84	78·29	·8518
9	7·24	·9869	35	28·99	·9583	60	52·20	·9126	85	79·50	·8488
10	8·05	·9857	36	29·86	·9570	61	53·20	·9104	86	80·71	·8458
11	8·87	·9845	37	30·74	·9556	62	54·21	·9082	87	81·94	·8428
12	9·69	·9834	38	31·62	·9541	63	55·21	·9059	88	83·19	·8397
13	10·51	·9823	39	32·50	·9526	64	56·22	·9036	89	84·46	·8365
14	11·33	·9812	40	33·39	·9510	65	57·24	·9013	90	85·75	·8332
15	12·15	·9802	41	34·28	·9494	66	58·27	·8989	91	87·09	·8299
16	12·98	·9791	42	35·18	·9478	67	59·32	·8965	92	88·37	·8265
17	13·80	·9781	43	36·08	·9461	68	60·38	·8941	93	89·71	·8230
18	14·63	·9771	44	36·99	·9444	69	61·42	·8917	94	91·07	·8194
19	15·46	·9761	45	37·90	·9427	70	62·50	·8892	95	92·46	·8157
20	16·28	·9751	46	38·82	·9409	71	63·58	·8867	96	93·89	·8118
21	17·11	·9741	47	39·75	·9391	72	64·66	·8842	97	95·34	·8077
22	17·95	·9731	48	40·66	·9373	73	65·74	·8817	98	96·84	·8034
23	18·78	·9720	49	41·59	·9354	74	66·83	·8791	99	98·39	·7988
24	19·62	·9710	50	42·52	·9335	75	67·93	·8765	100	100·00	·7939
25	20·46	·9700									

If there is no retort available, this second plan may be used with an ordinary evaporating dish, the alcohol being suffered to escape. The plan is very useful for medical officers, and if conducted with reasonable care and slowness of evaporation so as not to char the residue and render it insoluble, gives very satisfactory results.

Example.—Say 200 c.c. of beer are taken, and its sp. gr. at 60° F. is found to be 1·012; after boiling down to one-third, it is allowed to cool, and made up with distilled water to 200 c.c. Its sp. gr. is now taken again at 60° F., and found, say, to be 1·020. The difference between the first sp. gr. and the second is 0·008, and this deducted from 1·000 gives 0·9920; on referring to the table, we find that the nearest specific gravity given to this figure is 0·9919, corresponding to 5 volumes of alcohol per cent., and that consequently 0·9920 lies between 0·9919 and the one next above, namely, 0·9933, and that the percentage of alcohol corresponding to 0·9920 is something between 4 and 5 volumes. To find exactly how much it is, we calculate the proportional part. The difference between the gravities for 4 and 5 volumes per cent. of alcohol is 0·0014, and as the calculated gravity of 0·9920 is 0·0013 different from 0·9933, the one above it, and 0·0001 different from the one below it, the percentage of alcohol corresponding to it may be said to be 4, corresponding to 0·9933, *plus* $\frac{13}{14}$ of 1, or 0·928, which gives the exact volume percentage of alcohol, corresponding to a sp. gr. of 0·9920 as being 4·928.

Alcohol is sometimes stated as weight in volume and not as volume in volume. If the percentage of alcohol in *volume* be multiplied by 0·8, the *weight* of the alcohol is given per cent. If the percentage of alcohol in *weight* is multiplied by 1·25, the *volume* is given. If the percentage *volume* of alcohol be multiplied by 1·76, and the weight in volume by 2·21, the amount of *proof spirit* is given.

4. **Determination of the Extract.**—This can be estimated by taking a given quantity of the beer, evaporating down to dryness in a weighed capsule, re-weighing and calculating out the resulting residue as a percentage; or, it can be determined indirectly, as already explained, from the specific gravity of the de-alcoholised beer. In the example given above, the extract would be calculated, by this method, as being 0·020 divided by 0·004 or 5 per cent.

Complementary to this estimation, it may, sometimes, be necessary to determine what was the original extract of the wort before fermentation set in. As on fermentation about two parts by weight of sugar yield one part of alcohol, by doubling the alcohol found in the beer, and adding it to the extract found by direct estimation, we may calculate, approximately, how much extract the wort really contained before fermentation was established, or in other words, what has been the concentration of the wort. Thus, say in the preceding example we find 5 per cent. of extract and 4·92 per cent. of alcohol: then $(4{\cdot}92 \times 2) + 5 = 14{\cdot}84$ as the probable percentage of extract in the orginal wort, with a probable specific gravity of 1059. These figures are accurate enough for a general or rapid statement, but by means of the formula $\frac{100\,(E + 2{\cdot}0665A)}{100 + 1{\cdot}0665A}$, in which E = extract, and A = alcohol, we may calculate the original extract still more accurately: $\frac{100\,(5 + 2{\cdot}0665 \times 4{\cdot}92)}{100 + 1{\cdot}0665 \times 4{\cdot}92} =$ 14·41, and presuming that the specific gravity of that wort would rise 4 degrees above 1000, or 0·004 degree above unity for each 1 per cent. of extract in it, we can conclude that the specific gravity of that original wort was 1057 or 1·0576, according to which way we choose to state it.

5. **Determination of the Acidity.**—This is a very important matter, as the increase of acidity is an early effect when beer is undergoing changes. It may be stated either as a percentage, or in grains per pint.

The acidity of the beer consists of two kinds.

Volatile acids, viz., acetic and carbonic.

Non-volatile acids, viz., lactic, gallic or tannic, malic, and sulphuric, if it has been added as an adulteration.

To determine the acidity of beer we must use an alkaline solution of known strength, 1 c.c. of which is equal to 6 milligrammes of glacial acetic acid ($C_2H_4O_2$) or to 9 milligrammes of lactic acid ($C_3H_6O_3$). This is the same alkaline solution as was needed for estimating the acidity of bread (page 338).

Total or Free Acidity.—Take 10 c.c. of the beer to be examined, and drop into it the alkaline solution from a burette, till exact neutrality (as tested by turmeric and litmus papers) is reached. Then read off the number of c.c. of alkaline solution used; multiply by 6, and the result will be the amount of total acidity in the quantity of beer operated on, expressed as milligrammes of glacial acetic acid (the symbols being always used in the report). By shifting the decimal point two places to the left, the amount per cent. is given. To bring percentage into grains per pint multiply by 700 to bring to grains per gallon, and then divide by 8 to bring to grains per pint; or, what is the same thing, multiply at once the number of c.c. of alkaline solution used by 5·25 (short factor).

The total acidity can be divided into *fixed* and *volatile* by evaporation. While the total acidity is being determined, evaporate another measured quantity of beer to one-third, make up to the original bulk with distilled water, and determine the acidity. The acetic and carbonic acids being volatile are driven off, and lactic and other acids remain. Deduct the amount of alkaline solution used in this second process from the total amount used, and this will give the amount required for the volatile and fixed acidities respectively; express one in terms of acetic, the other of lactic acid. Short factor for lactic acid = 7·875. The fixed acidity is greater than the volatile in almost all beers, and sometimes five or six times as much.

Example.—10 c.c. of beer took 5 c.c. of alkaline solution: 5 × 5·25 = 26·25 grains of glacial acetic acid per pint = total acidity.

After boiling and making up to original bulk with distilled water, 10 c.c. took 4 c.c. of alkaline solution: 4 × 7·875 = 31·5 grains of lactic acid per pint = fixed acidity. The difference between the amounts of alkaline solution used, 5 − 4 = 1 multiplied by 5·25, gives the volatile acidity.

Generally speaking, the amount of total acidity of beer given in books is too great. It is seldom found to be more than 30 grains per pint, or 0·342 per cent., and even rarely reaches that; sometimes it is not more than 12 or 14 grains, or about 0·150 per cent. In thirty-one kinds of porter and stout the acidity per pint varied from 25·22 grains (the highest) to 14·14 grains (the lowest amount). In twenty-three kinds of ale the highest and the lowest amounts per pint were 34·39 and 7·97 grains.

6. **Determination of Adulterations.**—The most important are the following:—

Water.—Probably the most frequent adulteration; detected by taste; determining amount of alcohol and specific gravity of the beer free from alcohol.

Alcohol.—Seldom added; the quantity of alcohol is large in proportion to the amount of extract, as determined by the specific gravity after separation of the alcohol.

Sodium or Calcium Carbonate in order to lessen Acidity.—Neither adulteration can be detected without a chemical examination. Evaporate beer to a thick extract, then put it in a retort, acidulate with sulphuric acid, and distil; if calcium or sodium acetate be present, acetic acid in large quantity will pass over. The extract always contains some acetate, but only in small quantity.

Lime.—Evaporate to dryness another portion of beer, incinerate, dissolve in weak acetic acid, and precipitate by ammonium oxalate. In unadulterated beer the precipitate is moderate only.

Sodium Chloride.—This is hardly an adulteration, unless a very large quantity is added. Take a measured quantity of the beer; evaporate to dryness; incinerate at as low a heat as possible; dissolve in water, and determine the sodium chloride by the standard solution of nitrate of silver.

Ferrous Sulphate.—If the beer be light-coloured a mixture of potassium ferricyanide and ferrocyanide may be added at once, and will give a precipitate of Prussian blue; if the beer be very dark-coloured, it must be decolourised by adding solution of lead subacetate and filtering.

Or evaporate a portion of beer to dryness and incinerate; if any iron be present the ash is red; dissolve in weak nitric acid, and test with potassium ferrocyanide. Two grains of ferrous sulphate to nine gallons of water give a red ash. The ash of genuine porter is always white, or greyish-white.

Sulphuric acid is added to clarify beer, and to give it the hard flavour of age. If the beer be pale, add a few drops of hydrochloric acid, and test with barium chloride. A *very dense* precipitate may show that sulphuric acid has been added, but it must be remembered that the water used in brewing may contain large quantities of sulphates. (The Burton spring-water is rich in calcium sulphate.) If there be a *large* precipitate, then determine the acidity of the beer before and after evaporation; if the amount of fixed acid be found to be *very* large, there will be no doubt that sulphuric acid has been added; or precipitate with baryta, and weigh.

Mulder recommends that the extract of the beer be heated, and the sulphur dioxide which is disengaged led into chlorine water; sulphuric acid will be found in the chlorine water, and may be tested for as usual.

Alum.—Evaporate to dryness; incinerate, and proceed exactly as in the analysis of alum in Bread. The substance added to give "head" to beer is a mixture of alum, salt, and ferrous sulphate.

Liquorice.—Evaporate 1 litre of the beer to half its volume, and on cooling, precipitate with a slight excess of concentrated plumbic acetate. After twelve or twenty-four hours, the precipitate is filtered, well washed, and rinsed into a flask, so that the whole makes up to 300 to 400 c.c. The liquid is then heated for an hour, and sulphuretted hydrogen passed into it, while still warm, until the lead compounds are decomposed. After well shaking, the cold liquid is filtered through a folded filter and the sulphuretted hydrogen washed out.

The lead sulphide on the filter retains the glycyrrhizinic acid of the liquorice.

It is washed with 200 c.c. of 50 per cent. alcohol into a flask, heated to boiling and filtered. The filtrate is evaporated to a few c.c., and a few drops of ammonia added, which turns the pale yellow liquid brown-yellow; the latter is then evaporated to dryness, the residue dissolved in 3 c.c. of water and filtered. The filtrate possesses the characteristic taste of liquorice, if this latter be present, and separates out a flocculent resinous mass (glycyrretin) on heating with a few drops of hydrochloric acid on the water bath. The residue from a beer free from liquorice possesses no taste, or only a slightly bitter one, and gives at the most only a whitish turbidity.

Other substances have been supposed to be used as adulterants, and formerly this was the case, but not of late years.

WINE.

The term wine is held to mean "the fermented juice of the grape with such additions only as are essential to the stability or keeping quality of the wine." This definition admits as wines those beverages which, made from grape juice, require to preserve them the addition of spirit, as in the case with some wines from Spain and Portugal; but it excludes the so-called British wines, which are not made from the juice of the grape at all, and those wines from other countries which are fortified with spirit when they require no such addition.

When the sugary juice of a fruit, such as the grape, is left to itself at a moderate temperature, fermentation takes place from the influence and action of germs which adhere to the skin of the grapes and are introduced into the "must" on pressing; this process differing very much from that in the making of beer, when the starchy or sugary infusion or wort is boiled, and then yeast added to make it ferment. During the fermentation of the fruit juice, a part or whole of the sugar is converted into alcohol. Various ethers, which give the characteristic flavour or bouquet to wine, are formed, as well as acetic, malic, succinic, and other acids. The essential acid of wine is tartaric acid; much of this crystallises in the casks as cream of tartar or tartrate of potash. The newer wines contain aldehyde, which is very intoxicating, later on this gets oxidised into acetic acid, and, if exposed to the air long enough, all the alcohol in a wine will be converted into this acid so as to practically become ordinary wine vinegar. Much of the colour, taste, and character of wines depends upon how far they are made from the grape juice only, or how much this is mixed with the seeds and skins of the fruit. The seeds are rich in tannin and a bitter principle, while the skins yield a colouring matter, some flavouring principle, and tannin. If it is desired to produce white wine, the "must" is quickly pressed away from the skins and stalks: while for red wine the skins of purple grapes are allowed to ferment along with the must, yielding thus a wine rich in tannin and colouring matter.

	Specific Gravity.	Alcohol.	Extract.	Tartaric Acid.	Glycerin.	Mineral Salts.	Sugar.	Tannin and Colouring Matter.	Nitrogen.	Potash.	Phosphoric Acid.	Sulphuric Acid.
Red wine (French), .	0·9982	7·80	2·56	0·57	0·730	0·248	...	0·180	0·043	0·106	0·030	0·033
,, ,, (Rhine),	0·9966	10·08	3·04	0·52	...	0·249	...	0·158	...	...	...	...
,, ,, (Austrian),	0·9958	8·49	2·54	0·62	0·810	0·241	...	0·110	0·026	0·101	0·037	0·033
,, ,, (Hungarian),	0·9952	9·02	2·54	0·67	0·790	0·215	...	0·150	0·034	0·091	0·038	0·024
,, (Spanish),	0·9975	12·31	3·53	0·49	1·090	0·610	...	0·220	...	0·242	0·027	0·221
,, ,, (Australian),	0·9982	14·10	2·96	0·58	...	0·461	...	0·233	...	0·195	0·019	0·220
,, ,, (Cape), .	0·9976	11·36	2·86	0·62	...	0·550	...	0·226	0·021	0·231	0·230	0·225
White wine (French),	0·9963	10·31	3·03	0·66	0·970	0·250	...	...	...	0·098	0·032	0·038
,, ,, (Rhine),	1·0005	8·00	2·60	0·81	0·850	0·248	...	...	0·048	0·085	0·046	0·020
(Austrian),	0·9949	7·93	2·13	0·67	0·680	0·189	...	...	0·022	0·081	0·034	0·039
,, ,, (Hungarian),	0·9955	8·00	2·33	0·69	0·770	0·204	...	...	0·027	0·075	0·036	0·026
Moselle, . . .	0·9964	7·99	2·24	0·79	0·720	0·175	...	...	0·031	0·068	0·034	0·025
Champagnes (Cliquot),	1·0565	10·20	19·75	0·60	1·130	0·120	17·520	...	...	...	0·016	0·022
,, (Röderer), .	1·0572	9·50	20·24	0·70	0·970	0·120	18·500	...	...	...	0·012	0·017
,, (Monopole),	1·0280	8·21	10·15	0·57	0·230	0·135	8·450	...	...	0·059	0·016	0·025
Tokay,	0·9943	12·05	3·26	0·68	...	0·240	1·040	0·630	0·041	0·108	0·035	0·030
Port, .	1·0081	16·69	8·05	0·40	0·430	0·233	5·843	0·430	0·027	0·102	0·031	0·023
Sherry,	0·9932	17·45	3·98	0·45	0·520	0·380	2·120	...	...	0·206	0·031	0·128
Madeira,	1·0003	15·40	5·52	0·43	0·740	0·350	3·230	...	0·020	0·149	0·060	0·075
Marsala,	1·0022	15·85	5·27	0·49	0·510	0·380	3·530	...	...	0·142	0·029	0·114
Malaga,	1·0694	11·93	21·73	0·55	...	0·410	17·110	...	0·041	0·187	0·049	0·043

Composition of Wines.—According to the absence or presence of sugar in them, wines are conveniently divided into two great classes, namely, the light red and white wines, from which sugar is either entirely absent or present in only very small amounts, and the sweet wines, such as Port, Sherry, and the Champagnes, in which sugar largely is present. The light wines and the sparkling wines differ slightly in the amount of their contained alcohol, but chiefly differ in the quantity of their ethers and aromatic substances. The champagnes differ largely from the ports and sherries in their effects, but as they contain frequently large amounts of sugar, they are best classed with them under the same heading of sweet wines. The composition of wines, it will be readily understood, is somewhat complex, and moreover very variable. So far as it is possible to summarise this information, the chief constituents and their percentage proportions are given in the preceding table, compiled mainly from large numbers of analyses made by Nessler and Borgmann.

Alcohol.—With regard to the amount of alcohol which a wine contains there is no constancy. All wines can be divided according to their alcoholic strength into two classes; the natural wines, containing from 6 to 13 per cent. by weight of alcohol, and the fortified wines containing from 12 to 22 per cent. by weight of alcohol. The limit of alcoholic distinction between these two great classes of wine will be more readily understood if it be borne in mind that during the fermentation of any sugary liquid or mass, that process usually ceases when the alcohol formed reaches 14 per cent., so that any excess of alcohol over that amount must, of necessity, have been added artificially. The ports and sherries are all largely fortified with added alcohol; while many of the inferior clarets and champagnes are subject to very similar additions. The strongly alcoholic and fortified wines are slow to undergo change, hence keep well; but the lighter and natural wines deteriorate rapidly when exposed to air.

Ethers.—The chief of these present in wine are œnanthic, citric, malic, tartaric, acetic, racemic, butyric, caproic, caprylic, and some other ethers of indefinite composition. The "bouquet" of wine is partly owing to the volatile ethers and partly to extractive matter. The characteristic odour of wine is mainly due to œnanthic ether.

Albuminous Matters—Extractive Colouring Matter.—The quantity of albumin is not great; the extractives and colouring matter vary in amount. The colouring matter is derived from the grape skins; it is naturally greenish or blue, and is made violet and then red by the free acids of wine. The bluish tint of some Burgundy wines is owing, according to Mulder, to the very small amount of acetic acid which these wines contain. It is, according to Batilliat, composed of two matters—rosite and purpurite. With age, changes occur in the extractive matters; some of it falls (apothema), especially in combination with tannic acid, and the wine becomes pale and less astringent.

Sugar exists in varying amounts, and in the form, for the most part, of fruit sugar. Sherry generally contains sugar, but not always; it averages 8 grains per ounce, and appears to be highest in the brown sherries, and least in Amontillado and Manzanilla. In Madeira it varies from 6 to 66 grains per ounce; in Marsala a little less; in Port, from 12 to 28 grains per ounce, being apparently nearer the latter in the finest wines. In Champagne it amounts to from 6 to 28 grains, the average being about 24 grains; but a good deal of Champagne is now drunk as "vin brut," without any sugar. In the Clarets, Burgundy, Rhine, and Moselle wines it is absent, or present in small amount.

Fat.—A small amount exists in some wine.

Free Acids.—Wine is acid from free acids and from acid salts, as the potassium bitartrate. The amount varies from 2 to 3 grains per ounce. The principal acids are racemic, tartaric, acetic, malic, tannic (in small quantities), glucic, succinic, lactic (?), carbonic, and fatty acids, such as formic, butyric, or propionic. Some acids are volatile besides the acetic, but it does not seem quite certain what they are. The tannic acid is derived from the skins: it is in greatest amount in new port wines: it is trifling in Madeira and the Rhine wines; it is present in all white and most red-fruit wines, except champagne. The tannic acid on keeping precipitates with some extractive and colouring matter (apothema of tannic acid).

Salts.—The salts consist of bitartrate of potassium, tartrate of calcium and sodium, sulphate of potassium, a little phosphate of calcium and magnesium, chloride of sodium, and iron. The magnesia is in larger amount than the lime, and exists sometimes as malate and acetate. A little manganese and copper have been sometimes found. In Rhine wine a little ammonia is found (Mulder). The total amount of salts is 0·1 to 0·3 per cent., *i.e.*, about 9 to 26 grains per pint, or $\frac{1}{2}$ to $1\frac{1}{2}$ grain per ounce. The salts can only be detected by evaporation and ignition.

The total solids in wine vary from 3 to 14 per cent., or in some of the rich liqueur-like wines to more. The specific gravity depends upon the amount of alcohol and of solids, and varies from 0·973 to 1·002 or more.

Artificial Improvement of Wine.—There are several processes which are frequently employed for either artificially improving wine, or increasing its volume. Thus, the addition of alcohol to the wine renders it stronger and more permanent; so, too, the addition of glycerin makes it sweeter and fuller in the mouth, and various essences render it more fragrant and highly flavoured. Various colouring matters and preservative agents are also frequently added to wine, to improve its appearance and keeping qualities. Of the processes which aim exclusively at an increase of volume, the chief is the addition of alcohol and water, sometimes with glycerin. What is called "gallising" is the dilution of the "must," when it is too acid, by means of water until its acidity becomes normal (say 0·5 per cent.), and then adding cane or grape-sugar until it contains from 20 to 30 per cent. Yeast wines are obtained by causing sugar water to ferment with wine-yeast, with an addition of tartaric acid. Latterly much wine has been obtained by fermenting water and raisins, with the occasional addition of suitable ingredients. A manufacture of artificial wine from water, sugar, tartaric acid, and alcohol is by no means unknown.

Apart from adulterations in the direction of added spirit and artificial colouring, the most common sophistication of wine is "plastering" to secure clearness and dryness. The term "dryness," as applied to wines, is meant to express a flavour which is not that of sweetness. It has already been stated that the fermentation of grape juice, in the formation of wine, is the result of a vegetable growth, which the "must" or juice of the grape obtains spontaneously. Two distinct effects follow the growth of this fungus or process of fermentation; one is, the sugar of the "must" is converted into alcohol; the other is that the greater part of the albuminous or nitrogenous part of the "must" is consumed as food by the fungus. If left alone, the fermentation goes on until either all the sugar is used up, or until the supply of sufficient albuminous matter is exhausted. Now, it will be readily understood that the relative proportions of these present determine which of the two gets exhausted first; and if the sugar is used up before the albuminous food of the fungus, a dry or not sweet wine is produced, while if the nitrogenous food is exhausted first, the remaining unfermented sugar produces a sweet wine. Since the juice of the ripe grape contains from 10 to 30 per cent. of sugar, there is a very wide range.

A large number of people dislike sweet wines, hence the demand for what is called a dry wine. From what has been stated as to the difference in origin of a naturally sweet wine and a naturally dry wine, it will be apparent that the poorer the grape the drier the wine made from it; but the yield from a poor grape is less than that from a rich one, hence naturally dry wine costs more to produce than naturally sweet wine. It will also be apparent that the conversion of naturally sweet wines into dry ones will not be difficult, and since there is a demand for dry wines the artificial conversion is frequently performed. It is carried out either by making the wine from unripe or poor grapes, in which case the yield of alcohol and flavour are both low; or it is done by adding some nitrogenous material such as gelatin, isinglass, or white of egg to the "must," so as to feed the yeast fungus until all or nearly all the sugar in the grape has been converted into alcohol. This procedure is sometimes called *fining* in the wine trade, and is the least objectionable of all methods of artificial drying, being, as it is, almost identical with the natural cause of wine dryness. Unfortunately, there are other methods adopted which are less commendable but more common. These consist often in making an imitation of the natural dryness of wine by adding factitious salts and fortifying with alcohol. The sugar still exists as largely as before, only its taste is disguised.

Perhaps the most general method of increasing the dryness of a given wine is that of adding mineral acids and mineral salts, more particularly gypsum, or Spanish earth. This is technically known as "plastering," because gypsum is plaster of Paris. This being largely sulphate of lime modifies the chemical characters of the wine by decomposing the cream of tartar or potassium tartrate into calcium tartrate, potassium sulphate and free tartaric acid, at the same time altering the colouring matter and changing the neutral organic compounds which exist in grape juice. The use of gypsum materially clears a wine, making it look brilliant; this is explained by the fact that the resulting sulphate of potash is much more soluble than the antecedent tartrate of potash. To a certain extent, after the addition of gypsum, much of the tartaric acid of wine is replaced by sulphuric acid, a body which renders wine, so altered, distinctly unsuitable for daily use. The sherries suffer the most from plastering—so much so, that some chemists advise that the plastering of wines should be called adulteration.

The chemistry of plastering may be thus written:—

$$\overset{\text{Gypsum.}}{CaSO_4} + \overset{\substack{\text{Potassium}\\ \text{bitartrate.}}}{C_4H_5KO_6} = \overset{\substack{\text{Acid potassium}\\ \text{sulphate.}}}{SO_4HK} + \overset{\substack{\text{Calcium}\\ \text{tartrate.}}}{C_4H_4CaO_6}.$$

A further transposition may ensue, such as the following, though, according to Roos and Thomas, it is questionable.

$$\overset{\substack{\text{Acid potassium}\\ \text{sulphate.}}}{SO_4HK} + \overset{\substack{\text{Acid potassium}\\ \text{phosphate.}}}{PO_4H_2K} = \overset{\substack{\text{Neutral potassium}\\ \text{sulphate.}}}{SO_4K_2} + \overset{\text{Phosphoric acid.}}{PO_4H_3}.$$

The nutritive value of the wines is small, and in the main subsidiary to the stimulating properties of their contained alcohol. The clarets and lighter wines are more or less anti-scorbutic, owing to the presence of the organic acids. Port and sherry appear to predispose to gout. The presence of some albuminous principle in wine may give it a slight nourishing value, but in favour of such a view the evidence is small. Like the malt liquors, the wines act as stimulants to the secretion of gastric juice, but they all have a well-marked retarding effect on the chemical process of gastric digestion. According to Roberts, this retarding effect of both malt liquors and wines is not proportional to the amount of alcohol contained in them: there is something else which is more retarding than alcohol. Of the wines, port and sherry delay gastric digestion the most. Hock and claret have a less retarding effect, and champagne even still less. The retarding effects on digestion of wines and malt liquors is probably due to the neutral inorganic salts present, but the question cannot be yet regarded as settled.

EXAMINATION OF WINE.

This will be directed to ascertain Quality and Adulteration.

The Quality of wine can be best determined by noting the colour, transparency, and taste, and then determining the following points:—

Specific Gravity.—In the best clarets, before the loss of alcohol, the specific gravity is very nearly that of water. In some claret examined by Hoffmann, the specific gravity was 0·99952 and in others as low as 0·995. A low specific gravity shows that alcohol has been added, or that the solids are in small amount.

Amount of Alcohol.—A very small amount may show the addition of water, a large amount the addition of spirits. Its determination should be made as for beer.

Amount of Extract.—This may be estimated directly by evaporation of 50 c.c. on the water bath in a weighed capsule and calculating the residue as a percentage. Indirectly, the extract of wine may be ascertained from the specific gravity of the de-alcoholised liquid as explained in the examination of beer, but the result is only approximate.

Amount of Free Acidity.—This is an important point, as it seems clear that some persons do not readily digest a large amount of acid and acid salts. The amount is determined by the alkaline solution, as used for ascertaining the acidities of bread and beer. The total or free acidity is generally reckoned as crystallised tartaric acid ($C_4H_6O_6$), 1 c.c. of the standard alkaline solution being equal to 7·5 milligrammes. There is both fixed and volatile acidity; the relative amount of the two is difficult to determine satisfactorily, as some acid may be formed on distillation. The distillation should be conducted at a low temperature, so as not to decompose the fixed compound ethers. The volatile acidity is reckoned as glacial acetic, the fixed as tartaric acid. All the acidities of wine are usually reckoned as grains per *ounce*, but occasionally are stated as percentages.

Example.—Say 10 c.c. of wine are exactly neutralised by 9·5 c.c. of standard alkaline solution: $9{\cdot}5 \times 7{\cdot}5 = 71{\cdot}25$ milligrammes of tartaric acid in 10 c.c. of wine: this $71{\cdot}25 \times 7 = 498{\cdot}75$ grains of tartaric acid in a gallon of wine, and $498{\cdot}75 \div 160 = 3{\cdot}11$ grains of tartaric acid per ounce, or 0·712 per cent., of total or free acidity.

After de-alcoholisation, say 10 c.c. require 5 c.c. of alkaline solution: then $\frac{5 \times 7{\cdot}5 \times 7}{160} = 1{\cdot}65$ grain per ounce, or 0·377 per cent., of fixed acidity as tartaric acid.

The difference between the amounts of alkaline solution used, $9{\cdot}5 - 5 = 4{\cdot}5$ multiplied by $6 \times 7 \div 160 = 1{\cdot}15$ grain per ounce, or 0·27 per cent., of volatile acidity as acetic acid.

The amount of free acidity varies greatly even in the same kind of wines; the least acid wines are Sherry, Port, Champagne, the best Claret and Madeira; the more acid wines are Burgundy, Rhine wine, Moselle. The amount of free acid in good Clarets is equal to 2 to 4 grains of tartaric acid per ounce; in common Clarets and in Beaujolais it may be 4 to 6 grains, and in some extremely acid wines it may be even more than this. In the best Champagnes it is 2 to 3 grains usually; but it has been known to reach in excellent Champagne 1·12 per cent., or 4·9 grains per ounce. In

Port it averages 2 to $2\frac{1}{2}$ grains, but may reach 4 grains; in Sherry, $1\frac{1}{2}$ to $2\frac{1}{4}$ grains; in the Rhine wines, $3\frac{1}{2}$ to 4 or 6 grains. Thudichum and Dupré state that in good sound wine the amount of free acidity ranges from 0·3 to 0·7 per cent., or from 1·3 to 3 grains per ounce.

Excessive acidity of wine can be corrected by adding neutral potassium tartrate. Milk is also often used. The addition of the carbonated alkalies, or of chalk, alters the bouquet of the wine. When wine becomes stringy, in which case acetic and lactic acids are formed, it may be improved by adding a little tea; about one ounce of tea boiled in 2 quarts of water should be added to about 40 gallons of wine. Bitter wine is treated with hard water or sulphur; bad smelling wine with charcoal; too astringent wine with gelatin; wine which tastes of the cask with olive oil.

Amount of Sugar.—This can be estimated by means of the copper solution used in the determination of lactose (page 316). It is, however, necessary to render the wine alkaline by an addition of sodium carbonate and to decolourise before using the Fehling solution. Strongly coloured wines, if their proportion of sugar is low, may be decolourised with purified animal charcoal; but if the sugar exceeds 0·5 per cent. with basic lead acetate, and then to receive more sodium carbonate. As animal charcoal retains sugar from strong sugary solutions, its use is inadmissible for wines containing much sugar. If there is reason to suspect cane-sugar, the sugar must be inverted by boiling with hydrochloric acid, the sugar re-determined with copper and the cane-sugar calculated from the difference. As an alternative to the use of Fehling's solution, the saccharometer may be employed, after decolourisation of the wine.

In using the copper solution for determining the sugar, if any substance exists which is still turned green by the alkali of the Fehling solution, the wine must be neutralised, evaporated to dryness, and the sugar dissolved. As a rule, the estimation of wine sugar by means of the copper solution gives 0·5 per cent. too much sugar, and a correction to this amount should be made.

Adulterations of wine will be best detected by attention to the following:—

Water, if added, will be known by taste, by the amount of alcohol, and the specific gravity after the elimination of the alcohol.

Distilled Spirits.—Known by determining the amount of alcohol, the normal percentage of the particular kind of wine being known. By fractional distillations the peculiar-smelling fusel oils may be obtained; or merely rubbing some of the wine on the hand, and letting it evaporate, may enable the smell of these ethers to be perceived.

Artificial Colouring Matters.—For distinguishing between the genuine colouring matter of wine and artificial admixtures, Dupré suggests the use of cubes of gelatin made by dissolving 5 grammes of gelatin in 100 c.c. of distilled water; when cold, cut into cubes about $\frac{3}{4}$ inch square; immerse in the wine, and examine after twenty-four to forty-eight hours. If the wine is pure, the colour is confined almost to the margin, or does not extend inwards more than $\frac{1}{8}$ inch. Most other colouring matters permeate the jelly; an exception is furnished by Rhatany root, the colouring matter of which acts like that of wine.

Lime Salts.—If wine has been plastered, the lime salts are large. The only precise way of detecting this adulteration is by evaporating to dryness, incinerating, and determining the amount of lime. But the following method is shorter, and will generally answer. The natural lime salts of wine are tartrate and sulphate; when lime is added an acetate of calcium is formed.

Evaporate the wine to $\frac{1}{10}$th; add twice its bulk of strong alcohol; the calcium acetate is dissolved, but not the sulphate or tartrate; filter and test with oxalate of ammonium; if a large precipitate occur, lime has probably been added.

Tannin may be detected either by chloride of iron or by adding gelatin. But as tannin exists naturally in most of the red wines (Port, Beaune, Roussillon, Hermitage, &c.), the question becomes often one of quantity. The amount of tannin can be estimated by drying the tanno-gelatin, weighing it, and calculating on the basis that each 100 parts contain 40 of tannin.

Alum.—This is detected precisely in the same manner as in bread. Evaporate a pint of the wine to dryness; incinerate, and then proceed as directed in the EXAMINATION OF BREAD.

Lead.—Evaporate to dryness, and incinerate; dissolve in dilute nitric acid, and test as directed in the EXAMINATION OF WATER.

Copper.—Decolourise with animal charcoal, and test at once with ferrocyanide of potassium.

Port wine, as sold in the market, is stated to be a mixture of true Port, Marsala, Bordeaux, and Cape wines with brandy, although at present it is probably purer than it used to be, purer perhaps than most other wines. Inferior kinds are still adulterated with logwood, elderberries, catechu, prune juice, and a little sandalwood and alum.

SPIRITS.

Of all the alcoholic beverages, spirits contain the largest amount of alcohol. They are all made by the distillation of alcohol from the fermentation of various saccharine or starchy materials. The more common spirits in this country are brandy, whisky, rum, and gin. The basis of all of them is ethylic alcohol, mixed with water; but they all contain other alcohols, usually classed together under the name of fusel oil, various compound ethers and fragrant bodies produced during distillation. It is the varying proportions of these latter which give the respective spirits their characteristic taste and aroma. After being kept for some years, spirits become mellowed or softened down; this was formerly supposed to be due to the diminution of the so-called fusel oil, but it is now more generally regarded as due to a lessening both in quantity and quality of the empyreumatic or flavouring substances.

The following table gives the chief points of importance :—

Name.	Sp. gr. at 60° F.	Alcohol per cent.	Solids per cent.	Ash per cent.	Acidity per ounce, reckoned as tartaric acid.	Sugar per cent.
Brandy,	0·929-0·934	45-55	1·2	0·05-0·2	1 grain	0 or traces
Gin,	0·930-0·944	40-50	1·2	0·1	0·2	1
Whisky, .	0·915-0·920	50-55	0·6	trace	0·2	0
Rum,	0·874-0·926	50-60	1·0	0·1	0·5	0

Brandy is made by the distillation of fermented grape juice. When first distilled it is colourless, but gradually darkens with age, though too often artificially coloured by means of burnt sugar. Pure brandy consists of water, alcohol, acetic acid, acetic and œnanthic ethers, a volatile oil, colouring matter, and tannin. It usually contains from 45 to 55 per cent. of alcohol. The best kinds come from France, the more inferior from Spain, Portugal, and Italy. The chief adulterations are water, cayenne pepper, burnt sugar, and acetic ether. Some of the cheaper brandies are not made from grape juice at all, but are mere imitations, made from corn spirit, flavoured and coloured. According to Wynter-Blyth, a very usual process of making brandy artificially in England is to add to every 100 parts of proof spirit from ½ to 1 ℔ of argol, some bruised French plums, and a quart of good Cognac; the mixture is then distilled, and a little acetic ether, tannin, and burnt sugar added afterwards.

Whisky is really one of the corn spirits, being made from malted grain. The more inferior kinds are prepared from oats, barley, or rye, or from potatoes mashed up with malted barley and then roughly distilled and burnt in order to give it the peculiar smoky flavour characteristic of some varieties. Whisky usually contains from 40 to 50 per cent. of alcohol. Its adulterations are much the same as those of brandy.

Gin, in this country, is usually made from a mixture of malt and barley, flavoured not only with juniper berries, but with oil of turpentine, orange peel, and several other aromatic substances. In Holland, it is made from unmalted rye, and barley malt with juniper berries. In consequence of the juniper and turpentine contained in gin, it is a direct stimulant to the kidneys. It usually contains from 40 to 50 per cent. of alcohol. Its chief adulteration is water, which makes it turbid; to remove this, alum and acetate of lead are employed, followed by the addition of sugar and cayenne pepper to sweeten it and give it pungency. Speaking generally, gin is the spirit of which most is annually consumed by the public, and the spirit which is most often adulterated.

Rum is a spirit obtained by distillation from the fermented skimmings of sugar boilers or the drainings of sugar barrels (molasses). Like brandy, it is colourless when first distilled, but it is, later on, artificially coloured with burnt sugar. The peculiar flavour of rum is due to butyric ether and a volatile oil; the amount of alcohol present in rum is from 50 to 60 per cent. An imitation flavouring identical with that of the Jamaica rum, so often flavoured with slices of pine-apple, is made by distilling butter with sulphuric acid and alcohol, and then, by means of the resulting butyric compound, a factitious rum can be made from malt or molasses spirit.

When quite pure and free from water, alcohol is termed *absolute alcohol*, having a specific gravity, at 60° F., of 0·79381: when mixed with 16 per cent. of water, it is called *rectified spirit*, and when mixed with 56·8 per cent., volume in volume of water, it constitutes *proof spirit.*

Proof spirit is a term constantly in use for excise purposes, signifying a dilute spirit of definite strength. If expressed as volume in volume, proof spirit contains 56·8 per cent. of absolute alcohol: if as weight in weight, 49·25 per cent.: if as weight in volume, 45·4 per cent.: the remainder in each case being distilled water. The ratio of alcohol to proof spirit in each of these cases being for volume in volume, as 1 is to 1·76: for weight in weight, as 1 is to 2·03: and for weight in volume, as one is to 2·21. We can, therefore, if in any case the percentage of contained alcohol be known, calculate the amount of proof spirit present by multiplying the given percentage of alcohol by any of the foregoing ratios.

Spirits which are weaker than proof are described as being *under proof;* when stronger than proof, as being *over proof.* Thus, say a sample of whisky is found to contain 70 per cent., volume in volume, of alcohol;

then $70 \times 1·76 = 123·2$, and the excess of this product over 100, or 23·2, gives the number of degrees over proof which the sample is. If, on the other hand, it contained but 24 per cent. of alcohol, volume in volume, then $24 \times 1·76 = 42·24$, and by just so much as this figure is greater or less than 100, so is the sample degrees over or under proof, that being, in this case, just 57°·76 under proof. Conversely, if the degree of strength of any spirit over or under proof be known, the percentage of alcohol present can be calculated either as volume in volume, weight in weight, or weight in volume. Thus, say a sample of brandy be x degrees over proof; then $\frac{100+x}{1·76}$ gives the percentage, volume in volume, of alcohol which it contains. If it be x degrees under proof, then $\frac{100-x}{1·76}$ gives the percentage, volume in volume, again of alcohol.

The *Sale of Food and Drugs Amendment Act*, 1879, allows brandy, whisky, or rum to be 25 degrees under proof; equal to 42·6 per cent. of absolute alcohol, volume in volume, or 34·1 per cent. of weight in volume. This gives a specific gravity of 0·947. Gin is allowed to be 35 degrees under proof, equal to 36·9 per cent. volume in volume, or 29·5 per cent. weight in volume of absolute alcohol. This gives a specific gravity of 0·956. Proof spirit contains 56·8 volume in volume, or 45·4 weight in volume of absolute alcohol, sp. gr. 0·920, or 49·24 weight in weight per cent.

Although the alcohol in spirits can be determined by means of the specific gravities before and after de-alcoholisation, as explained for beer and wines, still the strength of spirits is freqently ascertained by the use of Sikes' hydrometer, and a book of tables for its employment.

A sample of the spirits to be tested is poured into a trial glass, and the temperature ascertained by means of a thermometer in the usual way. The hydrometer is taken, and one of the weights is attached to the stem below the ball: it is then pressed down to the 0 on the stem. If the right weight has been selected it will float up to one of the divisions on the stem. The number on the *stem* is then read off and added to the number on the *weight*; the sum is called the *indication*. The book of tables is then opened at the temperature first found, and the indication looked for in one of the columns: opposite it will be found the strength of the spirits *over* or *under* proof. If at the temperature 60° F. the *indication* is 58·8, then opposite this will be found zero, that is, the spirit is the exact strength of *proof*. If the indication is 50, then opposite that is 12·8, or the spirit is 12·8 *over* proof: if the indication is 70, then opposite is 18·9, or the spirit is 18·9 *under* proof. The meaning of these expressions is—(1) If the spirit be 12·8 over proof, then, in order to reduce it to proof, 12·8 gallons of water must be added to 100 gallons of the spirit: the resulting mixture will be proof; (2) if the spirit be 18·9 under proof, this means that 100 gallons contain only as much alcohol as 81·1 (*i.e.*, 100 − 18·9) of proof spirit: to raise it to proof it would have to be mixed with an equal quantity of spirit as much above proof as it is below it, so that $\frac{100 - 18·9 + 118·9}{2} = 100$.

The presence of sugar or extractives renders the use of the hydrometer fallacious unless the spirit is distilled off and the instrument then used on the distillate.

THE DIETETIC USE OF ALCOHOL AND ALCOHOLIC BEVERAGES.

In endeavouring to determine the dietetic value of alcoholic beverages, it is desirable to see, in the first place, what are the effects of their most important constituent, viz., alcohol.

Three sets of arguments have been used in discussing this question, drawn, namely, from—1, the physiological action of alcohol; 2, experience of its use or abuse; and 3, moral considerations.

The last point will not be further alluded to, for without underrating the great weight of the argument drawn from the misery which the use of alcohol produces,—a misery so great that it may truly be said, that if alcohol were unknown, half the sin and a large part of the poverty and unhappiness in the world would disappear,—yet this part of the subject is so obvious that it seems unnecessary to occupy space with it. The arguments, however, which are strongest for total abstinence, are drawn from this class. Nor does any one entertain a moment's doubt that the effect of intemperance in any alcoholic beverage is to cause premature old age, to produce or predispose to numerous diseases, and to lessen the chance of living very greatly. All statistics from life assurance offices and other provident institutions put this in a very strong light.

The physiological argument for the use or disuse of alcohol requires to be used with caution, as our knowledge of the action of pure alcohol (much more of the alcoholic beverages) is imperfect.

When taken into the stomach, alcohol is absorbed without alteration, or is perhaps in some small degree converted into acetic acid, possibly by the action of the mucus or secretion of the stomach. The rate of absorption is not known, and it has been supposed that when given in very large quantities it may not be absorbed at all. It has not, however, been recovered from the fæces in any great amount. After absorption it passes into the blood, and, according to Schmiedeberg, forms a compound with hæmoglobin, which more readily gives off oxygen than hæmoglobin itself. The result of this is that alcohol lessens oxidation in the blood and tissues. Most of the alcohol taken is oxidised in the body, the products being excreted in the urine. In dietetic doses, some of the alcohol may be detected in the expired air, but it can be detected in the urine only when the dose is excessive. The presence of alcohol in the urine is, therefore, to some extent, a chemical test of an excess of alcohol having been taken.

The place where the partial oxidation of alcohol occurs is yet doubtful; but it is not impossible that the transformation should take place in the various gland-cells in which almost all, or all, the changes in the body occur. As the change out of the body which most easily occurs is the formation of acetic acid, it seems at present most likely that some of the alcohol is thus transformed. The acetic acid would then unite with the soda of the blood, and a carbonate would eventually be formed which would be eliminated with the urine, as in the case when acetates are taken. This would account for the pulmonary carbonic acid not being increased. If this view be correct, the use of alcohol in nutrition would be limited to the effects it produces, first as alcohol, and subsequently as acetic acid, when it neutralises soda, and is then changed into carbonate.

The first point only (its effects as alcohol) need be considered.

In very small quantities it appears to aid digestion; in larger amount it checks it, reddens the mucous membrane, and produces the "chronic catarrhal condition" of Wilson Fox, viz., increase of the connective tissue between the glands ; fatty and cystic degeneration of the contents of the glands, and, finally, more or less atrophy and disappearance of these parts. Taken habitually in large quantities it lessens appetite.

The action of small quantities on the amount of bile, or glycogenic substances, or on the other chemical conditions of the liver, is not known. Applied directly to the liver by injection into the portal vein, it increases the amount of sugar (Harley). Taken daily in large quantities, it causes either enlargement of the organ by producing albuminoid and fatty deposit, or it causes at once, or following enlargement, increase of connective tissue, and, finally, contraction of Glisson's capsule, and atrophy of the portal canals and cells, by the pressure of a shrinking exudation. The exact amount necessary to produce these changes in the liver and stomach has not yet been fixed with precision.

It is said to lessen the amount of carbon dioxide (and of watery vapour ?) in the air of expiration, though there are some discrepancies in experiments with different kinds of spirits. E. Smith, for example, found the expired carbon dioxide lessened by brandy and gin, but increased by rum. It is very important that these experiments should be repeated, but they show, at any rate, that the usual effect is not to increase the carbon dioxide. In large quantities habitually taken it also alters the molecular constitution of the lungs, as chronic bronchitis and lobar emphysema are certainly more common in those who take much alcohol.

Alcohol, in healthy persons, increases the force and quickness of the heart's action. It further tends to increase the blood pressure, and to increase the flow of blood from the arteries into the veins. The effect on the blood pressure is, however, largely counterbalanced by a coincident dilatation of the cutaneous blood-vessels, which thus become flushed, and tend to produce more or less sensible perspiration.

In most persons, alcohol appears to act at once as an anæsthetic, lessening also the rapidity of impressions, the power of thought, and general acuteness and the perfection of the senses. In other cases it seems to cause increased rapidity of thought, and excites imagination, but even here the power of control over a train of thought is lessened. In no case does it seem to increase accuracy of sight ; nor is there any good evidence that it quickens hearing, taste, smell, or touch ; indeed, Edward Smith's experiments show that it diminishes all the senses. In almost all cases moderate quantities cause a feeling of comfort and exhilaration, which ensues so quickly as to make it probable that the local action on the nerves of the stomach has at first something to do with this. Afterwards the increased action of the heart may have an effect. Different spirits act differently on the nervous system, owing probably to the presence of the ethers and oils. Absinthe appears especially hurtful, apparently from the presence of the essential oils of anise, wormwood, and angelica, as well as from the large amount of alcohol.

In spite of much large experience, it is uncertain whether alcohol really increases mental power. The brain circulation is no doubt augmented in rapidity ; the nervous tissues must receive more nutriment, and for a time must work more strongly. Ideas and images may be more plentifully produced, but it is a question whether the power of clear, consecutive, and continuous reasoning is not always lessened. In cases of great exhaustion of the nervous system, as when food has been withheld for many hours and the mind begins to work feebly, alcohol revives mental power greatly, probably from the augmented circulation. But, on the whole, it seems questionable whether the brain finds in alcohol a food which by itself can aid in mental work.

After taking alcohol, voluntary muscular power seems to be lessened, and this is most marked when a large amount of alcohol is taken at once; the finer combined movements are less perfectly made. Whether this is by direct action on the muscular fibres, or by the influence on the nerves, is not certain. In very large doses it paralyses either the respiratory muscles or the nerves supplying them, and death sometimes occurs from the interference with respiration.

A small quantity of alcohol does not seem to produce much effect, but more than 2 fluid ounces manifestly lessens the power of sustained and strong muscular work. In the case of a man on whom Parkes experimented, 4 fluid ounces of brandy (= 1·8 fluid ounce of absolute alcohol) did not apparently affect labour, though it could not be affirmed it did not do so; but 4 ounces more given after four hours, when there must have been some elimination, lessened muscular force; and a third 4 ounces, given four hours afterwards, entirely destroyed the power of work. The reason was evidently twofold. There was, in the first place, narcosis and blunting of the nervous system—the will did not properly send its commands to the muscles, or the muscles did not respond to the will; and, secondly, the action of the heart was too much increased, and induced palpitation and breathlessness, which put a stop to labour. The inferences were, that even any amount of alcohol, although it did not produce symptoms of narcosis, would act injuriously, by increasing unnecessarily the action of the heart, which the labour alone had sufficiently augmented. These experiments are in accord with common experience, which shows that men engaged in very hard labour, as iron-puddlers, glass-blowers, navvies on piece-work, and prize-fighters during training, do their work more easily without alcohol.

In the exhaustion following great fatigue, alcohol may be useful or hurtful according to circumstances. If exertion must be resumed, then the action of the heart can be increased by alcohol and more blood sent to the muscles; of course, this must be done at the expense of the heart's nutrition, but circumstances may demand this. In the case of an army, for example, called on to engage the enemy after a fatiguing march, alcohol might be invigorating. But the amount must be small, *i.e.*, much short of producing narcosis (not more than $\frac{1}{2}$ fluid ounce of absolute alcohol), and, if possible, it should be mixed with Liebig's meat extract, which, perhaps on account of its potash salts, has a great power of removing the sense of fatigue.

About two ounces of red claret wine with two teaspoonfuls of Liebig's extract and half pint of water is a very reviving draught, and if it could be issued to troops exhausted by fatigue, would prove a most useful ally.

But when renewed exertion is not necessary it would appear most proper after great fatigue to let the heart and muscles recruit themselves by rest; to give digestible food, but to avoid unnecessary and probably hurtful quickening of the heart by alcohol.

How far alcohol sensibly lowers the temperature of the body in health is still a matter of dispute, but there is no doubt that in some cases of fever, especially in children, alcohol does lower the temperature. Lauder Brunton has suggested that, in health, it tends to lower the body temperature in two ways: first, in medium doses, "by dilating the cutaneous vessels, whereby more blood comes to the surface of the body, and thus more heat is lost by radiation and by means of the increased perspiration; second, when given in large doses, by lessening the processes of oxidation in the body." Although there are doubts whether alcohol really lowers the temperature of the healthy body, there is no doubt whatever that it lowers the natural resistance of the body against cold. "When a person is exposed to extreme cold for long periods, as in the Arctic regions, he may derive some temporary comfort and sensation of warmth from taking alcohol; but his power of resistance to the intense cold is lessened, and instances have been recorded where death has occurred under such conditions during sleep."

Under circumstances of great heat, the evidence is almost equally conclusive against the use of spirits or beverages containing much alcohol. It seems quite certain, also, that not only is heat less well borne, but that heat-stroke is predisposed to.

When there is want of food, it is generally considered that alcohol has a sustaining force, and possibly it acts partly by keeping up the action of the heart, and partly by deadening the susceptibility of the nerves. It was formerly supposed that it lessened tissue-change, and thus curtailed the waste of the body; but this is not true of the nitrogenous tissues, and it is not yet quite certain in respect of the carbonaceous. It seems unlikely that alcohol would be applied differently during starvation and during usual feeding.

Cases are recorded in which persons have lived for long periods on almost nothing but wine and spirits. In most cases, however, some food has been taken, and sometimes more than was supposed, and in all instances there has been great quietude of mind and body. It seems very doubtful whether in any case nothing but alcohol has been taken; and, in fact, we may fairly demand more exact data before weight can be given to this statement.

There are instances for and against the view that spirits are useful against malaria. On both sides the evidence is defective; but there are so many cases in which persons have been attacked with malarious disease who took spirits, that it is impossible to consider the preventive powers great, even if they exist at all. On the other hand, when teetotallers have escaped malaria there have been other circumstances, such as more abundant food and better lodging, which will explain their exemption. The probability is, that the reception and action of malaria are not influenced by the presence or absence of alcohol in the blood unless the amount of alcohol is so great as to lessen the amount of food taken.

Alcohol is contra-indicated where zymotic diseases generally are likely to be prevalent, as it retards due elimination of effete azotised products, and thus renders the system more prone to disease. On the other hand, there is no direct evidence that teetotallers are more exempt from cholera, yellow fever, and other zymotics than those who use alcohol with moderation.

The question arises, is alcohol desirable as an article of diet in health? To it a satisfactory answer can hardly be given, with our present knowledge. The data for passing a judgment are partly physiological, but still more largely empirical.

The obvious useful physiological actions of alcohol are an improvement in appetite, produced by small quantities, and an increased activity of the circulation, which, within certain limits, may be beneficial. It is difficult to perceive proof at present of any other useful action, since it is uncertain whether, during its partial destruction in the system, it gives rise to energy. In cases of disease, in addition to its effect on digestion and circulation, its narcotising influence on the nervous system may be sometimes useful. Beale suggests that it may restrain the rapidity of abnormal growth or development of multiplying cells, and that by such arrest it may possibly diminish bodily temperature; but proof of this has not been given.

The dangerous physiological actions in health, when its quantity is larger, are evidently its influence on the nervous system generally, and on the regulating nerve-centres of the heart and vaso-motor nerves in particular; the impairment of appetite produced by large doses; the lessening of muscular strength; and remotely the production of degenerations. Except when it lessens appetite, it does not alter the transformation of the nitrogenous tissues and the elimination of nitrogen; nor can it be held to be absolutely proved to lessen the excretion of carbon. If it did so, this effect in health would be simply injurious.

It is a matter of the highest importance to determine when the limit of the useful effect of alcohol is reached. The experiments are few in number, but are tolerably accurate. From experiments made by Anstie, an amount of one fluid ounce and a half (42·6 c.c.) caused the appearance of alcohol in the urine, which Anstie regards as a sign that as much has been taken as can be disposed of by the body. Parkes and Wollowicz obtained almost precisely the same result. When only one fluid ounce of absolute alcohol was given none could be detected in the urine. They found that in a strong healthy man, accustomed to alcohol in moderation, the quantity given in twenty-four hours that begins to produce effects which can be considered injurious is something between one fluid ounce (= 28·4 c.c.) and two fluid ounces (56·7 c.c.). The effects which can then be detected are slight but evident narcosis, lessening of appetite, increased rapidity of rise in the action of the heart, greater dilatation of the small vessels as estimated by the sphygmograph, and the appearance of alcohol in the urine. These effects manifestly mark the entrance of that stage in the greater degrees of which the poisonous effects of alcohol become manifest to all.

It may be considered, then, that the limit of the useful effect is produced by some quantity between 1 and 1½ fluid ounce in twenty-four hours. There may be persons whose bodies can dispose of larger quantities; but as the experiments were made on two powerful healthy men, accustomed to take alcohol, the average amount was more likely to be over than under stated. In women, the amount required to produce decided bad effects must, in all probability, be less. For children, there is an almost universal consent that alcohol is injurious, and the very small quantity which produces symptoms of intoxication in them indicates that they absorb it rapidly and tolerate it badly.

Assuming the correctness of these experimental data, which, though not extensive, are yet apparently exact, it is evident that moderation must be something below the quantities mentioned; and considering the dangers of taking excess of alcohol, it seems wisest to assume 1 to 1½ fluid ounce of absolute alcohol in twenty-four hours as the maximum amount which a healthy man should take. It must be admitted that this is provisional, and that more experiments are necessary; but it is based on the only safe data we possess. One ounce is equivalent to 2 fluid ounces of brandy (containing 50 per cent. of alcohol); or to 5 ounces of the strong wines (sherries, &c., 20 per cent. of alcohol); or to 10 ounces of the weaker wines (clarets and hocks, 10 per cent. of alcohol); or to 20 ounces of beer (5 per cent. of alcohol). If these quantities are increased one-half, 1½ ounce of absolute alcohol will be taken, and the limit of moderation for strong men is reached. This standard appears to be fairly correct; since, from inquiries of many healthy men who take alcohol in moderation, Parkes found that they seldom exceeded the above amounts. Women, no doubt, ought to take less; and alcohol in any shape only does harm to healthy children.

Another question now arises, to which it is more difficult to reply. Is alcohol, even in this moderate amount, necessary or desirable? are men really better and more vigorous, and longer lived with it than they would be without any alcohol? If distinctly hurtful in large quantities, is it not so in these smaller amounts?

There is no difficulty in proving, statistically, the vast loss of health and life caused by intemperance; and the remarkable facts of the Provident Institution show the great advantage total abstainers have over those who, though not intemperate, use alcohol more freely. But it is almost impossible, at present, to compare the health of teetotallers with those who use alcohol in the moderate scale given above. In both classes are found men in the highest health, and with the greatest vigour of mind and body; in both are to be found men of the most advanced age. If the question is looked at simply as a scientific one, it is hardly possible at present to give an answer. Failing in accurate information on this point, the usual arguments for and against the use of alcohol cannot be held to settle the point. These are—

(*a*) That the universality of the habit of using some intoxicating drink proves utility. This seems incorrect, since whole nations (Mohammedan and Hindoo) use no alcohol or substitute; and since the same argument might prove the necessity of tobacco, which, for this generation at any rate, is clearly only a luxury. The wide-spread habit of taking intoxicating liquids merely proves that they are pleasant.

(*b*) That if not necessary in healthy modes of life, alcohol is so in our artificial state of existence, amid the pressure and conflict of modern society. This argument is very questionable, for some of our hardest workers and thinkers take no alcohol. There are also thousands of persons engaged in the most anxious and incessant occupations who are total abstainers, and, according to their own account, with decided benefit.

(*c*) That though it may not be necessary for perfectly healthy persons, alcohol is so for the large class of people who live on the confines of health, whose digestion is feeble, circulation languid, and nervous system too excitable. It must be allowed there are some persons of this class who are benefited by alcohol in small quantities, and chiefly in the form of beer or light wine. Unless these persons wilfully deceive themselves, they feel better, and are better, with a little alcohol.

(*d*) That common experience on the largest scale shows that alcohol in not excessive quantities cannot be an agent of harm; that it is and has been used by millions of persons who appear to suffer no injury, but to be in many cases benefited, and therefore that it must be in some way a valuable adjunct to food. A grand fact of this kind must, it is contended, override all objections based on physiological data, which are confessedly incomplete, and which may have left undiscovered some special useful action. It must be admitted that this is a very strong argument, and that it seems incredible that a large part of the human race should have fallen into an error so gigantic as that of attributing great dietetic value to an agent which is of little use in small quantities, and is hurtful in large. At first sight the common sense of mankind revolts at such a supposition, but the argument, though strong, is not conclusive; and unfortunately we know that in human affairs no extension of belief, however wide, is *per se* evidence of truth.

(*e*) That though a man can do without alcohol under ordinary circumstances, there are certain conditions when it is useful.

These considerations make it difficult to avoid the conclusion that the dietetic value of alcohol has been much overrated. It does not appear possible at present to condemn alcohol altogether as an article of diet in health, or to prove that it is invariably hurtful, as some have attempted to do. It produces effects which are often useful in disease and sometimes desirable in health, but in health it is certainly not a necessity, and many persons are much better without it. As now used by mankind (at least in our own, and in many other countries), it is infinitely more powerful for evil than for good; and though it can hardly be imagined that its dietetic use will cease in our time, yet a clearer view of its effects must surely lead to a lessening of the excessive use which now prevails. As a matter of public health, it is most important that the medical profession should throw its great influence into the scale of moderation; should explain the limit of the useful power, and show how easily the line is passed which carries us from the region of safety into danger, when alcohol is taken as a common article of food.

In the previous remarks, the effect of alcohol only has been discussed, but beer and wine contain other substances besides alcohol.

In beer there appear to be four ingredients of importance, viz., the extractive matters and sugar, the bitter matters, the free acids, and the alcohol. The first, no doubt, are carbo-hydrates, and play the same part in the system as starch and sugar, appropriating the oxygen, and saving fat and proteids from destruction. Hence one cause of the tendency of persons who drink much beer to get fat. The bitter matters are supposed to be stomachic and tonic; though it may be questioned whether we have not gone too far in this direction, as many of the highest priced beers contain now little else than alcohol and bitter extract. The action of the free acids is not known; but their amount is not inconsiderable; and they are mostly of the kind which form carbonates in the system, and which seem to play so useful a part. The salts, especially potassium and magnesium phosphates, are in large amount.

It is evident that in beer we have a beverage which can answer several purposes, viz., can give a supply of carbo-hydrates, of acid, of important salts, and of a bitter tonic (if such be needed), independent of its alcohol, but whether it is not a very expensive way of giving these substances is a question.

In moderation, it is no doubt well adapted to aid digestion, and to lessen to some extent the elimination of fat. It may be inferred that beer will cause an increase of weight of the body, by increasing the amount of food taken in, and by slightly lessening metamorphosis; and general experience confirms those infcrences. When taken in excess, it seems to give rise to gouty affections more readily even than wine.

In wine there are some proteid substances, much sugar (in some wines), and other carbo-hydrates, and abundant salts. Whether it is that the amount of alcohol is small, or whether the alcohol be itself, in some way, different from that prepared by distillation, or whether the co-existence of carbo-hydrates and of salts modifies its action, certain it is that the moderate use of wine, which is not too rich in alcohol, does not seem to lead to those profound alterations of the molecular constitution of organs which follow the use of spirits, even when not taken largely. Considering the large amounts of vegetable salts which most wines contain, it may reasonably be supposed that they play no unimportant part in giving dietetic value to wine. Indeed, it is quite certain that, in one point of view, they are most valuable; they are highly anti-scorbutic, and the arguments of Lind and Gillespie, for the introduction of red wine into the Royal Navy instead of spirits, have been completely justified in our own time by both French and English experience. It is now certain that with the same diet, but giving in one case red wine, in another rum, the persons on the latter system will become scorbutic long before those who take the wine. This is a most important fact, and in a campaign the issue of red wines should never be omitted. The ethers may also be important if, as indicated by Bernard, and recently pointed out by Sir B. W. Forster, they excite the flow of the pancreatic secretion, and thereby promote the absorption of fat.

In spirits, alcohol is the main ingredient, chiefly in the form of ethyl-alcohol, though there are small amounts of propyl-, butyl-, and in some cases amyl-alcohols. In addition, there are sometimes small quantities of ether; and, in some cases, essential oils (as apparently in absinthe, and in one kind of Cape brandy), which have a powerful action on the nerves. But spirits are, for the most part, merely flavoured alcohol, and do not contain the ingredients which give dietetic value to wine and beer. They are also more dangerous, because it is so easy to take them undiluted, and thus to increase the chance of damaging the structure and nutrition of the albuminous structures with which they come first in contact. There is every reason, therefore, to discourage the use of spirits, and to let beer and wines, with moderate alcoholic power, take their place.

Some of the undoubtedly deleterious effects of crude spirits must be ascribed to the presence of furfurol, and other bodies which both diminish in quantity and change in quality, as the spirit "mellows" with age. These substances, as present in new spirit, tend to derange digestion and also appear to have a profound effect upon the nervous system.

TEA.

Tea consists of the dried leaves of a shrub called the *Camellia thea*, which grows in China, India, Ceylon, and Japan. As met with in everyday life, tea-leaves are curled, but they uncurl on being placed in hot water, and when so treated are found to have a characteristic shape and structure. The border is serrated nearly, but not quite to the stalk; the primary veins run out from the midrib nearly to the border, and then turn in, so that a distinct space is left between them and the border. The leaf may vary in point of size and shape, being sometimes broader, and sometimes long and narrow. The border and the primary venation distinguish it from all leaves (fig. 55). The leaves which it is said have been mixed with or substituted for tea in this country are the willow, sloe, oak, Valonia oak, plane, beech, elm, poplar, hawthorn, and chestnut; and in China *Chloranthus inconspicuus* and *Camellia Sasanqua* are said to be used. Of these the willow and the sloe are the only leaves which at all resemble tea-leaves. The willow is more irregularly, and the sloe is much less perfectly and uniformly serrated.

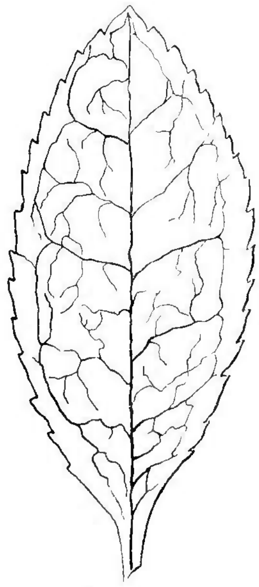


Fig. 55.

To examine the leaves, make an infusion, and then spread out a number of leaves; if a leaf be placed on a glass slide, and covered with a thin glass, and then held up to the light, the border and venation can usually be well seen.

The leaves of the Valonia, if used, are at once detected by acicular crystals being found under the microscope.

Sometimes exhausted tea-leaves are mixed with catechu or with a coarse powder of a reddish-brown colour, consisting chiefly of powdered catechu. Gum and starch are added, the leaves being steeped in a strong solution of gum, which, in drying, contracts them. The want of aroma, and the collection at the bottom of the infusion of powdered catechu, or the detection of particles of catechu, will at once indicate this falsification, which is, however, very uncommon. Sand and magnetic oxide of iron are added by the Chinese. At first the latter was mistaken for iron filings; and when it was proved to be really magnetic oxide, it was suggested that it came accidentally from the soil where the tea was cultivated, but there exist good reasons for considering its presence to be due to wilful addition.

Practically all tea in the market is grown from the same species of shrub, the various names given as indicating different kinds are only trade names, and do not indicate really different varieties of tea-leaf so much as different qualities dependent upon mixing or blending, and on the age of the leaves, or on the soil on which the plant has been grown. In all cases, the leaf most highly valued is the small top leaf of the twig and the bud. Possibly these small leaves are neither finer in quality nor richer and better in flavour than the leaves next in succession, but being more tender and softer in structure give better and more flavoured infusions. The various teas known under the trade names of Orange Pekoe, Pekoe, Suchong, Congou are all the same in respect of origin; they are picked at the same time from the same shrub. The bud and top leaf constitute Orange Pekoe, the two or three larger leaves growing on the same twig a little lower down are Suchong, and below that the leaves become Congou.

The most simple division of teas is into the green and the black; both are from the same plant, the only difference is their colour. Green tea is now little used, in consequence of the disrepute into which it fell as the result of the artificial colouring it received; but real green tea owes its coloration to being dried over wood fires when fresh. Black teas owe their colour to the leaves having been allowed to lie in heaps for twelve hours, during which they undergo a process of fermentation and are afterwards dried slowly over charcoal fires. "Brick tea" is made from the refuse, broken leaves and twigs, moulded into shapes. "Lie tea" consists of the dust of tea and other leaves made up by means of gum or starch into little masses, which are coloured or painted so as to resemble black or green tea; it is called "lie" tea because it is a false article and not tea at all. In selecting a fine tea, one should not be guided by any trade name, but determine, by pouring a little boiling water over the leaves and examining them, whether the leaf was a whole leaf and not a large leaf cut into small pieces. The larger the leaf, the weaker will be the infusion and the less the value. What are called "digestive" teas are varieties in which the tannin of the tea has been so altered by electrical treatment that it does not precipitate gelatin, and interferes but little with the digestion of starch.

The average percentage composition of tea may be expressed as follows:

Water,	8·0	
Thein,	2·6	
Tannin,	14·0	
Oil, .	0·4	
Extractives,	15·0	
Insoluble organic matter,	54·0	
Ash,	6·0	Potash, iron, silica, alumina, magnesia.

There is rather more tannic acid, and more thein and ætherial oil, in green than black tea, but less cellulose: otherwise the composition is much the same.

The most essential points in making good tea of the finest quality, and with the least waste, are to have actually boiling water, and tea-leaves so crushed and subdivided that the largest possible surface is rapidly exposed to the boiling water in infusing it. This explains why the best tea infusion in the world is that made by the Japanese from their carefully prepared "tea powder," which is made by crushing to a fine powder certain well-selected leaves. The tea bricks of China probably owe their superiority to being well-crushed leaves of good quality. About $\frac{6}{7}$ths of the soluble matters in the tea-leaves are taken up by the first infusion with hot water.

If water contain much lime or iron it will not make good tea; in each case the water should be well boiled with a little carbonate of soda for fifteen or twenty minutes, and then poured on the leaves.

In the infusion are found dextrin, glucose, tannin, and thein. About 47 per cent. of the nitrogenous substances pass into the infusion, and 53 per cent. remain undissolved. If soda is added, a still greater amount is given to water. The amount of tannin taken up by the infusion varies according to the character of the tea as well as the time the infusion is allowed to stand: the following numbers are given by Hale White:—

	Per cent. by weight after 3 minutes.	After 15 minutes.
Finest Assam,	11·30	17·73
Finest China,	7·77	7·97
Common Congou,	9·37	11·15

As an article of diet, tea seems to have a decidedly stimulant and restorative action on the nervous system, followed by no after-depression. This effect is mainly due to the alkaloid thein which it contains, aided, perhaps, by the warmth of the infusion. Thein or caffein is chemically trimethyl xanthin or methyl theobromine, $C_8H_{10}N_4O_2$. Though considered to be chemically identical with caffein, thein differs somewhat from it in physiological action. After taking tea, the pulse is a little quickened, the action of the skin increased, and that of the bowels lessened. The kidney excretion is little affected, at most the urea is slightly diminished, but the evidence with respect to this is somewhat contradictory. Roberts has shown that tea retards both salivary and peptic digestion, and it is probable that most of the symptoms resulting from excessive consumption of tea are those of delay of digestion, that is, of food remaining undigested in the stomach. A prevalent idea is that the tannin, in tea, chiefly produces the disturbances of digestion so commonly associated with abuse of tea; according to Roberts, however, it is not clear what constituent of tea is the really active agent in producing dyspepsia.

Examination of Tea.—Judge of the aroma of the dry tea and its infusion; spread out the leaves and see their characters; collect anything like mineral powder and examine under microscope. The microscope will also show if the tea has deteriorated by keeping; sometimes *acari*, *fungi*, and *bacteria* may be found.

The tea should not be too much broken up, or mixed up with dirt. Spread out, the leaves should not be all large, thick, dark, and old, but some should be small and young. There will always be in the best tea a good deal of stalk and some remains of the flower. In old tea much of the ætherial oil evaporates, and the aroma is less marked.

The infusion should be fragrant to smell, not harsh and bitter to taste, and not too dark. The buyers of tea seem especially to depend on the smell and taste of the infusion.

Formerly, the chief adulteration of tea was by mixing with it other leaves, such as those of the sloe and willow, which have a superficial resemblance to tea-leaves. At the present time the chief adulteration of tea is the admixture of old and exhausted tea-leaves, while in the inferior kinds there is often clay, lime, or ferruginous sand. The total soluble matters obtainable from tea are a ready and convenient index of its quality: they are estimated by infusing a weighed quantity with an excess of distilled water, and evaporating this down to dryness; the amount of extract so obtained should be at least 30 per cent. If the sample contain many exhausted leaves, the amount of extract obtained will be, of course, less than this.

To make the infusion, take 10 grammes of tea, and infuse in 500 c.c. of *boiling* distilled or rain water. Let it stand five or six minutes before smelling and tasting it. Exhaust the leaves by boiling with successive portions of water, until no colour is given up to the water. Measure the total amount of the infusion and decoction mixed together; take 100 c.c. and dry it in a water bath, and weigh. Calculate out the percentage. The sp. gr. of the infusion will be found, if made from a good tea, to vary from 1011 to 1015.

Example.—The total quantity of the infusion from 10 grammes of tea was 1890 c.c.; 100 c.c. taken and dried yielded 0·21 of extract; then $\frac{1890}{100} \times 0{\cdot}21 = 3{\cdot}969$ of extract in 10 grammes; this multiplied by $10 = 39{\cdot}69$ per cent.

The exhausted leaves may also be dried and weighed, the loss representing the amount of extract, which ought to correspond with the amount obtained directly.

The ash should also be determined; 5 or 10 grammes are to be incinerated; the ash is generally grey, sometimes slightly greenish. Any excess above 6 per cent. is suspicious; if above 8 per cent. on the *perfectly dry tea*, adulteration is certain. About one-half of the ash is soluble in water; the solution is often (but not always) pink, from the presence of manganese. The amount and character of the ash form good means of detecting the use of exhausted leaves.

The acidity of the infusion, and the amount of tannin and thein, may also be determined; as also the chlorine, alkalinity, and iron of the ash. The best tests of the *quality* of the tea are the aroma and the physical characters.

Extraction of Thein.—Occasionally it may be desired to determine the quantity of thein. Take 10 grammes of tea, exhaust with boiling water, and add solution of subacetate of lead; filter; pass hydrosulphuric acid through to get rid of excess of lead; filter; evaporate to small bulk, and add a little ammonia; add more water, decolourise with animal charcoal, and evaporate slowly to small bulk. White feathery crystals of thein form, which should be collected on filtering paper, dried at a very low heat, and weighed.

Determination of Tannin.—Make an infusion and add solution of gelatin; collect precipitate, dry and weigh—100 = 40 of tannin.

COFFEE.

Coffee is the seed or berry of the *Caffea Arabica*, a plant growing in most parts of the tropics, but chiefly in Arabia, Abyssinia, Ceylon, and the West Indies. After the seeds have been roasted to a chocolate brown, they are ground to a powder in a mill, and then used in the form of a decoction or infusion. The percentage composition of unroasted coffee may be expressed as follows:—

Water,	11·23
Nitrogenous matter,	12·07
Caffein,	1·21
Fat,	12·27
Sugar or dextrin,	8·55
Tannin,	32·79
Cellulose,	18·17
Salts,	3·71

The chief properties of coffee depend upon an aromatic oil and the alkaloidal body, caffein. Caffein itself is a nitrogenous crystalline alkaloid, identical with thein; in the roasting of coffee, this body is not destroyed, but dissociated, as it were, from its previously existing combination with tannin. During the same process, the sugar and dextrin are changed into caramel, and the gas and water of the berry driven off.

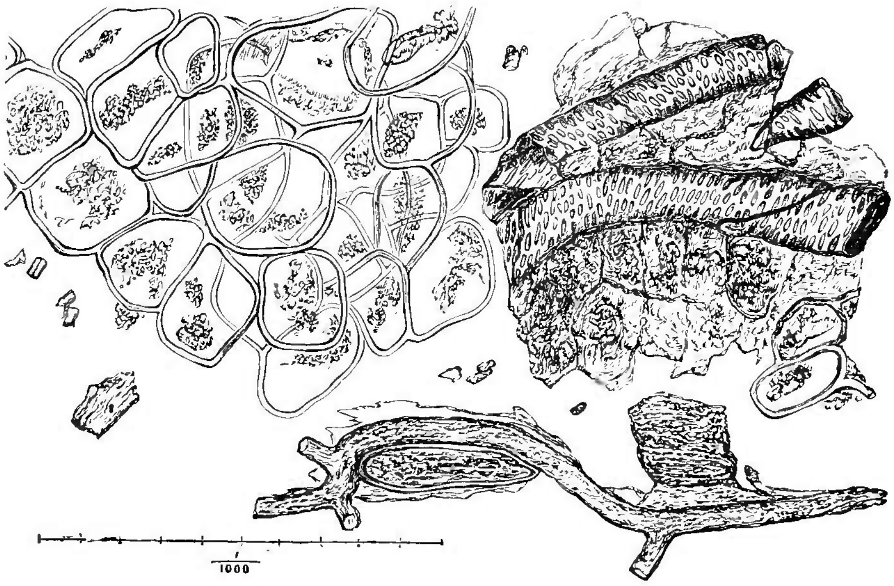


Fig. 56.

As an article of diet, coffee stimulates the nervous system, and in large doses produces tremors. Caffein given to animals augments reflex action, and may produce tetanus, or peculiar stiffness of muscles. It increases the frequency of the pulse in men (but taken in large quantity diminishes it), and removes the sensation of commencing fatigue during exercise. It has been said (J. Lehmann and others) to lessen the amount of urea and phosphoric acid, but this is doubtful. It appears, however, to increase the urinary water. The pulmonary carbon dioxide is said to be increased (E. Smith), as well as the action of the skin.

Sir W. Roberts' experiments showed that coffee does not retard the salivary digestion as compared with tea, and he considers that this can be accounted for by the fact that in coffee tannin is replaced by caffeo-tannic acid. Coffee, however, was found to exercise a greater retarding influence on stomach digestion than tea, on account of its being taken in much stronger infusion. It slightly increases the action of the kidneys, and with some stimulates the intestines so as to act as an aperient.

To make good coffee, the berry must be freshly roasted. Good drinkable coffee requires as much as an ounce of recently roasted and ground coffee to each large cup, the result of which means that the cost of a cup of good coffee, including milk and sugar, is about twopence. The prevalent custom of making coffee in this country is to use barely an ounce to two pints of water, the resulting infusion being more or less mawkish, tasteless, and wanting in stimulating properties.

Detection of Adulterations.—The adulterations of coffee are chiefly chicory, but at times dates, beans, maize, and acorns have been added. Chicory is a legal addition to coffee, provided such admixture is stated, no limit being fixed as to their relative proportions: as a rule, it amounts to about 30 per cent. The addition of chicory to coffee is considered by most people to add to its flavour. It is probable that much of the present decadence of coffee drinking is due to want of care in its preparation, and the excessive addition of chicory, whereby the resulting infusion is wanting in the desired alkaloid caffein.

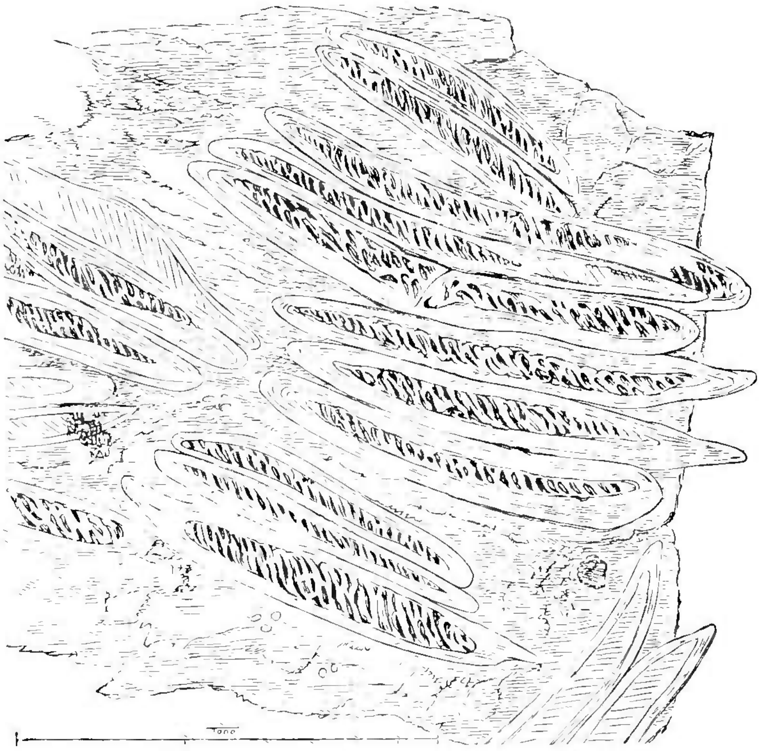


Fig. 57.

Chicory is the dried and powdered root of the wild endive (*Cichorium intybus*). In composition it differs much from coffee, containing no caffein, less fat, but more sugar. It may be readily distinguished from coffee by the fact that when thrown into water it rapidly sinks and colours the liquid brown, while coffee floats and does not yield any colour. The surest test, however, is microscopical examination, as both the cells and dotted ducts of chicory (fig. 56) are quite characteristic: at least nothing like them exists in coffee. The long cells of the testa of coffee berries are equally marked (fig. 57). The interior of the berry also presents characters which are quite evident: an irregular areolar tissue containing light or dark yellow angular masses and oil globules, such as are very different from any adulterations. The little corkscrew-like unrolled spiral fibres are chiefly found in the bottom of the raphe.

The percentage of ash has been suggested as a means of detection. Coffee yields about 4 per cent., of which four-fifths are soluble in water: chicory yields only about 5 per cent., of which only one-third is soluble.

Chicory contains a notable amount of sugar, 10 to 18 per cent., whereas roasted coffee has never more than 1 per cent. Wanklyn has proposed to make this a basis of detection, using the standard copper solution.

Other methods for the estimation of chicory in mixtures of coffee and chicory are based respectively upon the specific gravity of the infusion, and upon the amount of solid extract obtainable from it. Take 10 grammes of the sample, infuse in 100 c.c. of water, boil for half a minute, filter, and after filtrate cools to 60° F., take the specific gravity. The sp. gr. of a 10 per cent. infusion of pure coffee is 1010, that of a similar infusion of pure chicory, 1022: that is, a standard difference of 12 between the two specific gravities.

Example.—Say the sp. gr. of the infusion made from sample $= 1014$,
then difference between sp. gr. of sample and coffee or $1014 - 1010 = \frac{4}{12}$ of $100 = 33{\cdot}3$ per cent. of chicory;
then difference between sp. gr. of sample and chicory or $1014 - 1022 = \frac{8}{12}$ of $100 = 66{\cdot}7$ per cent of coffee.

Next place the filter with the coffee dregs on it into a large flask with 150 c.c. of water. Stir gently, boil for five minutes, allow sediment to subside, filter off the supernatant liquid and add filtrate to the original filtrate obtained above. Allow to cool, measure, and make up with distilled water to 250 c.c.: mix the whole thoroughly, then pipette 50 c.c. ($= 2$ grammes of the sample) of this infusion into a weighed capsule. Evaporate to dryness over a water bath, re-weigh, and calculate solid extract as a percentage.

Treated as above, chicory gives a mean percentage extract of 70; while coffee gives a remarkably constant percentage extract of 24; or a standard difference of 46. Consequently, we have percentage of coffee $=$

$$\frac{100\ (70 - \text{percentage of extract found})}{46}.$$

Example.—Say 50 c.c. of infusion ($= 2$ grammes of the sample) have yielded $1{\cdot}03$ gramme of extract: this equals $51{\cdot}5$ percentage of extract, and $\frac{100\,(70 - 51{\cdot}5)}{46} = 40$ per cent. of coffee in the sample.

Roasted corn or beans are at once known by the starch grains, which commonly preserve their characteristic form. Iodine turns them at once blue, while the infusion will also give a blue with iodine. Potato starch is also at once detected, there being nothing like it in coffee. Sago starch, which is sometimes used, is also easily detected. The presence of sugar can be readily estimated by the standard copper solution: if caramel has been added, the extract will be found to be brittle, dark coloured, and bitter to the taste.

Occasionally, chicory itself is adulterated with mangel-wurzel, parsnip, carrot, acorn, or sawdust. The cells of mangel-wurzel are like chicory, but much larger; those of carrot and parsnip are something like chicory, but contain starch cells; the starch grains of the acorn are round or oval, with a deep culvert depression, or hilum. The infusion of chicory is not turned blue by iodine; when incinerated the ash of chicory should not be less than 5 per cent.

DESCRIPTION OF PLATE II.

Fig. 1.—COFFEE.

A loose mesh of irregularly hexagonal cells, thick walled, and enclosing oil drops with amorphous material.

Fig. 2.—COFFEE ADULTERATED WITH CHICORY.

Chicory alone appears in this field. It is a mass of confused cellular tissue traversed by two broad bands with transverse markings. These bands are the juice ducts.

Fig. 3.—MUSTARD.

Fine granular masses, with drops of oil.

Fig. 4.—PEPPER.

Adulterated with wheat (the large round grains), maize (the next smaller angular grains), and buckwheat (the smallest angular grains).

Fig. 5.—CAYENNE.

This is from a genuine specimen.

Fig. 6.—COMPOUND GINGER.

Consisting chiefly of wheat, maize, and saw-dust. The mass in the upper right-hand corner shows the characteristic structure of soft wood.

(To Binder—To face Plate II.)

PLATE II.

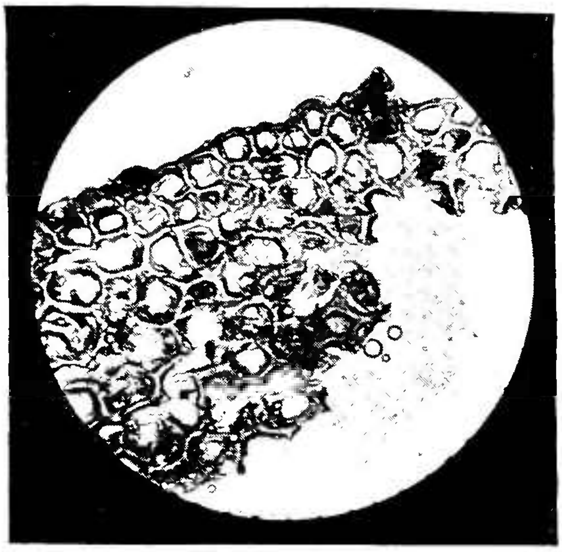


Fig. 1.—Coffee.

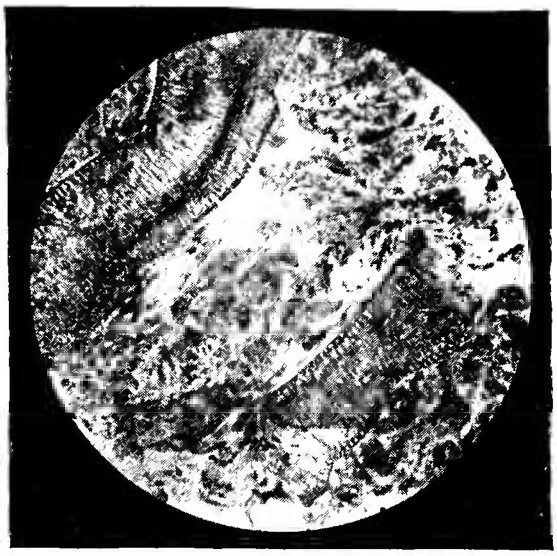


Fig. 2.—Coffee and Chicory.

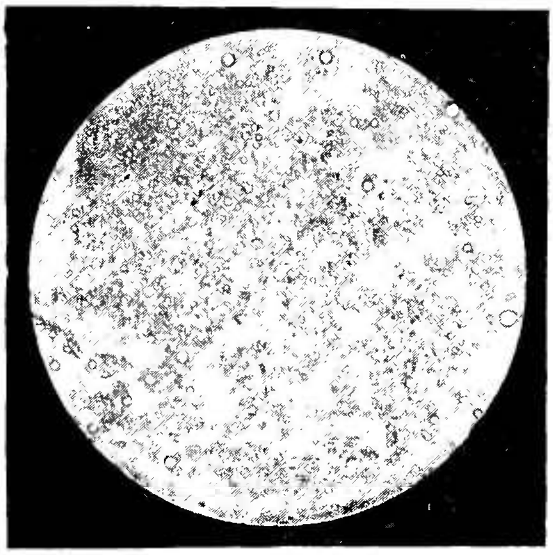


Fig. 3.—Mustard.

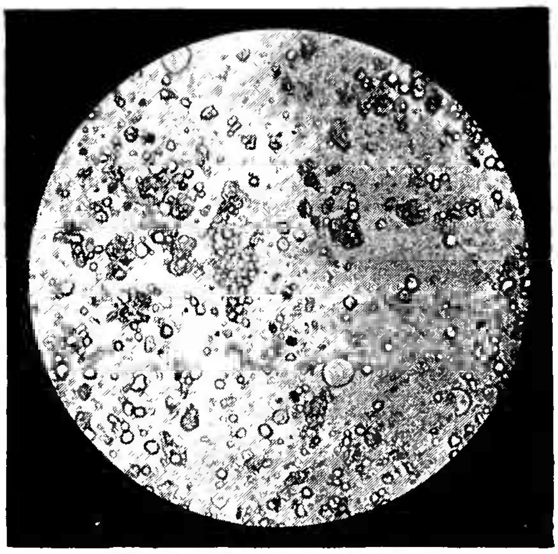


Fig. 4.—Pepper and Wheat.

Fig. 5.—Cayenne.

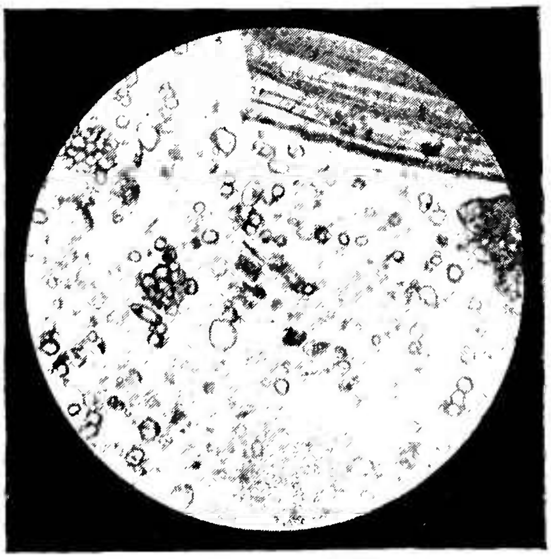


Fig. 6.—Compound Ginger.

PARAGUAY TEA, KOLA, AND COCA.

Paraguay tea, sometimes known as *maté*, is obtained by roasting the leaves of *Ilex paraguayensis* and exposing them to the action of the sun. It is much used in various parts of South America. The mean of several analyses of dried *maté* show it to contain 3·87 per cent. of proteids, about 3 per cent. of fats and resinous oil, 2·38 per cent. of sugar, 3·92 per cent. of salts, about 1 per cent. of thein and 4 per cent. of tannin. About 24 per cent. of the solids are soluble in water. Its infusion has an action similar to other thein-containing beverages, but is more apt, it is said, to cause digestive disturbance.

Closely allied to Paraguay tea is **Guarana**, obtained by roasting the seeds of *Paullinia sorbilis*. It contains nearly 5 per cent. of thein or caffein, and has some medicinal value in migraine.

Kola is prepared from the seeds of the *Sterculia acuminata*, a tree resembling the chestnut and growing wild on the west coast of Africa. Its percentage composition is as follows: water 11·9, proteids 6·7, fat 0·68, starch and sugar 36·5, caffein 2·42, tannin 1·6, cellulose 33·7, ash 6·5. It is, therefore, closely allied to tea and coffee, but differing from them in the relatively large amount of alkaloid which it contains. Kola nuts are hard and irregularly shaped, of a reddish-brown colour, and presenting a faintly aromatic odour. When powdered, their taste is bitter, leaving a harsh and earthy flavour on the palate.

Kola has some slight fatigue-dispelling power, if masticated, or taken when freshly ground in the form of an infusion like coffee. It increases the urinary water, and reduces the total solids of the urine, especially the extractives; it acts as a stimulant to the nervous system, and increases arterial tension; its stimulating and sustaining qualities are, however, largely overrated. True kola nuts are somewhat difficult to obtain; many of these nuts now in the market are not those of *Sterculia acuminata* at all, but those of *Garcinia kola* and *Sterculia cordifolia*, species which do not contain caffein, and which, consequently, are more or less without any physiological action.

Coca, from the leaves of *Erythroxylon coca*, when chewed, is said to have a similar action to that claimed for kola, namely, to take away the feeling of fatigue after and during excessive exertion. It is much used as a stimulant in Peru, and contains the alkaloid cocaine, the use of which as a local anæsthetic is well known. Some observations upon the sustaining and stimulating properties of coca-leaves have been made on soldiers, both during and after long marches, but with only indifferent success. The ill-success which has attended various attempts to use both kola nuts and coca-leaves, by Europeans, as stimulants during unusual bodily exertion, is probably due to the fact that the normal diet of Europeans is rich in stimulant extractives of the xanthin group. Consequently, the consumption of substances, however rich in caffein, by them, would have less effect than on the indigenous races of Africa or South America, whose ordinary dietary is of a less stimulating character.

COCOA AND CHOCOLATE.

Cocoa is the roasted seed of the *Theobroma cacao*, growing chiefly in the West Indies. Cocoa nibs are the seeds or beans roughly broken; flake cocoa is the same completely ground and crushed; soluble cocoa is the same freed from cellulose; while prepared cocoa is the same after half or more of its contained oil or fat has been removed, and in most cases starch and sugar added. The percentage composition of cocoa beans may be said to be as follows:—

Water,	6·0
Theobromine,	1·5
Fat,	50·0
Starch,	10·0
Salts,	3·6
Gum,	8·0
Cellulose,	20·9

The active principle of cocoa, theobromine, is closely related to caffein, being dimethylxanthine, $C_7H_8N_4O_2$. Its physiological action is chiefly exerted on the muscular system, and is a greater restorer of muscular activity than either thein or caffein. Its effect on the nervous system is not well defined.

The adulteration of cocoa is chiefly in the direction of the addition of sugar and starch, which the microscope will detect; while, by some, the removal of the fat, so as to reduce it below 20 per cent., is regarded as an adulteration. Apart from cocoa, by nature, containing nitrogenous and fatty matter, in its commercial forms it contains so much starch and sugar that it is rightly regarded to some extent not only as a proteid and fatty food, but also a carbo-hydrate one. Cocoa differs much from both tea and coffee in having but little stimulant action, but it does possess some nutritive value, and, as such, may in a limited sense be regarded as a food.

The starch grains of cocoa are small and embedded usually in the cells. The presence of starch grains of cereals, arrowroot, sago, or other kinds of starch, is at once detected by the microscope. Sugar can be detected by the taste, and by Fehling's solution. Mineral substances are best detected by incineration, digesting it in an acid and testing for iron, lead, &c.

Chocolate is a preparation of cocoa, from which the greater part of the fat has been removed, and which, after being mixed with sugar and various flavouring substances, is made into a paste with water, and then pressed in moulds.

LEMON AND LIME JUICE.

These juices contain free acids in large quantities, chiefly citric, and a little malic acid, sugar, vegetable albumin, and mucus.

Lemon juice is the expressed juice of the *Citrus limonum*, and lime juice that of the *Citrus limetta*. The British Pharmacopœia directs that lemon juice should have a specific gravity of 1039, and should contain 32·5 grains of citric acid per ounce. The Board of Trade standard for lemon juice is a specific gravity of 1030, when de-alcoholised, and an acidity equivalent to 30 grains per ounce of citric acid. It occasionally may be met with, with a density as high as 1050.

Lime juice has usually a less specific gravity than lemon juice, of about 1037 or 1035, and also contains less acid, or about 32·22 grains per ounce.

As found in commerce, for merchant shipping, or used in the Royal Navy, the lime or lemon juice is chiefly prepared in Sicily or the West Indies; it is mixed with spirit (usually brandy or whisky, which gives it a slightly greenish-yellow hue), and olive oil is poured on the top.

Sugar is added to it when issued, to make it more agreeable to taste, in the proportion of half its weight. Lemon juice is usually issued in bottles containing from three to four pints, not quite filled, and covered with a layer of olive oil. About 1 ounce of brandy is added to each 10 ounces of juice. Sometimes the juice is boiled, and no brandy is added; the former kind keeps better. Both are equal in anti-scorbutic power. Good lemon juice will keep for some years, at least three years; bad juice soon becomes turbid, and then stringy and mucilaginous, and the citric and malic acids decompose, glucose and carbon dioxide being formed. Some turbidity and precipitate do not, however, destroy its anti-scorbutic powers.

As found in the market, it is frequently mixed with water, and sometimes with other acids, such as tartaric and sulphuric acids. The lime juice used in the Arctic Expedition 1875–6, gave on analysis 27 grains of citric acid per ounce as issued, that is, after being fortified with about 15 per cent. of proof spirit. Before fortifying it contained 32 grains. Some samples analysed at Netley showed a density of 1023 as issued, and of 1035·7 after de-alcoholisation: the extract was about 8·5 per cent. The unfortified juice froze at 25° F., the fortified remained liquid down to 15° F. Prolonged freezing at a temperature of nearly 0° F. produced no change in the character or amount of the constituents.

In the examination, the points which seem of consequence, in addition to the determination of the free acidity, are the fragrancy of the extract and the alkalinity of the ash, proving the existence of some alkaline citrate. The latter can, however, be imitated, but the fragrancy cannot be so.

Examination of Lemon or Lime Juice.—This will have reference to both quality and adulterations.

1. Pour into a glass, and mark physical characters; turbidity, precipitate, stringiness, &c. The taste should be pleasant, acid, but not bitter. Add lime water, and boil; if free citric acid is present, a large precipitate of calcium citrate is formed, which redissolves as the solution cools. Evaporate carefully in order to prepare an extract, and to test the fragrancy, &c.

2. Take the specific gravity, remembering that spirit is present; then, if necessary, evaporate to one-half to drive off alcohol, dilute to former amount, and take specific gravity at 60° F.

3. Determine acidity by the standard alkaline solution. Express the acidity as citric acid ($C_6H_8O_7$); 1 c.c. of the alkaline solution = 6·4 milligrammes of citric acid. As the acidity is considerable, the best way is to take 10 c.c. of the juice, add 90 c.c. of water, and take 10 c.c. of the dilute fluid, which will give the acidity of 1 c.c. of the undiluted juice. If the number of c.c. used for the diluted juice is multiplied by 2·8, it gives the acidity in grains per ounce.

4. Test for adulteration, viz:—(*a*) *Tartaric Acid.*—Dilute and filter, if the lime juice be turbid; add a little solution of acetate of potash; stir well, without touching the sides of the glass, and leave for twenty-four hours; if tartaric acid be present, the potassium tartrate will fall.

(*b*) *Sulphuric Acid.*—Add barium chloride after filtration, if necessary; if any precipitate falls, add a little water and a few drops of dilute hydrochloric acid to dissolve the barium citrate, which sometimes causes a turbidity.

(*c*) *Hydrochloric Acid.*—Test with silver nitrate and a few drops of dilute nitric acid.

(*d*) *Nitric Acid.*—This is an uncommon adulteration; the iron or brucine test can be used as in the case of water.

Factitious Lemon Juice.—It is not easy to distinguish well-made factitious lemon juice; about 552 grains of crystallised citric acid are dissolved in a wine pint of water, which is flavoured with essence of lemon dissolved in spirits. This corresponds to about 19 or 20 grains of dry citric acid per ounce. The flavour is not, however, like that of the real juice, and the taste is sharper. Evaporation detects the falsification.

Use of Lemon Juice.—In military transports, the daily issue of one ounce of lemon juice per head is commenced when the troops have been ten days at sea, and by the Merchant Shipping Act (1867) the same rule is ordered, except when the ship is in harbour, and fresh vegetables can be procured. It is mixed with sugar.

If preserved vegetables can be procured, half the amount of juice will perhaps do.

In campaigns, when vegetables are deficient, the same rules should be enforced. On many foreign stations, where dysentery takes a scorbutic type (as formerly in Jamaica, and even of late years in China), lemon juice should be regularly issued, if vegetables or fruit cannot be procured.

Substitutes for Lemon Juice.—Citric acid is the best, or citrate of sodium; then perhaps vinegar, though this is inferior; and lowest of all is citrate of potassium. The tartrates, lactates, and acetates of the alkalies may all be used, but there are no good experiments on their relative anti-scorbutic powers on record. If milk is procurable, it may be allowed to become acid, and the acid then neutralised with an alkali. The fresh juices of many plants, especially species of cacti, can be used, the plant being crushed and steeped in water; and in case neither vegetables, lemon juice, nor any of the substitutes can be procured, we ought not to omit the trial of such plants of this kind as may be obtainable.

VINEGAR.

Ordinary commercial vinegar is really a more or less impure acetic acid, containing besides acetic acid, alcohol, acetic ether, sugar, extractive matters, alkaline acetates, and a variable amount of salts. It usually also contains some sulphuric acid, which by law must not exceed one-thousandth part of its weight of pure acid.

There are four kinds of vinegar commonly in use in Europe. These are, Malt Vinegar, Wine Vinegar, Vinegar from starch, sugar, &c., and Wood Vinegar. The acid in all these products is identical, but there are distinct differences of flavour and odour between them. Owing, however, to the addition of colouring matter and flavouring essences, it is often very difficult to detect the sources of some of the inferior vinegars. All varieties of vinegar, except that obtained by means of the destructive distillation of wood, are formed by the oxidation of alcohol.

Malt vinegar, which constitutes the greater part of the vinegar used in this country, is derived from the acetous fermentation of a wort made from malt and barley. It is of a distinct brown colour, having a specific gravity of from 1016 to 1019. It commonly contains traces of alcohol, 0·4 per cent. of extract, 4 per cent. of acetic acid, and about 0·1 per cent. of sulphuric acid.

Wine vinegar is chiefly used on the Continent, where it is prepared from grape juice and inferior new wines, that made from white wine being the most esteemed. These vinegars vary in colour from straw to red, have usually an alcoholic odour, and a specific gravity of from 1015 to 1022. They usually contain 1 per cent. of alcohol, 1 per cent. of extract, from 5 to 6 per cent. of acetic acid, with small quantities of tartaric acid and tartrate of potash.

The chief adulterations of vinegar are water, mineral acids, especially sulphuric, metals, such as copper, arsenic, lead and tin, pyroligneous acid and various organic substances, such as colouring agents and capsicum.

Examination of Vinegar.—This will have reference to both quality and adulterations.

There are several kinds of vinegar now in the market, known by the numbers 16, 18, 20, 22, and 24. Numbers 22 and 24 are the best, and contain about 5 per cent. of pure glacial acetic acid. The inferior kinds contain 3 per cent. or even less. The Society of Public Analysts have adopted 3 per cent. as the minimum of acetic acid permissible.

Quality.—1. Take specific gravity: white wine vinegar varies from 1015 to 1022, malt vinegar from 1016 to 1019. If below this water has been added.

2. Determine acidity of 10 c.c. with the alkaline solution. It is generally best to dilute the vinegar ten times with distilled water, and to take 10 c.c. of the diluted vinegar. Multiply the c.c. of alkaline solution used by 0·6; the result is acetic acid per cent.

Example.—10 c.c. of diluted vinegar took 8 c.c. of alkaline solution: $8 \times 0{\cdot}6 = 4{\cdot}8$. per cent. of acetic acid.

An alternative method of estimating the strength of vinegar has been suggested by Wynter-Blyth. Distil 110 c.c. until 100 c.c. have come over, that is, ten-elevenths. The 100 c.c. will contain 80 per cent. of the whole acetic acid present in the 110 c.c. and may be titrated, or the specific gravity of the distillate taken, and the percentage of acetic acid found from the following table:—

Specific gravity.	Per cent. of acetic acid.	Specific gravity.	Per cent. of acetic acid.
1001	1	1016	11
1002	2	1017	12
1004	3	1018	13
1005	4	1020	14
1007	5	1022	15
1008	6	1023	16
1010	7	1024	17
1012	8	1025	18
1013	9	1026	19
1015	10	1027	20

The acidity of English vinegar is chiefly caused by acetic and sulphuric acids, but it is usually calculated at once as glacial acetic acid. If it falls below 3 per cent., water has probably been added. If the specific gravity be low, and the acidity high, excess of sulphuric acid may have been added.

Sodium carbonate or ammonia gives a purplish precipitate in *wine* vinegar, but not in *malt* vinegar.

If excess of sulphuric acid be suspected, it must be determined by baryta; this requires care, as sulphates may be introduced in the water. Hydrochloric acid and barium chloride are added; the sulphate of barium collected, dried, weighed, and then multiplied by 0·412, gives the weight of sulphuric acid.

Adulterations.—Water; sulphuric acid in excess; hydrochloric acid (uncommon); or common salt (detected by nitrate of silver and dilute nitric acid); pyroligneous acid (distil and re-distil the distillate, the residue will have the smell of pyroligneous acid); lead; copper from vessels (evaporate to dryness, incinerate, dissolve in weak nitric acid, divide into two parts, pass hydrogen sulphide through one, and test for copper in the other by ammonia, or by a piece of iron wire); corrosive sublimate (pass hydrogen sulphide through, collect precipitate); capsicum, pellitory, or other pungent substances (evaporate nearly to dryness, and dissolve in boiling alcohol, evaporate to syrup, taste; burnt sugar gives a bitter taste and a dark colour to the syrup).

The presence of copper in the vinegar used for pickles may be easily detected by simply inserting the bright blade of a steel knife. Many vinegars, especially the weaker and inferior kinds, often contain in extraordinary abundance *Anguillula oxyphila* or vinegar eels, these being minute worms from 1 to 2·5 mm. in length. Lindner and others have endeavoured to show that these worms have an injurious action upon those drinking the vinegar. Beyond rendering the condiment somewhat disgusting to the eye, it is doubtful whether they have any prejudicial effect.

As an article of diet, vinegar holds the same rank as the vegetable acids generally. It tends to maintain the alkalinity of the blood and the liquids which bathe the tissues. The acetic acid is largely converted into carbonates in the body, and in doses of from half to one ounce daily, vinegar is a valuable anti-scorbutic. But this valuable dietetic quality is partly counterbalanced in English vinegar by the unfortunate circumstance that sulphuric acid ($\frac{1}{1000}$th in weight) is allowed to be added to it, and thus a strong acid is taken into the body, which is not only not useful in nutrition, but is hurtful from the tendency to form insoluble salts of lime. This defect is not present in the wine vinegar from the Continent. If taken well diluted with water, vinegar makes a useful and far from disagreeable drink.

MUSTARD.

Mustard is the seed of the *Sinapis alba* and *Sinapis nigra*. Commonly sold as a powder, it is liable to considerable adulteration by being mixed with different kinds of the starches or with turmeric.

Good mustard is known by the sharp acid smell and taste. Its chief adulterations can be usually detected with the microscope. Further, the microscopic characters of mustard seed are equally well marked. The outer coat of the white mustard consists of a stratum of hexagonal cells, perforated in the centre, and other cells which occupy the centre portion of the hexagonal cells, and which escape through the opening when swollen from imbibition of water (fig. 58). These cells are believed to contain the mucilage which is obtained when mustard is placed in water. There are two internal coats made up of small angular cells: the structure of the seed consists of numerous cells containing oil, but no starch. The black mustard has the same characters, without the infundibulum cells.

Pure mustard contains 13·95 per cent. of carbo-hydrates, 0·66 per cent. of volatile oil, and 35·42 per cent. of fixed oil. In an adulterated mustard, the carbo-hydrates may be as high as 67 per cent. sometimes, and the fixed oils as low as or even below 7 per cent.

PEPPER.

There are two kinds of pepper, the black and the white. Black pepper is obtained from *Piper nigrum*, while white pepper is the same decorticated. Dried black pepper contains about 7·87 per cent. piperin and fixed oil, with not less than 50 per cent: of carbo-hydrate which is transformable into sugar. This quantity of carbo-hydrate has been suggested as a test for the purity of pepper. In white pepper, the piperin and fixed oil is about 8·24 per cent., and the carbo-hydrates 64·95 per cent., of which 47 per cent. is starch.

The microscopic characters of pepper are rather complicated; there is a husk composed of four or five layers of cells and a central portion. The cortex has externally elongated cells, placed vertically, and provided with a central cavity, from which lines radiate towards the circumference; then come some strata of angular cells, which towards the interior are larger, and filled with oil. The third layer is composed of woody fibre and spiral cells. The fourth layer is made up of large cells, which towards the interior become smaller and of a deep red colour; they contain most of the essential oil of the pepper. The central part of the berry is composed of large angular cells, about twice as long as broad (fig. 59). Steeped in water, some of these cells become yellow, others remain colourless. It has been supposed that the yellow cells contain piperin, as they give the same reactions as piperin does: the tint, namely, is deepened by alcohol and nitric acid, and sulphuric acid applied to a dry section causes a reddish hue.

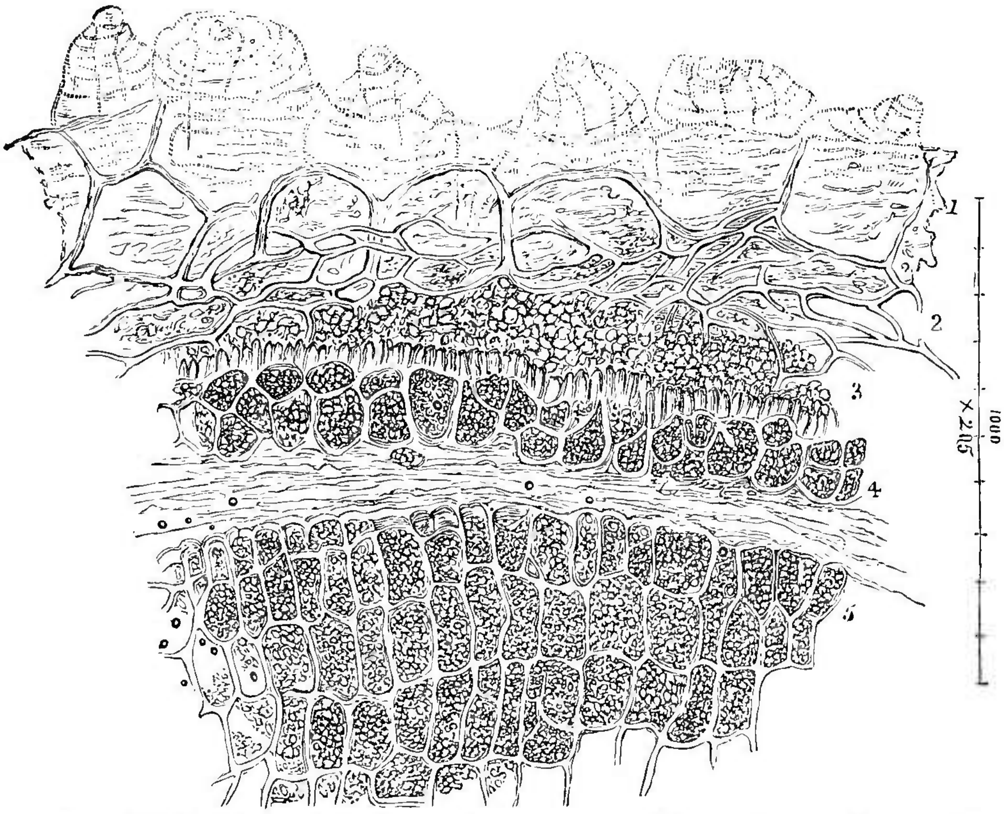


Fig. 58.—White Mustard Seed.—1, Outer coat, cuticle mucilage cells; 2, Fibrous reticular; 3, Small angular cells; 4, Large cells and very delicate membrane; 5, Interior of seed with a few minute oil globules.

White pepper is the central part of the seed, but some small particles of cortex are usually mixed with it. It is composed of cells containing very small starch grains. Hassall says that the central white cells are so hard that they may be mistaken for particles of sand. A little care would avoid this. The starch grains are easily detected, however small, by iodine.

Pepper is adulterated with linseed, mustard husks, wheat and pea flour, rape cake, and ground rice. The microscope at once detects these adulterations.

Pepper is also largely adulterated with husks and palm-nut powder (Poivrette), and with mineral substances: these latter may be separated by shaking up with chloroform. No pure pepper should give less than 50 per cent. of reducing sugar on the ash-free substance (piperin and piperidine reducing the Fehling's solution); palm-nut powder gives 23 per cent. (Leng).

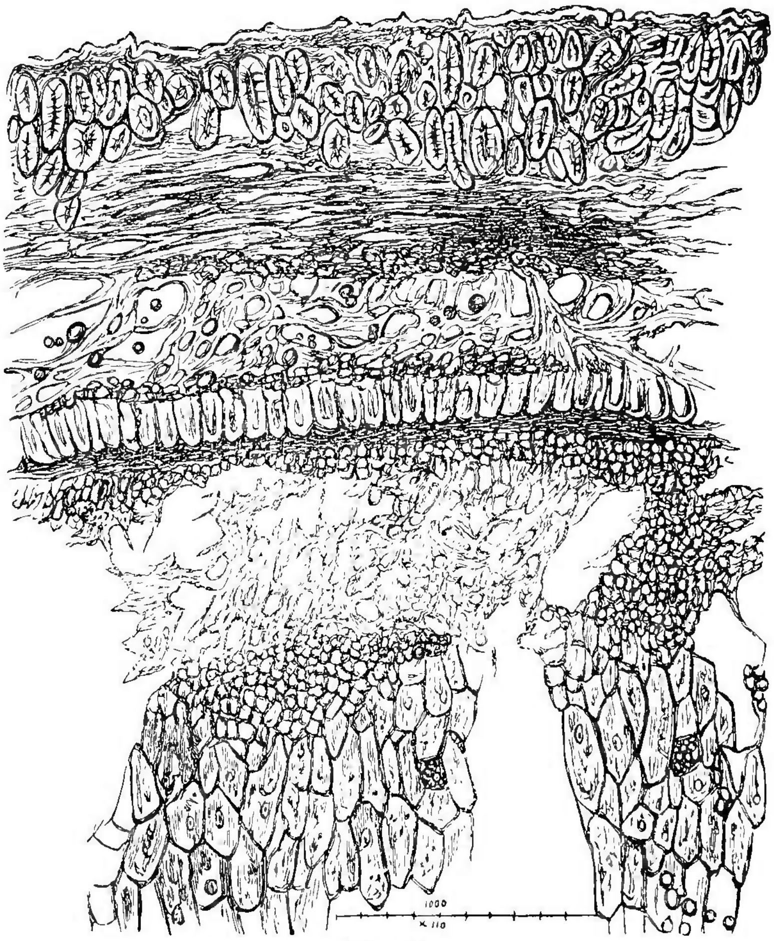


Fig. 59.

Neuss recommends covering the powder with pure hydrochloric acid: true pepper becomes intensely yellow, and from among it other substances can be picked out.

Pepper dust is merely the sweepings of the warehouses. Rape or linseed cake, cayenne and mustard husks, are mixed with pepper dust, and it is then sold as pepper.

SALT.

The purity of ground salt is known by its whiteness, fine crystalline character, dryness, complete and clear solution in water. The coarser kinds, containing often chloride of magnesium, and perhaps lime salts, are darker coloured, more or less deliquescent, and either not thoroughly crystallised or in too large crystals. In large masses rock salt is often of a reddish colour, which disappears on grinding.

Dietetic Use of the Condiments.—The various condiments owe their action as food accessories to the aromatic oils which they contain. These oils or active principles have practically three kinds of action. In the first place they are *antiseptic*, and by virtue of this property serve to prevent acid fermentation in the digestive tract. They are also *stimulants of digestive juices*, and of *peristaltic action*. Taken in quantity and by themselves, possibly some act as stimulants of the nervous system, but this action is quite independent of their *rôle* as food accessories.

BIBLIOGRAPHY AND REFERENCES.

Anstie, *Stimulants and Narcotics, their Mutual Relations*, Philadelphia, 1865; also *On the Uses of Wines in Health and Disease*, New York, 1870. Aubry, Articles "Beer," "Yeast," "Hops," and "Malt," in Dammer's *Lexikon der Verfälschungen*.

Bell, Sir J., *Report on British and Foreign Spirits* to a Committee of the House of Commons, 1891. Blyth, *Foods, their Composition and Analysis*, Lond., 1882. Borgmann, *Anleitung zur chemischen Analyse des Weines*, Wiesbaden, 1884. Brunton, *Pharmacology*, London, 1890.

Church, *Food, its Sources, Constituents, and Uses*, London, 1882.

Dujurdin-Beaumetz, "On the Poisonous Effects of Alcoholic Impurities," *Comptes Rendus*, lxxxi. p. 192.

Gardner, *The Brewer, Distiller and Wine Manufacturer*, Lond., 1883. Griffin, *Chemical testing of Wine and Spirits*, Lond., 1872.

Hasterlick, *Kritische Studien u. die bisherigen Methoden zum Nachweis fremder Farbstoffe im Wein*, Dissertat. Erlangen, 1889. Hassall, *Food and its Adulterations*, London, 1876. Hooper, *Manual of Scientific and Technical Brewing*, Lond., 1885.

Kramer, "On the Action of Bacteria on the Breaking or Inversion of Wine," *Landwirthschaftliche Versuchstationen*, xxxvii. p. 325.

Lehmann, *Methods of Practical Hygiene*, translated by Crookes, Lond., 1893. List, "Die Schaumweine," *Proc. 8th Congress of Bavarian Chemists*, Wurzburg, 1889.

Maitz and Morris, *Text-book of the Science of Brewing*, with Plates, London, 1891. Marquard, Article "Essig," in Dammer's *Lexikon der Verfälschungen*. Matthews and Lott, *The Microscope in the Brewery and Malthouse, including recent researches in connection with Lager Beer, Yeast, &c.*, London, 1891. Mulder, *Die Chemie des Weines*, transl. and edited by Bence Jones, Lond., 1857.

Nessler, *Die Bereitung, Pflege, und Untersuch. des Weines*, 5th Edit., Stuttgart, 1889.

Parkes, "On the Elimination of Alcohol from the Body," *Proc. Roy. Soc. Lond.*, Nos. 120, 123, and 136; also *On the Issue of a Spirit Ration in the Ashanti Campaign*, 1875. Pasteur, *Studies on Fermentation and the Diseases of Beer*, translated by Faulkner and Robb, London, 1879. Piesse, *Chemistry in the Brewing Room, with Tables of Alcohol, Extract and Original Gravities*, London, 1891.

Ralfe, *An Enquiry into the General Pathology of Scurvy*, London, 1877. *Report of the Admiralty Committee on the Scurvy which occurred in the Arctic Expedition of* 1875–76, issued as a Blue-Book, 1877. Roberts, Sir W., *Dietetics and Dyspepsia*, Lond., 1885. Roos and Thomas, "On the Chemistry of the Plastering of Wines," *Comptes Rendus*, 1890, vol. cxi. p. 575.

Spooner, "Dietary Scales in connection with the Health of Seamen," *Trans. 7th Internat. Cong. of Hygiene and Demogr.*, Lond., 1891, Section viii. p. 41.

Thudichum and Dupré, *A Treatise on the Origin, Nature, and Varieties of Wine*, London, 1872.

CHAPTER VI.

CLOTHING.

THE main objects of clothing are: (1) to protect the body from cold, heat, wind, and rain; (2) to maintain its warmth, protect it from injury, and also to adorn it.

The subject naturally divides itself into two parts, namely, first a description of the materials of clothing, and second, the principles which should guide us in the selection and construction of clothing.

MATERIALS OF CLOTHING.

The chief materials used for clothing are derived from animals and vegetables. From the animal world we get wool, fur, leather, feathers, and silk; while from vegetable life we draw cotton, flax, jute, hemp, coir, india-rubber, and gutta-percha. To these might be added various inorganic bodies, such as iron, steel, brass and glass for buttons, &c.

Although the greater number of materials used for clothing are readily recognised by their naked eye and microscopical characters, certain chemical reactions are of value in appreciating the nature of mixed fabrics. They may be thus summarised.

Chemical Reactions.—Wool and silk dissolve in boiling liquor potassæ or liquor sodæ of sp. gr. 1040 to 1050, while cotton and linen are not attacked. Wool is little altered by lying in sulphuric acid, but cotton and linen change in half an hour into a gelatinous mass, which is coloured blue by iodine. Silk is slowly dissolved. Wool and silk take a yellow colour in strong nitric acid; cotton or linen do not. So also wool and silk are tinged yellow by picric acid; cotton or linen are not, or the colour is slight, and can be washed off. Silk, again, is dissolved by hot concentrated chloride of zinc, which will not touch wool. In a mixed fabric of silk, wool, and cotton, first boil in strong chloride of zinc, and wash; this gets rid of the silk; then boil in liquor sodæ, which dissolves the wool, and the cotton is left behind. Another reagent is recommended by Schlesinger, viz., a solution of copper in ammonia; this rapidly dissolves silk and cotton, and, after a longer time, linen; wool is only somewhat swollen by it. By drying thoroughly first, and after each of the above steps, the weight of the respective materials can be obtained.

Wool.—Round fibres, transparent or a little hazy, colourless, except when artificially dyed. The fibres have on their surface imbricated scales which all run in one direction (fig. 60). These imbrications or serrations cause wool fibres to adhere tightly, and make it difficult to unravel closely woven woollen fabrics. The serrations are most numerous in the fine wools, as many as 2800 per inch being counted. In some inferior wools the serrations are not more than 500 to the inch. When old and worn, the fibre breaks up into fibrillæ; and, at the same time, the markings become indistinct. By these characters old wool can be recognised. The size of the fibres varies, but averages from $\frac{1}{1800}$ to $\frac{1}{300}$ inch.

As an Article of Clothing.—Wool is a bad conductor of heat and a great absorber of water; but it is non-absorbent of odours. The water penetrates into the fibres themselves and distends them (hygroscopic water), and also lies between them (water of interposition). In these respects it is greatly superior to either cotton or linen, its power of hygroscopic absorption being at least double in proportion to its weight, and quadruple in proportion to its surface.

This property of hygroscopically absorbing water is a most important one. During perspiration the evaporation from the surface of the body is necessary to reduce the heat which is generated by the exercise. When the exercise is finished, the evaporation still goes on, and, if unchecked, to such an extent as to chill the frame. When dry woollen clothing is put on after exertion, the vapour from the surface of the body is condensed in the wool, and gives out again the large amount of heat which had become latent when the water was vaporised. Therefore a woollen covering, from this cause alone, at once feels warm when used during sweating. In the case of cotton and linen the perspiration passes through them, and evaporates from the external surface without condensation; the loss of heat then continues. These facts make it plain why dry woollen clothes are so useful *after* exertion.

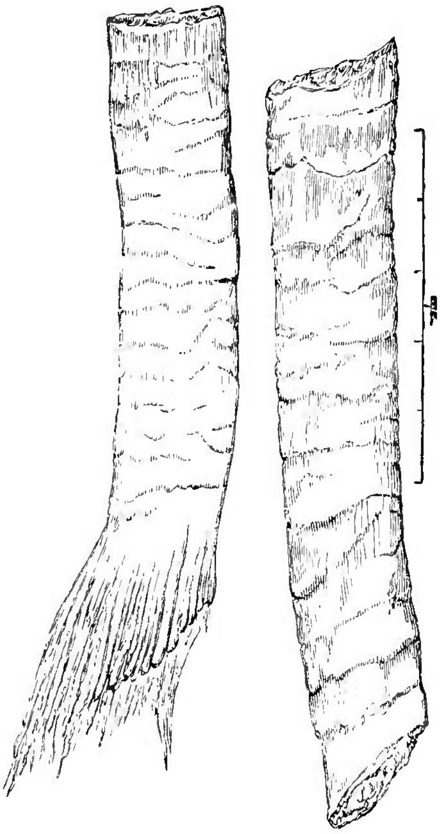


Fig. 60.

In addition to this, the texture of wool is warmer, from its bad conducting power, and it is less easily penetrated by cold winds. The disadvantage of wool is the way in which its soft fibre shrinks in washing, and after a time becomes smaller, harder, and probably less absorbent. In washing woollen articles they should never be rubbed or wrung out. They should be placed in hot soap and water, moved about, and then plunged into cold water: when the soap is got rid of, they should be hung up to dry without wringing.

In the choice of woollen underclothing the touch is a great guide. There should be smoothness and great softness of texture; to the eye the texture should be close; the hairs standing out from the surface of equal length, not long and straggling. The heavier the substance is, in a given bulk, the better. In the case of blankets, the softness, thickness, and closeness of the pile, the closeness of the texture, and the weight of the blanket, are the best guides.

In woollen cloth the rules are the same. When held against the light, the cloth should be of uniform texture, without holes; when folded and suddenly stretched, it should give a clear ringing note; it should be very resistent when stretched with violence; the "tearing power" is the best way of judging if "shoddy" (old used and worked-up wool and cloth) has been mixed with fresh wool. A certain weight must be borne by every piece of cloth. At the Government Clothing Establishment at Pimlico, a machine is used which marks the exact weight necessary to tear across a piece of cloth. Schlesinger recommends the following plan for the examination of a mixed fabric containing shoddy:—Examine it with the microscope, and recognise if it contains cotton, or silk, or linen, besides wool. If so, dissolve them by ammoniacal solution of copper. In this way a qualitative examination is first made. Then fix attention on the wool. In shoddy both coloured and colourless wool fibres are often seen, as the fibres have been derived from different cloths which have been partially bleached; the colouring matter, if it remains, is different—indigo, purpurin, or madder. The diameter of the wool is never so regular as in fresh wool, and it changes suddenly or gradually in diameter, and suddenly widens again with a little swelling, and then thins off again; the cross markings or scales are also almost obliterated. When liquor potassæ is applied the shoddy wool is attacked much more quickly than fresh wool.

The wool from the Angora goat is known as mohair, and is largely used in the making of plushes, velvets, astrachans, and other fancy fabrics. Alpaca comes from the Peruvian sheep, a kind of llama. It is a very fine silky wool and greatly used for shawls and umbrellas. Cashmere is a specially soft and fine wool from the Thibet goat; it is very expensive and difficult to get. Camel's hair is really a fine wool; it is now chiefly met with in the underclothing of Jaeger. Wool is largely used for the making of flannel, cloth, blankets, worsteds, and knitted goods. Felt is really wool made up without either weaving or spinning, the whole holding together simply by the cohesion of the serrated fibres.

Furs.—These are the skins of certain animals from cold countries, which have, in addition to their long "overhair," a dense hairy covering called fur. The chief are bear, seal, chinchilla, ermine, and Russian sable or marten. Fur is often used for making felt; hat felts are chiefly made by compression under heat and moisture of the fur from horses and rabbits. The coarser felts used for carpets are made from cow-hair.

Leather.—The skins of animals, if appropriately prepared by tanning, tawing, or shammoying, are rendered tough, yet soft and fit for use by man as clothing. The chief skins so used are those of the ox, sheep, horse, and goat. *Tanning* is the steeping of a skin in an infusion of oak bark or other substances rich in tannic acid. By this process, insoluble tannates of the gelatin and albumin of the hides are formed. To be properly carried out, tanning takes nearly a year. *Tawing* is the same process as tanning, except that mineral astringents, such as alum and bichromate of potash, are used in place of the vegetable product, tannic acid. Tawing is more rapid, but yields an inferior and harsher leather than tanning. *Shammoying* is the impregnating of a skin with fish oil; it is chiefly applied to light skins, and is the process by which chamois leather is prepared.

Feathers are not much used for actual clothing, but rather as ornaments. Their employment is still considerable for stuffing pillows and beds. These latter, if not made too soft and luxurious, are quite as healthy as any other bed.

Silk.—This is the strong fibre produced or spun by the caterpillar or larval stage of certain moths. The silk threads are formed in two small glands situated on the under part of the body and opening by a duct on the lower lip; the silk serves as a protecting sheath or covering, called a cocoon, for the silkworm when about to assume the chrysalis stage. The silk thread so ejected by each worm and wound into a cocoon measures some 4000 yards in length and consists of two fine filaments, one from each gland, laid side by side and agglutinated together into a single thread or fibre. The best silk is produced by the larva of the moth called *Bombyx mori*, or Chinese silk-moth. Other kinds of silk are spun from other silkworms closely allied to the *B. mori*. There are the *B. textor* and *B. fortunatus*, common in Bengal; the *B. cræsi*, found in Madras; the *B. arracanensis*, met with in Burmah; and the *B. sinensis*, belonging to China. All these are mulberry feeders. The caterpillar of another moth called *Antheræa pernyi*, found in Mongolia, and which feeds on oak leaves, spins the kind of silk known as tussur silk. The *A. mylitta* is another variety of the tussur silk-moth, common in India. It feeds on bher trees and other shrubs. Similar moths are found in Assam and Japan. The silk fibre (fig. 61) consists of a central core or fibre, covered with a waxy and albuminous colouring matter. Microscopically, silk fibres are structureless and glass-like, usually measuring some $\frac{1}{2000}$th inch thick, and without surface markings or scales. Silk is insoluble in water, alcohol, and ether, but dissolves in very strong alkalies, mineral acids, and acetic acid. It is readily distinguished from wool or other animal fibre by the action of an alkaline solution of lead oxide, which, owing to the presence of sulphur in wool, darkens it, but does not affect silk. Silk is distinguishable from the vegetable fibres by being stained yellow by picric acid, which they are not. The average cocoon yields some 500 yards of workable silk, which in its manufactured form is either reeled or spun silk—this latter being prepared by carding or spinning from the waste and spoiled cocoons. During its manufacture into fabrics, silk fibre is largely altered, expanded, weighted, and dyed by various reagents, notably salts of tin and iron, which render the term "silk," as applied to actual articles of clothing, a more or less conventional expression of what something is meant and ought to be. Silk is mainly used in the manufacture of satins, silks, plushes, velvets, ribbons, crape, and in a few woollen goods to give them lustre. Silk is very absorbent of moisture, and is a non-conductor of electricity.

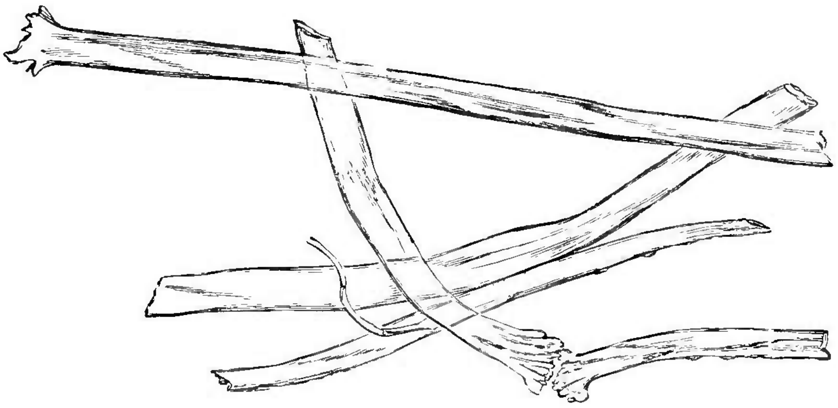


Fig. 61.

Cotton is the downy hair of the seeds of plants belonging to the family Gossypium, of the order Malvaceæ. The cotton fibres consist mainly of cellulose, and vary from a half to one inch in length. The fibres are freed from the seeds by machinery, and after being cleaned and spun into yarn, are woven into fabrics, which, after being bleached, are "finished" for the market. This finishing process usually involves mangling, starching, and damping, and often includes filling up the interstices between the fibres with compounds to give weight and a false appearance. Cotton is largely made up into sheeting, calico, towelling, jean, fustian, velveteen, flannelette, and paper. When mixed with wool, it constitutes the merino of vests, socks, and many fancy materials; it is also mixed with silk or the cheaper kinds of silken goods.

Microscopically, cotton is a diaphanous substance forming fibres about $\frac{1}{4000}$th of an inch in diameter, flattened in shape, and riband-like, with an interior canal which is often obliterated, or may contain some extractive matters, borders a little thickened, the fibres twisted at intervals (about 600 times in an inch) (fig. 62). It has been stated that the fresh cotton fibre is a cylindrical hair with thin walls, which collapse and twist as it becomes dry. Iodine stains them brown; iodine and sulphuric acid (in very small quantities) give a blue or violet-blue; nitric acid does not destroy them, but unrolls the twist.

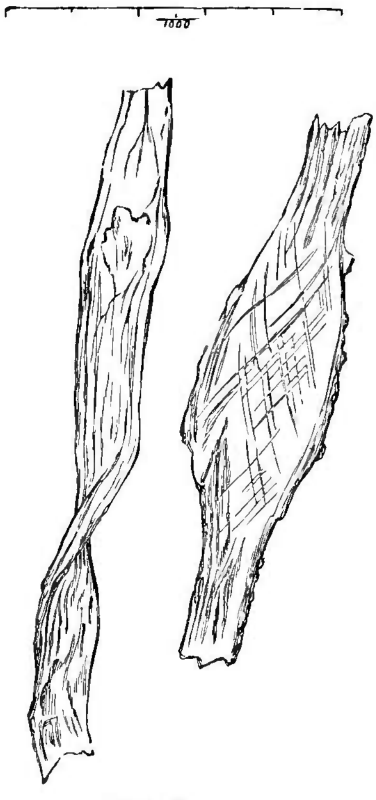


Fig. 62.

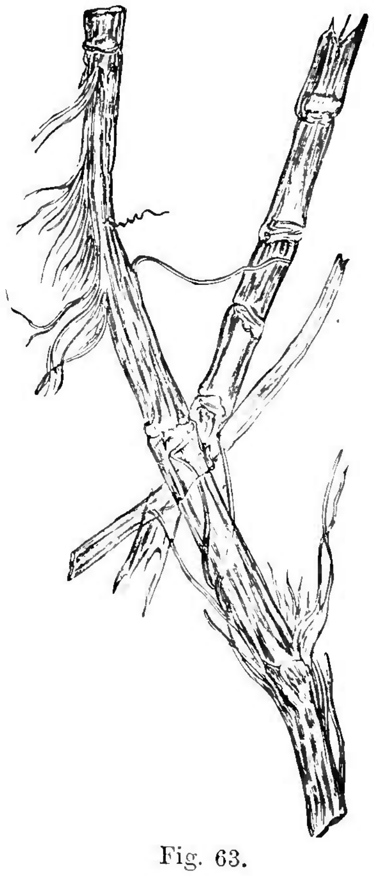


Fig. 63.

As an Article of Dress.—The fibre of cotton is exceedingly hard, it wears well, does not shrink in washing, is very non-absorbent of water (either into its substance or between the fibres), and conducts heat rather less rapidly than linen, but much more rapidly than wool. It is very absorbent of odours.

The advantages of cotton are cheapness and durability; its hard non-absorbing fibre places it far below wool as a warm water-absorbing clothing. In the choice of cotton fabrics there is not much to be said; smoothness, evenness of texture, and equality of spinning, are the chief points.

In cotton shirting and calico, cotton is alone used; in merino and other fabrics it is used with wool, in the proportion of 20 to 50 per cent. of wool, the threads being twisted together to form the yarn.

Cellular cloth is made principally from cotton. The fibres are so woven as to leave large cellular interspaces in the fabric, and the air contained therein renders it an excellent non-conductor: its warmth depends on its porous character. It is said to be very durable.

Flax is a fibre obtained from the stalks of a plant called the *Linum usitatissimum*, which grows to a large extent in Russia and Ireland. The seeds are the familiar linseed, from which linseed meal, oil, and cake are prepared. The stalks, after being allowed to ferment or rot on the ground in the damp, are beaten and combed until something like 6 per cent. of saleable flax fibre is obtained from the plant. The flax or linen fibres (fig. 63), when seen under the microscope, are marked by transverse striæ at regular intervals; they are not flat like cotton, but more like silk, only they show a fibrous and jointed structure which is not met with in silk. Flax is much more expensive than cotton, and is used chiefly for the manufacture of linen, cambric, and lawn. Linen resembles cotton in being a good conductor of heat and a bad absorbent of moisture. It is in many respects even inferior to cotton for underclothing, but from its smoothness and lustre is unequalled as a material for collars, cuffs, and shirt fronts. Weight for weight, flax fibre is stronger than cotton, in the ratio for single yarn of 3 to 1·8, for double yarn as 3 to 2·25, and for cloth as 3 to 2·1.

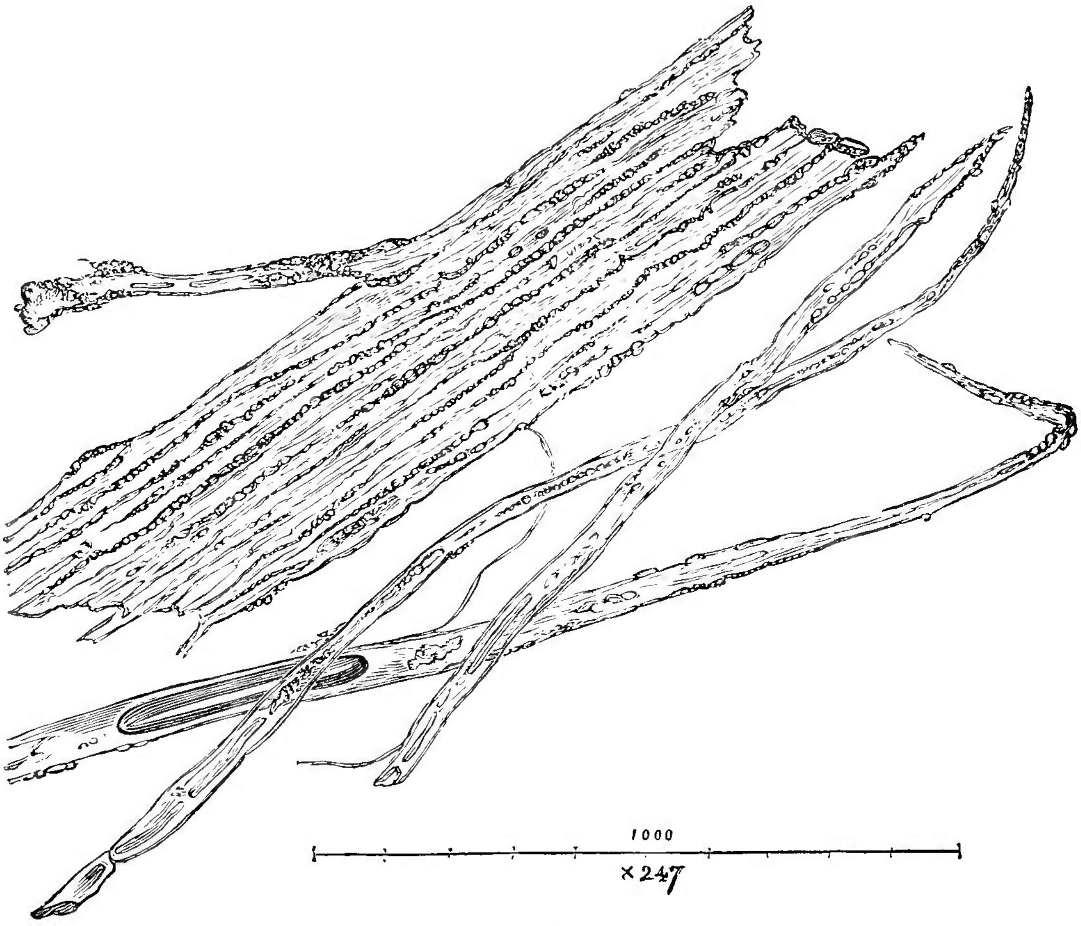


Fig. 64.

Jute is a brittle and very hygroscopic fibre obtained from the *Corchorus capsularis*, a plant growing chiefly in Bengal. Jute is not much used for clothing except as an adulteration of silk and in the making of false hair; it is chiefly employed for coarse fabrics such as mats, cheap carpets, sacking, curtains, and table-covers. It is used also as a backing for floorcloths. The fibres are brittle and very hygroscopic; often hollow, thickened, and marked by constrictions; sometimes an air-bubble may be in the fibre, as shown in the drawing (fig. 64).

Hemp is another fibre not much used in European countries for clothing. It is a coarse fibre, prepared from the stem of the *Cannabis sativa*, a plant growing in Europe, Asia, and America. It is prepared like flax and jute, and chiefly used for rope, yarn, canvas packing, and sail cloth. The Indian plant yields a narcotic drug, while hemp-seed is a popular food for birds.

The hemp fibre is something like flax, but much coarser, and at the knots it separates often into a number of smaller fibres.

Coir is a coarse, tough, harsh, yet light fibre obtained from the husk of the cocoanut. It is rarely used for clothing, but largely so for making mats, brushes, and ropes.

India-rubber enters largely in the present day into the constitution of our clothing, chiefly because it is elastic and impermeable to water. Under the name of caoutchouc, it is the milky juice of several plants growing in Africa, Asia, and South America. Caoutchouc is a somewhat complex body, dissolving in chloroform, ether, petroleum, benzene, and carbon disulphide. Freezing impairs its elasticity, while great heat softens and melts it. Fats also destroy it. When steeped in melted sulphur at 140° C., caoutchouc becomes vulcanised. Macintosh cloth is merely a cotton or silk fabric covered, layer by layer, with a solution or paste of caoutchouc. Gutta-percha is, like india-rubber, the juice of certain trees; but these grow only in the Malay peninsula. Excepting as boot soles, gutta-percha is little used in clothing.

PRINCIPLES OF SELECTION AND CONSTRUCTION OF CLOTHING.

Warmth and coolness, or the power of maintaining the body heat at its normal height, being the most important property of all dress materials, it follows that our choice of clothing will depend largely upon this feature. How far a given clothing will give warmth depends upon its material, its texture, number of layers, and its colour. Owing to fabrics conducting heat in the following order from highest to lowest, namely, linen, cotton, silk, feathers, fur, and wool, it follows that wool, fur, and feathers are the warmest materials, then silk and cotton; while linen is the coolest. The more readily a material conducts heat, of course, the cooler it feels. This heat-conducting property is mainly proportionate as to how close it is woven, and as to how little air it contains. On this account, all soft, furry fabrics, no matter whether of wool or cotton, always feel warmer than the closely woven, smooth-surfaced silks and linens. In the same way, the more layers of clothing there are, the more layers of air there are retained between them. The influence of colour is dependent upon the heat-absorbing powers of that colour. White absorbs heat the least, and is consequently the coolest; then comes yellow, red, green, blue, and black. It is obvious this effect of colour can only be of influence when outside, and that the popular idea that red flannel, when worn next the skin, or as part of an under-garment, is warmer than white is imaginary. As a rule, it is a mistake to wear coloured clothing next the skin, as not unfrequently the dyes are irritative, and, coming off, give rise to skin diseases.

In determining the selection of a material for clothing, its hygroscopic or absorbent power for water is of the first importance. The hygroscopic qualities of wool are undoubtedly far greater than those of other fibres, especially the vegetable, but these latter certainly absorb more water than is generally realised. The variations in this respect, between different materials, is largely due to the manner in which the manufactured article is woven. There can be no doubt that, as a general rule, woollen goods will absorb far more water than cotton, but if we compare the absorbent power of a closely woven woollen fabric with that of a loosely woven cotton, such as bath towelling, there is very little difference between them, in fact, if anything, the margin is in favour of the cotton material. Flannel absorbs moisture readily, and by virtue of its high hygroscopic power, evaporation from its surface is slow. It is for this reason that flannel constitutes the best material for garments for those perspiring freely: the evaporation being slow and gradual causes the chilling of the body, when exercise ceases, to be comparatively slight. On the other hand, if a man perspires freely in an ordinary close woven cotton or linen garment, this rapidly becomes wet through, adheres to the skin, evaporation quickly proceeds, leading to great surface chilling and loss of heat. The more recent method of weaving cotton materials more loosely has undoubtedly reduced the general defects of cotton clothing in this respect.

For this country, flannel and woollen goods are the safest materials to wear; but if cotton or linen be worn, it must be woven loosely, so as to give some thickness and porosity to the fabric. In the tropics, wool is too heavy a material, linen or cotton shirting being more generally suitable. The Chinese habit of wearing a net next to the skin in hot weather, with a thin silken garment over it, is a good one; the net, without increasing the heat, prevents the perspiration soaking into the upper garment, and the latter from fitting too closely to the skin.

Reference, in this place, may not be inappropriate to the various forms of waterproof clothing now worn. Except under extreme circumstances of rain, the use of india-rubber garments is to be absolutely condemned; being impermeable, evaporation is minimised, with the result that the body quickly breaks out into perspiration, accompanied by more or less discomfort. On the other hand, impregnated woollen and other materials, waterproof but at the same time porous, have probably a great future. In examining such materials, it is essential to note whether they are permeable to air or not. This can very readily be done by stretching the fabric over a pipe or tube and observing whether air blown down the tube can pass through the tissue sufficiently to affect a candle flame.

A well-prepared waterproof material will permit of a candle being extinguished, when blown through a 1 inch pipe, at a distance of 6 inches. Poore, quoting from Cooley, gives the following methods for preparing a waterproof cloth:—

1. Moisten the cloth on the wrong side with a weak solution of isinglass, and, when dry, further moisten with an infusion of nut-galls.

2. Moisten the cloth on the wrong side with a solution of soap, and, when dry, with a solution of alum.

3. Thoroughly rub the wrong side of the cloth with pure beeswax, free from grease, until it presents an even grey appearance; a hot iron is then to be passed over it, and the cloth being brushed whilst warm, the process is complete.

While affording warmth, protection from wind, wet and injury, clothing should always be so made as not to in any way impede natural movements, nor unduly constrict any part of the body, nor be needlessly heavy, and also not afford unnatural support. The more we analyse the common forms of clothing, the more we see that their main faults are in the direction of impediment, constriction, and weight. This is particularly emphasised in the case of long and close-fitting skirts, tight sleeves, stays, garters, bands round the waist and neck, ill-fitting gloves, hats, and boots.

Many of these defects and faults would be obviated if people would remember that (1) no article of clothing should be either so tight as to interfere with the circulation, or so shaped as to change the natural outline of any part of the body; (2) no garment should contain more material than is actually necessary; (3) all garments requiring suspension should be suspended directly or indirectly from the shoulders or hips.

Probably no article of attire is more faulty than the boot. A properly made boot should fit the foot accurately; the great toe should be in a straight line with the inside of the foot; the shape of the sole of the boot should be taken by drawing a pencil round the outline of the foot when the weight of the body is resting on the foot, as in standing, so that the sole may be big enough to support the fully expanded foot; the material should be of soft and flexible leather; even when new, the wearer ought to be able to move all the toes with freedom in the boot; the heel should be broad and low. The stocking or sock should, whenever possible, be of a woollen material or a mixed material in which wool predominates. If no sock be worn, the boot needs to be high and close-fitting round the ankle, so as to prevent dust and stones getting into the boot. The sole of a boot should be wider than the foot, and if the boot is meant for hard wear, the excess of breadth in the sole should be considerable, so as to serve as a protection against loose stones.

BIBLIOGRAPHY AND REFERENCES.

Bowman, *The Structure of the Cotton Fibre in its Relation to Technical Applications*, Manchester, 1881; also *The Structure of the Wool Fibre in its Relation to the Use of Wool for Technical Purposes*, Manchester, 1885.

Hananseck, Article "Bekleidung," in Dammer's *Lexicon der Verfälschungen*. Hoehnel, von, *Die Mikroscopie der technisch verwendeten Faserstoffe*, Vienna, 1887.

Krieger, "Untersuch. u. Beobachtungen über die Enstchung von Krankheiten," *Zeitsch. f. Biol.*, v. 1869.

Linroth, "Einige Versuch über das Verhalten des Wassers in unseren Kleidern," *Zeitsch. f. Biol.*, xvii., 1881.

Mense, *Uber das Verhalten von Kleidungstoffen gegenüber tropfbarflüssigem Wasser*, Dissertation, Munich, 1890.

Müller, "Die Beziehung des Wassers zur Militärkleidung," *Archiv. f. Hyg.*, ii.

Nocht, "Vergleichende Untersuchungen u. verschicdene zu Unter Kleidern verwendete Stoffe," *Zeitsch. f. Hyg.*, v.

Pettenkofer, von, "Uber die Funktion der Kleider," *Zeitsch. f. Biol.*, i.; also *Uber das Verhalten der Luft zum bekleideten Körper des Menschen*, Brunswick, 1888. Poore, Article "Clothing," in Stevenson and Murphy's *Hygiene*, Lond., 1892.

Rubner, *Archiv. f. Hyg.*, ix.; also *Zeitsch. f. Biol.*, 1888.

Schlesinger, *Mikroskop. Untersuch. der Gespinnst-Fasern*, Zurich, 1873. Schuster, "Uber das Verhalten der trockenen Kleider gegen den Warmedurchgang," *Archiv. f. Hyg.*, viii.

Wardle, *Handbook of the Wild Silks of India*, London, 1890.

CHAPTER VII.

EXERCISE.

A PERFECT state of health implies that every organ has its due share of exercise. If this is deficient, nutrition suffers, the organ lessens in size, and evidently more or less degenerates. If it be excessive, nutrition, at first apparently vigorous, becomes at last abnormal, and in many cases a degeneration occurs which is as complete as that which follows the disuse of an organ. Every organ has its special stimulus which excites its action, and if this stimulus is perfectly normal as to quality and quantity, perfect health is necessarily the result.

But the term exercise is usually employed in a narrower sense, and expresses merely the action of the voluntary muscles. This action, though not absolutely essential to the exercise of other organs, is yet highly important, and, indeed, in the long-run, is really necessary; the heart especially is evidently affected by the action of the voluntary muscles, and this may be said of all organs, with the exception, perhaps, of the brain. Not only the circulation of the blood, but its formation and its destruction, are profoundly influenced by the movement of the voluntary muscles. Without this muscular movement health must inevitably be lost, and it becomes therefore important to determine the effects of exercise, and the amount which should be taken.

THE EFFECTS OF EXERCISE.

On the Lungs—Elimination of Carbon.—The most important effect of muscular exercise is produced on the lungs. The pulmonary circulation is greatly hurried, and the quantity of air inspired, and of carbon dioxide expired, is marvellously increased. Edward Smith investigated the first point carefully, and the following table shows his main results. Taking the lying position as unity, the quantity of air inspired was found to be as follows:—

Lying position,	1·00
Sitting,	1·18
Standing,	1·33
Singing,	1·26
Walking 1 mile per hour,	1·90
,, 2 ,,	2·76
,, 3 ,,	3·23
,, and carrying 34 ℔,	3·50
Walking and carrying 63 ℔,	3·84
,, ,, 118 ℔,	4·75
,, 4 miles per hour,	5·00
,, 6 ,,	7·00
Riding and trotting,	4·05
Swimming,	4·33
Treadmill,	5·50

The great increase of air inspired is more clearly seen when it is put in this way: under ordinary circumstances, a man draws in 480 cubic inches per minute; if he walks four miles an hour he draws in (480 × 5 =) 2400 cubic inches; if six miles an hour (480 × 7 =) 3360 cubic inches. Simultaneously, the amount of carbon dioxide in the expired air is increased.

The most reliable observations in this direction are those made by E. Smith, Hirn, Speck, and Pettenkofer and Voit. As there is no doubt that the peculiar means of investigation render the experiments of the last-named authors as accurate as possible in the present state of science, they are given briefly in the following table:—

Absorption and Elimination in Rest and Exercise.

Weight of man experimented upon, 60 kilos = 132 ℔ avds.	Absorption of Oxygen in Grammes.	Elimination in Grammes of –		
		Carbon Dioxide.	Water.	Urea.
Rest-day.	708·9	911·5	828·0	37·2
Work-day,	954·5	1284·2	2042·1	37·0
Excess on work-day (with exception of urea),	245·6	372·7	1214·1	– 0·2

In other words, during the work-day 3790 grains, or 8·66 ounces, of oxygen were absorbed in excess of the rest-day, and 5751 grains, or 13·15 ounces, of carbon dioxide in excess were evolved. Expressing this as carbon, an excess of 1046 grains, or 2·39 ounces, were eliminated on the work-day. There was an excess of oxidation of carbon equal to 41 per cent., and it must be remembered that the so-called "work-day" included a period of rest; the work was done only during the working hours, and was not excessive.

It will be observed from these experiments that a large amount of water was eliminated during exercise, while the urea was not really changed.

It seems certain that the great formation of carbon dioxide takes place in the muscles; it is rapidly carried off from them, and if it were not so, it would seem highly probable that their strong action becomes impossible. At any rate, if the pulmonary circulation and the elimination of carbon dioxide are in any way impeded, the power of continuing the exertion rapidly lessens. The watery vapour exhaled from the lungs is also largely increased during exertion.

Muscular exercise is then clearly necessary for a sufficient elimination of carbon from the body, and it is plain that, in a state of prolonged rest, either the carboniferous food must be lessened or carbon will accumulate.

Excessive and badly arranged exertion may lead to congestion of the lungs, and even hæmoptysis. Deficient exercise, on the other hand, is one of the conditions which favour those nutritional alterations in the lung which we class as tuberculous.

Certain rules flow from these facts. During exercise the action of the lungs must be perfectly free; not the least impediment must be offered to the freest play of the chest and the action of the respiratory muscles. The dress and accoutrements of the soldier should be planned in reference to this fact, as there is no man who is called on to make, at certain times, greater exertion. And yet, till a very recent date, the modern armies of Europe were dressed and accoutred in a fashion which took from the soldier, in a great degree, that power of exertion for which, and for which alone, he is selected and trained.

The action of the lungs should be watched when men are being trained for exertion; as soon as the respirations become laborious, and especially if there be sighing, the lungs are becoming too congested, and rest is necessary.

A second point is that the great increase of carbon excreted demands an increase of carbon to be given in the food. There seems a general accordance among physiologists that this is best given (as far as digestion permits) in the form of fat, and not of starch, and this is confirmed by the instinctive appetite of a man taking exertion, and not restrained in the choice of food.

A third rule is that, as spirits lessen the excretion of pulmonary carbon dioxide, they are hurtful during exercise; and it is perhaps for this reason, as well as from their deadening action on the nerves of volition, that those who take spirits are incapable of great exertion. This is now well understood by trainers, who allow no spirits, and but little wine or beer. It is a curious fact, stated by Artmann, that if men undergoing exertion take spirits, they take less fat. Oxidation of fat is interfered with, and therefore less fat is required. Water alone is the best liquid to train on.

A fourth rule is that, as the excretion of carbon dioxide (and perhaps of pulmonary organic matter) is so much increased, a much larger amount of pure air is necessary; and in every covered building (as gymnasia, riding-schools, &c.), where exercise is taken, the ventilation must be carried to the greatest possible extent, so soon does the air become vitiated.

On the Circulation.—The action of the heart rapidly increases in force and frequency, and the flow of blood through all parts of the body, including the heart itself, is augmented. The amount of increase is usually from ten to thirty beats, but occasionally more. After exercise, the heart's action falls below its normal amount; and if the exercise has been exceedingly prolonged and severe, may fall as low as fifty or forty per minute, and become intermittent. During exertion, when the heart is not oppressed, its beats, though rapid and forcible, are regular and equable; but when it becomes embarrassed, the pulse becomes very quick, small, and then unequal, and even at last irregular. When men have gone through a good deal of exertion, and then are called upon to make a sudden effort, the pulse may become very small and quick (160–170), but still retain its equability. There seems no harm in this, but such exertion cannot be long continued.

The ascension of heights greatly tries a fatigued heart. The accommodation of the heart to great exertion is probably connected with the easy flow of blood through its own structure. Certain forms of chronic disease of the heart have been treated by the "mountain cure," introduced by Oertel; but very great caution is required in carrying out this treatment, and high elevations are contra-indicated in these affections.

Excessive exercise leads to affection of the heart,—rupture (in some few cases), palpitation, hypertrophy in a good many cases, and more rarely valvular disease. These may be avoided by careful training, and a due proportion of rest. Injuries to vessels may also result from too sudden or prolonged exertion. The sphygmographic observations of Fraser on the pulses of men after rowing show how much the pressure is increased.

Deficient exercise leads to weakening of the heart's action, and probably to dilatation and fatty degeneration.

In commencing an unaccustomed exercise, the heart must be closely watched; excessive rapidity (120–140), inequality, and then irregularity, will point out that rest, and then more gradual exercise, are necessary, in order that the heart may be accustomed to the work.

On the Skin.—The skin becomes red from turgescence of the vessels, and perspiration is increased; water, chloride of sodium, and acids (probably in part fatty) pass off in great abundance. Some nitrogen passes off in a soluble form as urea, but the amount is extremely small; it is increased on exertion with the increased perspiration. No gaseous nitrogen is given off in healthy men from the skin.

The amount of fluid passing off is not certain, but is very great. Speck's experiments show that it is at least doubled under ordinary conditions. Pettenkofer and Voit's experiments show even a larger increase. The usual ratio of the urine to the lung and skin excreta is reversed. Instead of being as 1 to 0·5 or 0·8, it becomes as 1 to 1·7 or 2, or even 2·5. This evaporation reduces and regulates the heat of the body, which would otherwise soon become excessive; so that the body temperature rises little above the ordinary temperature. No amount of external cold seems to be able to check the passage of fluid, though it may partly check the rapidity of evaporation. If anything check evaporation, the body-heat increases, and soon languor comes on and exertion becomes difficult.

During exertion there is little danger of chill under almost any circumstances; but when exertion is over, there is then great danger, because the heat of the body rapidly declines, and falls below the natural amount, and yet evaporation from the skin, which still more reduces the heat, continues.

The rules to be drawn from these facts are—that the skin should be kept extremely clean; during the period of exertion it may be thinly clothed, but immediately afterwards, or in the intervals of exertion, it should be covered sufficiently well to prevent the least feeling of coolness of the surface. Flannel is best for this purpose.

On the Voluntary Muscles.—The muscles grow, become harder, and respond more readily to volition. Their growth, however, has a limit; and a single muscle, or group of muscles, if exercised to too great an extent, will, after growing to a great size, commence to waste. But this seems not to be the case when all the muscles of the body are exercised, probably because no single muscle or group of muscles can then be over-exercised. It seems to be a fact, however, that prolonged exertion, without sufficient rest, damages to a certain extent the nutrition of the muscles, and they become soft.

The rules to be drawn from these facts are, that all muscles, and not single groups, should be brought into play, and that periods of exercise must be alternated, especially in early training, with long intervals of rest.

On the Nervous System.—The effect of exercise on the mind is not clear. It has been supposed that the intellect is less active in men who take excessive exercise, owing to the greater expenditure of nervous energy in that direction. But there is no doubt that great bodily exercise is quite consistent with extreme mental activity: and, indeed, considering that perfect nutrition is not possible except with bodily activity, we should infer that sufficient exercise would be necessary for the perfect performance of mental work. Doubtless, exercise may be pushed to such an extreme as to leave no time for mental cultivation; and this is perhaps the explanation of the proverbial stupidity of the athlete. Deficient exercise causes a heightened sensitiveness of the nervous system, a sort of morbid excitability, and a greater susceptibility to the action of external agencies.

On the Digestive System.—The appetite largely increases with exercise, especially for meat and fat, but in a less degree, it would appear, for the carbo-hydrates. Digestion is more perfect, and absorption is more rapid. The circulation through the liver increases, and the abdominal circulation is carried on with more vigour. Food must be increased, especially nitrogenous substances, fats, and salts and of these especially the phosphates and the chlorides. The effects of exercise on digestion are greatly increased if it be taken in the free air, and it is then a most valuable remedy for some forms of dyspepsia. Conversely, deficient exercise lessens both appetite and digestive power.

On the Generative Organs.—It has been supposed that puberty is delayed by physical exertion, but perhaps the other circumstances have not been allowed full weight. Yet, it would appear that very strong exercise lessens sexual desire, possibly because nervous energy is turned in a special direction.

On the Kidneys.—The water of the urine and the chloride of sodium often lessens in consequence of the increased passage from the skin. The urea is not much changed, but the uric acid and also apparently the pigment increase after great exertion. The phosphoric acid is not augmented unless the exertion is excessive; while the sulphuric acid and free carbonic acid are commonly increased (North). The exact amount of the bases has not been determined, but a greater excess of soda and potash is eliminated than of lime or magnesia: nothing certain is known as to hippuric acid, sugar, or other substances. In the careful observations made by Pavy on Weston, the pedestrian, it was found that all the constituents of the urine were increased, except the chlorine and the soda, which were notably diminished, especially the chlorine; the magnesia was also lessened, but in a much smaller degree. In these experiments, however, the diet was not uniform, and the exercise was excessive.

On the Bowels.—The general effect of exercise is to lessen the amount of excreta passed, partly probably from a reduced amount of water entering the intestines. The experiments of Parkes and North indicate that the amount of nitrogen voided by the bowels is not much altered.

On the Elimination of Nitrogen.—A great number of experiments have been made on the amount of nitrogen passing off by the kidneys during exercise, notably by Parkes, Voit, Pettenkofer, Ranke, Smith, Haughton, and others. The amount of urea has been usually determined, and the nitrogen calculated from this. The observations have been commonly made by determining the nitrogenous excretion in twenty-four hours with and without exercise; but in some the period during which work was actually performed was compared with previous and subsequent equal rest periods. Some experiments were performed on men who took no nitrogen as food; others were on men on a constant diet, so that the variation produced by the altering ingress of nitrogen was avoided as far as possible.

In this place it is impossible to give an account of these long researches, and therefore only a short summary can be given. (1) When a period of exercise is compared after an interval with one of rest (the diet being without nitrogen or with uniform nitrogen), the elimination of nitrogen by the kidneys is decidedly not increased in the exercise period. The experiments on this point are now so numerous that it may be stated without doubt. It is possible that the elimination may even be less during the exercise than during the rest period.

(2) When a day of rest is compared with a day of work (*i.e.*, a day with some hours of work and some hours of rest), the amount of nitrogen is almost or quite the same on the two days; if anything there is a slight increase in the nitrogen on the rest-day. In a day of part exercise and part rest, it is quite possible that there may be compensatory action, one part balancing the other, so as to leave the total excretion little changed.

(3) When a period of great exercise is immediately followed by an equal period of rest, the nitrogenous elimination is increased in the latter.

Meissner's observations show that this is in part owing to increased discharge of kreatin and kreatinin; Parkes' observations also show an increase of non-ureal nitrogen. But the urea is also slightly increased in this period.

(4) When two days of complete rest are immediately followed by days of common exercise, the nitrogenous elimination diminishes during the first day of exercise (Parkes).

North's experiments in the main confirm the observations of Parkes, but he shows that the effects of heavy labour are more immediate and severe than was shown by those observations. North found that deprivation, or an excessive output of nitrogen, was followed by retention and absorption. There is also a tendency to the storage of nitrogen in the system under ordinary conditions, which shows a tendency to economy in the body. From this we might deduce the value of a good diet as providing a reserve against a period of deprivation or excessive work. A similar tendency to the storage of nitrogen was shown in the case of Weston, whose ingesta or egesta were examined by Wynter Blyth.

On the whole, if the facts have been stated correctly, the effect of exercise is certainly to increase the elimination of nitrogen by the kidneys, but within narrow limits, and the time of increase is in the period of rest succeeding the exercise; whereas during the exercise period the evidence, though not certain, points rather to a lessening of the elimination of nitrogen.

It would appear from these facts that well-fed persons taking exercise would require a little more nitrogen in the food, and it is certain, as a matter of experience, that persons undergoing laborious work do take more nitrogenous food. This is the case also with animals. The possible reason of this will appear presently.

On the Temperature of the Body.—As already stated, the temperature of the body, as long as the skin acts, rises little. Clifford-Allbutt, from observations made on himself when climbing the Alps, found his temperature fairly uniform; the most usual effect was a slight rise, compensated by an earlier setting in of the evening fall. On two occasions he noticed two curious depressions, amounting to no less than 4°·5 F.; he believes these were due to want of food, and not to exercise *per se*. In experiments on soldiers when marching, Parkes found no difference in temperature; or if there was a very slight rise, it was subsequently compensated for by an equal fall, so that the mean daily temperature remained the same. A decided rise in temperature during marching would therefore show lessening of skin evaporation, and may possibly be an important indication of impending heatstroke.

Changes in the Muscles.—The discussion on this head involves so many obscure physiological points, that it would be out of place to pursue it here to any length. The chief changes during action appear to be these:—There is a considerable increase in temperature, which, up to a certain point, is proportioned to the amount of work. It is also proportioned to the kind, being less when the muscle is allowed to shorten than if prevented from shortening; the neutral or alkaline reaction of the tranquil muscle becomes acid from para-lactic acid and acid potassium phosphate; the venous blood passing from the muscles becomes much darker in colour, is much less rich in oxygen, and contains much more carbonic acid; the extractive matters soluble in water lessen, those soluble in alcohol increase; the amount of water increases, and the blood is consequently poorer in water; the amount of albumin in tetanus is less according to Ranke, but Kühne has pointed out that the numbers do not justify this inference. Liebig stated that the kreatin is increased (but this was an inference from old observations on the *extractum carnis* of hunted animals, and requires confirmation). Sarokin has stated the same fact in respect of the frog. The electro-motor currents show a decided diminution during contraction.

That great molecular changes go on in the contracting muscles is certain, but their exact nature is not clear; according to Hermann, there is a jelly-like separation and coagulation of the myosin, and then a resumption of its prior form, so that there is a continual splitting of the muscular structure into a myosin coagulum, carbon dioxide, and a free acid, and this constitutes the main molecular movement. But no direct evidence has been given of this.

The increased heat, the great amount of carbon dioxide, and the disappearance of oxygen, combined with the respiratory phenomena already noted, all seem to show that an active oxidation goes on, and it is very probable that this is the source of the muscular action. The oxidation may be conceived to take place in two ways: either during rest oxygen is absorbed and stored up in the muscles and gradually acts there, producing a substance which, when the muscle contracts, splits up into lactic acid, carbon dioxide, &c.; or, on the other hand, during the contraction an increased absorption of oxygen goes on in the blood and acts upon the muscles, or on the substances in the blood circulating through the muscles. The first view is strengthened by some of Pettenkofer and Voit's experiments, which show that during rest a certain amount of storage of oxygen goes on, which no doubt in part occurs in the muscles themselves. Indeed, it has been inferred that it is this stored-up oxygen, and not that breathed in at the time, which is used in muscular action. The increased oxidation gives us a reason why the nitrogenous food must be increased during periods of great exertion. An increase in the supply of oxygen is a necessity for increased muscular action: but Pettenkofer and Voit's observations have shown that the absorption of oxygen is dependent on the amount and action of the nitrogenous structures of the body, so that, as a matter of course, if more oxygen is required for increased muscular work, more nitrogenous food is necessary. But apart from this, although experiments on the amount of nitrogenous elimination show no very great change on the whole, there is no doubt that, with constant regular exercise, a muscle enlarges, becomes thicker, heavier, contains more solid matter, and in fact has gained in nitrogen. This process may be slow, but it is certain; and the nitrogen must either be supplied by increased food, or be taken from other parts.

Although we do not know the exact changes going on in the muscles, it seems certain that regular exercise does produce in them an addition of nitrogenous tissue.

Whether this addition occurs, as usually believed, in the period of rest succeeding action, when in some unexplained way the destruction, which it is presumed has taken place, is not only repaired, but is exceeded (a process difficult to understand), or whether the addition of nitrogen is actually made during the action of the muscle, must be left undecided for the present.

The substances which are thus oxidised in the muscle, or in the blood circulating through it, and from which the energy manifested, as heat or muscular movement, is believed to be derived, may probably be of different kinds. Under ordinary circumstances, the non-nitrogenous substances, and perhaps especially the fats, furnish the chief bodies acted upon. But it is probable that the nitrogenous substances also furnish a contingent of energy. The exact mode in which the energy thus liberated by oxidation is made to assume the form of mechanical motion is quite obscure.

The Exhaustion of Muscles.—There seems little doubt but that this is chiefly owing to two causes—first, and principally, to the accumulation in them of the products of their own action; and, secondly, from the exhaustion of the supply of oxygen. Hence rest is necessary, in order that the blood may neutralise and carry away the products of action, so that the muscle may recover its neutrality and its normal electrical currents, and may again acquire oxygen in sufficient quantity for the next contraction. In the case of all muscles these intervals of action and of exhaustion take place, in part even in the period which is called exercise, but the rest is not sufficient entirely to restore it. In the case of the heart, the rest between the contractions (about two-thirds of the time) is sufficient to allow the muscle to recover itself perfectly.

The body after exertion absorbs and retains water eagerly; the water, though taken in large quantities, does not pass off as rapidly as usual by the kidneys or the skin, and instead of causing an augmented metamorphosis, as it does in a state of rest, it produces no effect whatever. So completely is it retained, that although the skin has ceased to perspire, the urine does not increase in quantity for several hours. The quantity of water taken is sometimes so great as not only to cover the loss of weight caused by the exercise, but even to increase the weight of the body.

We can be certain, then, of the absolute necessity of water during and after exercise, and the old rule of the trainer, who lessened the quantity of water to the lowest point which could be borne, must be wrong. In fact, it is now being abandoned by the best trainers, who allow a liberal allowance of liquid. The error probably arose in this way: if, during great exertion, water is denied, at the end of the time an enormous quantity is often drunk, more in fact than is necessary, in order to still the overpowering thirst. The sweating which the trainer had so sedulously encouraged is thus at once compensated, and, in his view, all has to be done over again. All this seems to be a misapprehension of the facts. The body must have water, and the proper plan is to let it pass in in small quantities and frequently; not to deny it for hours, and then to allow it to pass in in a deluge. The plan of giving it in small quantities frequently does away with two dangers, viz., the rapid passage of a large quantity of cold water into the stomach and blood, and the taking of more than is necessary.

General Effect of Exercise on the Body.—As judged by the preceding facts, the main effect of exercise is to increase oxidation of carbon and perhaps also of hydrogen; it also eliminates water from the body, and this action continues for some considerable time; after exercise the body is therefore poorer in water, especially the blood; it increases the rapidity of circulation everywhere, as well as the pressure on the vessels, and therefore it causes in all organs a more rapid outflow of plasma and absorption,—in other words, a quicker renewal. In this way also it removes the products of their action, which accumulate in organs, and restores the power of action to the various parts of the body. It increases the outflow of warmth from the body by increasing perspiration. It therefore strengthens all parts. It must be combined with increased supply both of nitrogen and carbon (the latter possibly in the form of fat), otherwise the absorption of oxygen, the molecular changes in the nitrogenous tissues, and the elimination of carbon, will be checked. There must be also an increased supply of salts, certainly of chloride of sodium; probably of potassium phosphate and chloride. There must be proper intervals of rest, or the store of oxygen, and of the material in the muscles which is to be metamorphosed during contraction, cannot take place. The integrity and perfect freedom of action both of the lungs and heart are essential, otherwise neither absorption of oxygen nor elimination of carbon can go on, nor can the necessary increased supply of blood be given to the acting muscles without injury.

In all these points, the inferences deducible from the physiological inquiries seem to be quite in harmony with the teachings of experience.

AMOUNT OF EXERCISE WHICH SHOULD BE TAKEN.

It would be extremely important to determine, if possible, the exact amount of exercise which a healthy adult, man or woman, should take. Every one knows that great errors are committed, chiefly on the side of defective exercise. It is not, however, easy to fix the amount even for an average man, much less to give any rule which shall apply to all the divers conditions of health and strength. But it is certain that muscular work is not only a necessity for health of body, but for mind also; at least it appears that diminution in the size of the body from deficient muscular work seems to lead in two or three generations to degenerate mental formation.

The external work which can be done by a man daily has been estimated at $\frac{1}{7}$th of the work of the horse; but if the work of a horse is considered to be equal to the 1-horse power of a steam engine (viz., 33,000 pounds raised 1 foot high per minute, or 8839 tons raised 1 foot high in ten hours), this must be an over-estimate, as $\frac{1}{7}$th of this would be 1263 tons raised 1 foot in a day's work of ten hours. As already stated elsewhere, a usual day's work for an adult ranges from 300 to 450 foot-tons. The following table, by Haughton, may be useful as expressing the amount of work done, under certain forms of labour.

Labouring Force of Man.

Kind of Work.	Amount of Work.	Authority.
Indian dhooli bearer,	600 tons lifted 1 foot.	de Chaumont.
Indian hill coolie	500 ,, ,,	,,
Pile driving,	312 ,, ,,	Coulomb.
Pile driving,	352 ,, ,,	Lamande.
Turning a winch,	374 ,, ,,	Coulomb.
Porters carrying goods and returning unladen,	325 ,, ,,	,,
Pedlars always loaded,	303 ,, ,,	,,
Porters carrying wood up a stair and returning unloaded,	381 ,, ,,	,,
Paviours at work,	352 ,, ,,	Haughton.
Military prisoners at shot drill (3 hours), and oakum picking, and drill,	310 ,, ,,	,,
Shot drill alone (3 hours),	160·7 ,, ,,	,,

The hardest day's work of twelve hours noted by Parkes was in the case of a workman in a copper rolling-mill. He stated that he occasionally raised a weight of 90 pounds to a height of 18 inches 12,000 times a day. Supposing this to be correct, he would raise 723 tons 1 foot high. But this much exceeds the usual amount. The same man's ordinary day's work, which he considered extremely hard, was raising a weight of 124 ℔ 16 inches 5000 or 6000 times in a day. Adopting the larger number, this would make his work equivalent to 443 tons lifted a foot; and this was a hard day's work for a powerful man. Some of the puddlers in the iron country, and the glass-blowers, probably work harder than this; but there are no calculations recorded. From the statement of a pedlar, his ordinary day's work was to carry 28 ℔ 20 miles daily. The weight is balanced over the shoulder,—14 ℔ behind and 14 ℔ in front. Assuming the man to weigh 160 ℔, the work is equal to 443 tons lifted 1 foot. It would, therefore, seem certain that an amount of work equal to 500 tons lifted a foot is an extremely hard day's work, which perhaps few men could continue to do. 400 tons lifted a foot is a hard day's work, and 300 tons lifted a foot is an average day's work for a healthy, strong adult. The work usually calculated for a horse in the army is 3000 foot-tons, and $\frac{1}{7}$th of this is just 430, nearly the work of the pedlar above mentioned.

The external work is thus 300 to 500 tons on an average; the internal work of the heart, muscles of respiration, digestion, &c., has been variously estimated; the estimates for the heart alone vary from 122 to 277 tons lifted a foot. The former is that given by Haughton, who estimates the respiratory movements as about 21 tons lifted a foot in twenty-four hours. Adopting a mean number of 260 tons for all the internal mechanical work, and the external work of a mechanic being 300 to 500 tons, this will amount to from $\frac{1}{8}$th to $\frac{1}{7}$th of all the force obtainable from the food.

The exertion which the infantry soldier is called upon to undergo is chiefly drill, and carrying weights on a level or over an uneven surface.

By his philosophical studies and writings on this subject, Haughton has shown that walking on a level surface at the rate of about 3 miles an hour is about equivalent to raising $\frac{1}{20}$th part of the weight of the body through the distance walked; an easy calculation changes this into the weight raised 1 foot. When ascending a height, a man of course raises his whole weight through the height ascended.

The formula is $\frac{(W + W') \times D}{2240} \times C = \text{foot-tons}$: where W = weight of the person, and W' the weight carried, both in pounds; D the distance, in feet; and C the coefficient of traction; 2240 is the number of pounds in a ton: the distance walked in miles must be multiplied by 5280 to bring it to feet. The result is the number of tons raised one foot.

Using this formula, and assuming a man to weigh 160 ℔ with his clothes, we get the following table:—

Kind of Exercise.		Work done in Tons lifted one foot.
Walking 1 mile,		18·86
,, 2 ,,		37·72
,, 10 ,,		188·60
,, 20 ,,		377·20
,, 1 ,,	and carrying 60 ℔,	25·93
,, 2 ,,	,,	51·86
,, 10 ,,	,,	259·30
,, 20 ,,	,,	518·60

It is thus seen that a march of 10 miles, with a weight of 60 ℔ (which is nearly the weight a soldier carries when in marching order, but without blanket and rations), is a moderate day's work. A 20 miles march, with 60 ℔ weight, is a very hard day's work. As a continued labouring effort, Haughton believes that walking 20 miles a day, without a load (Sunday being rest), is good work (323 tons lifted a foot); so that the load of 60 ℔ additional would make the work too hard for a continuance.

It must, however, be remembered that it is understood that the walking is on level ground, and is done in the easiest manner to the person, and that the weights which are carried are properly disposed. The labour is greatly increased if the walk is irksome, and the weights are not well adjusted. And this is the case with the soldier. In marching, his attitude is stiff; he observes a certain time and distance in each step; he has none of those shorter and longer steps, and slower and more rapid motion, which assist the ordinary pedestrian. It may be questioned, indeed, whether the formula does not under-estimate the amount of work actually done by a soldier. The work becomes heavier, too, *i.e.*, more exhausting, if it is done in a shorter time; or, in other words, velocity is gained at the expense of carrying power. The velocity, in fact, *i.e.*, the rate at which work is done, is an important element in the question, in consequence of the strain thrown on the heart and lungs.

From certain calculations made by Weber, Haughton determined the coefficients of resistance for three velocities, as follows:—

Miles per hour.	Coefficient of Resistance.
1·818	$\frac{1}{28\cdot27}$
4·353	$\frac{1}{15\cdot70}$
10·577	$\frac{1}{7\cdot51}$

Interpolating between these numbers we can obtain the coefficients at other velocities. The following table shows the coefficients, the distance in miles that would equal 300 foot-tons for a man of 160 ℔, and the time in hours and minutes that would be required without rest:—

Velocity in Miles per hour.	Coefficient of Resistance.	Distance for Men of 160 ℔, to equal 300 foot-tons.	Time required in Hours and Minutes. H.	M.
1	$\frac{1}{38\cdot08}$ =	30·2	30	12
2	$\frac{1}{26\cdot74}$	21·2	10	36
3	$\frac{1}{20\cdot59}$	16·3	5	24
4	$\frac{1}{16\cdot74}$	13·3	3	18
5	$\frac{1}{14\cdot10}$	11·2	2	36
6	$\frac{1}{12\cdot18}$	9·6	1	36
7	$\frac{1}{10\cdot72}$	8·5	1	12
8	$\frac{1}{9\cdot60}$	7·6	0	57
9	$\frac{1}{8\cdot65}$	6·9	0	46
10	$\frac{1}{7\cdot89}$	6·3	0	38

or this may be stated thus: the residual resistance equivalent to the erect posture is equal to $\frac{1}{66\cdot44}$, or 0·01505; for every mile of velocity per hour add $\frac{1}{89\cdot51}$, or 0·01117; thus for three miles an hour we have $0\cdot01505 + (0\cdot01117 \times 3) = 0\cdot04856$, or $\frac{1}{20\cdot59}$, as above. The coefficient $\frac{1}{20}$ corresponds very nearly to 3·1 miles an hour, and this appears to be the rate at which the greatest amount of work can be done at the least expenditure of energy. As regards velocity, Haughton states the "Law of Fatigue" as follows:—"When the same muscle (or group of muscles) is kept in constant action till fatigue sets in, the total work done, multiplied by the rate of work, is constant." The "Law of Refreshment" depends on the rate at which arterial blood is supplied to the muscles, and the "Coefficient of Refreshment" is the work restored to the muscles in foot-pounds per ounce of muscle per second; for voluntary muscle it is on an average 0·1309, and for the heart 0·2376, or exactly equal to the work of the heart, which never tires.

In the University boat races, when the speed is about a mile in five minutes, or 18·56 foot-tons in five minutes, the work is not apparently very hard, but it is very severe for the time, and has considerable effect on the circulatory system.

Some experiments made by North, upon himself, are remarkable as having been done under circumstances of great precision. His weight was 132 ℔, and he carried 28 ℔, the total weight being 160 ℔. In his first experiment he walked 30 miles at 4·28 per hour; work done, 712 foot-tons. Second experiment—32 miles at 4·57 per hour; work done, 728 foot-tons. Third experiment—33 miles at 4·71 per hour; work done, 843 foot-tons. Fourth experiment—47 miles at 4·7 per hour; work done, 1200 foot-tons.

Looking at all these results, and considering that the most healthy life is that of a man engaged in manual labour in the free air, and that the daily work will probably average from 250 to 350 tons lifted 1 foot, we can, perhaps, say, as an approximation, that every healthy man ought, if possible, to take a daily amount of exercise in some way, which shall not be less than 150 tons lifted 1 foot. This amount is equivalent to a walk of about 9 miles; but then, as there is much exertion taken in the ordinary business of life, this amount may be in many cases reduced. It is not possible to lay down rules to meet all cases; but probably every man with the above facts before him could fix the amount necessary for himself with tolerable accuracy.

In the case of a soldier, if he were allowed to march easily, and if the weights were not oppressively arranged, he ought to do easily 12 miles daily for a long time, provided he was allowed a periodical rest. But he could not for many days, without great fatigue, march 20 miles a day with a 60 ℔ load, unless he were in good condition and well fed. If a greater amount still is demanded from him, he must have long subsequent rest. But all the long marches by our own or other armies have been made without weights, except arms and a portion of ammunition. Then great distances have been traversed by men in good training and condition.

V. Harley's observations indicate that the periods of digestion, as well as the kinds of food taken, have a marked influence on voluntary muscular energy, and that, irrespective of the influence of food, there is a periodical diurnal rise and fall of power for the performance of muscular work. He shows that more work can be done after than before mid-day; the minimum being about 9 A.M., and the maximum about 3 P.M. Sugar taken early in the evening is capable of obliterating the diurnal fall in muscular power that occurs at this time, and increases the resistance to fatigue. Harley states that the effect of sugar is so great that the amount of work performed on a diet of sugar alone is almost equal to that obtained on a full diet; fatigue, however, setting in sooner. Moderate smoking, although it may have a slight influence in diminishing the power of doing voluntary muscular work, neither stops the morning rise, nor, when done early in the evening, hinders the evening fall. These conclusions are very interesting, but having been made exclusively upon a small group of muscles of the forearm under very artificial conditions, it is doubtful whether they can be accepted entirely for the whole body.

What is known as "training" is a systematic effort to increase breathing power: to make the muscular action more vigorous and enduring, and to lessen the amount of fat. This is obtained by a very careful diet, containing little or no alcohol; by regular and systematic exercise; and by increasing the action of the eliminating organs, especially of the skin. What the trainer thus accomplishes is in essence the following: a concordant action is established between the heart and blood-vessels, so that the strong action of the heart, during exercise, is met by a more perfect dilatation of the vessels, and there is no blockage of the flow of blood; in the lungs, the blood not only passes more freely, but the amount of oxygen is increased;

this gradual improvement in breathing power is well seen when horses are watched during training. The reciprocal action of heart and blood-vessels is the most important point in training; the nutrition of nerves and muscular fibres improves from the constant action and the abundant supply of food; the tissue changes are more active, and elimination, especially of carbon, increases. A higher condition of health ensues, and, if not carried to excess, "training" is simply another word for healthy and vigorous living.

BIBLIOGRAPHY AND REFERENCES.

Allbutt, *Alpine Journal*, May 1871.

Blyth, *Proc. Roy. Soc. Lond.*, 1884, xxxvii. p. 46.

De Chaumont, Appendix 24 to *Report of Committee on Outbreak of Scurvy*, Blue Book, 1875; also *Lectures on State Medicine*, Lond., 1875, p. 46.

Fraser, *Journ. of Physiology*, Nov. 1868.

Harley, *Journ. of Physiology*, xvi. Nos. 1 and 2, 1894, p. 97. Haughton, *A New Theory of Muscular Action*, Lond., 1870; also *Principles of Animal Mechanics*, Lond., 1873. Hermann, *Untersuchungen über den Stoffwechsel der Muskeln*, Berlin, 1865; also *Weitere Untersuch. zur phys. der Muskeln*, 1867. Hirn, Ludwig's *Physiol.*, 2nd ed., Bd. i. p. 743.

Lagrange, *Physiology of Exercise*, Lond., 1889. Lee, *Exercise and Training*, Lond., 1880.

Maclaren, *On Training*, Lond., 1882. Marcet, "The History of the Respiration of Man," being the Croonian Lectures for 1895. *Lancet, June 22nd* and *29th*; also *July 6th* and *13th*, 1895. Morgan, *University Oars*, Lond., 1877.

North, "On the Elimination of Nitrogen during Exercise," *Proc. Roy. Soc. Lond.*, xxxvi. p. 11, and xxxix. p. 46.

Parkes, *Proc. Roy. Soc. Lond.*, Nos. 89 and 94, 1867; also Nos. 127 and 136; also *On the Composition of the Urine*, Lond., 1860. Pavy, *Lancet*, Dec. 1876. Power, "On the Excretion of Nitrogen by the Skin," *Proc. Roy. Soc. Lond.*, 1882, xxxiii. p. 354.

Speck, *Archiv. des Vereins. f. wiss. Heilkunde*, Bd. vi. p. 285. Smith, "On the Work of the Horse," *Veterinary Hygiene*, Lond., 1887.

Voit, von, *Zeitsch. f. Biol.*, ii. and iii.; also in Ranke's *Physiol. des Menschen*, p. 551.

CHAPTER VIII.

SOIL.

Though the term soil may, in a general sense, be taken to express all the portion of the earth's crust which by any property or condition can affect health, it is usual and convenient to divide all soils into an upper or surface soil and a deeper or subsoil layer. While the former or surface soil consists in the main of the products of the decay of large quantities of both animal and vegetable matter, constituting mould or "humus," the latter, strictly speaking, results entirely from the breaking up of the underlying primitive rocks, under the influence of water, gases and other agencies, and constitutes thereby an intermediate stage between the subjacent rock formation and the upper layers of true soil or mould. The relative thicknesses of these two layers constantly varies, for while the surface soil may be measured often only in inches or a few feet, the subsoil may extend some hundreds of feet in depth. The expression rock is here used in its geological sense, as meaning any hard or soft material which goes to form the solid earth, and includes clays, loose sands, and gravels.

Since the chief origin of the surface layers of the ground is from the gradual disintegration of rocks, the nature and composition of a soil in any given place will greatly vary, according to the geological history of the locality. Hence, from the nature of the soil, we can infer what is the quality of the rock that lies beneath it, or knowing what is the underlying rock, we may fairly correctly form an opinion as to the character of the overlying soil. Thus, sandstones, when disintegrated or denuded, will produce sandy soil, and a clay, a clayey soil, or if the two kinds of rock be together, they will produce a loam or sandy clay: the resulting soils being also more or less mixed with the remains of vegetable and animal matter. Owing, however, to the action of rain and other forces constantly moving matters to a greater or less distance from their source, the soils of various localities do not necessarily and strictly correspond to the rocks beneath them, but may result in such instances of a clay soil overlying a sandstone, or a highly fertile soil being found to rest upon a substratum of rock which, from its known composition, must, on disintegration, obviously produce a poor one. Similarly, the continual advance of sand over a country, under the action of the prevalent wind, has utterly ruined many fertile tracts, as, for example, the sandy region known as the "Landes" along the shores of the Bay of Biscay, and the "Dunes" of Norfolk and North Wales.

THE GEOLOGICAL ORIGIN OF SOILS.

Recognising the origin of all soils from the disintegration of rocks, it is of primary importance, for a complete comprehension of the nature of soils, to have some idea as to the composition of these earlier formations. All rocks are made up of one or more minerals. Those which contain more than one mineral are merely mechanical mixtures of them and not chemical compounds. **Minerals**, on the other hand, have, as a rule, a more or less definite chemical composition, which can be expressed by a formula: they, however, differ very greatly in composition. Some consist of only one element, others of two: in the latter case, one element is often a metal, as in *pyrites*, a compound of iron and sulphur: or *fluor*, which is a compound of calcium and fluorine. The elements constituting a mineral may, however, be both non-metals, as in the case of *silica*, which consists of silicon and oxygen. The greater number of minerals consist of at least three elements, and form salts of a very complicated nature. This is particularly the case with those salts in which a non-metallic oxide like silica has combined with two or more metallic bases. Certain elements greatly preponderate in soils: those most frequently met with are, oxygen, silicon, aluminium, calcium, magnesium, sodium, and potassium. The minerals may be classified in the following manner:—

Elements.—Native gold, silver, and copper: carbon as graphite and diamonds: sulphur.

Sulphides of zinc (blende), lead (galena), copper (copper glance), mercury (cinnabar), iron (pyrites), arsenic (realgar and orpiment), antimony (stibuite), and mispickel, which is a combination of iron with arsenic.

Chlorides of sodium (rock salt) and of ammonium (sal-ammoniac).

Fluorides.—Fluor-spar or the fluoride of calcium.

Oxides.—Cuprite or the oxide of copper: spinel or a compound of magnesia, aluminium, and oxygen: magnetite or the magnetic oxide of iron, Fe_3O_4: hæmatite, another oxide of iron, frequently met with in an earthy condition and known as red ochre: corundum, a sesquioxide of aluminium, which as a red crystal is the ruby, when blue, the sapphire, and in other tints is the emerald, topaz, and amethyst: pyrolusite, an ore of manganese; cassiterite or the common tin ore of Cornwall: quartz, or crystallised silicon, and familiar under the various forms of flint, Brazilian pebbles, cairngorm, agate, opal, chalcedony, and jasper.

Carbonates of iron (chalybite), calcium (calcite and aragonite), magnesium (magnesite), barium (witherite), zinc (calamine), strontium (strontianite), copper (malachite), and a double carbonate of calcium and magnesium known as bitter spar or dolomite.

Sulphates of calcium, existing as selenite, gypsum, alabaster or anhydrite, and of barium in the form of heavy spar.

Silicates.—These are of a complex and variable constitution: the chief being hornblende, felspar, and mica. Hornblende is a dark green silicate of calcium, magnesium, and iron together often with aluminium. It enters largely into the formation of rocks, and a fibrous form is in daily use as asbestos. Closely allied to hornblende are augite, jade, meerschaum, and serpentine. The felspars are silicates of aluminium, united with one or more metallic oxides. Next to quartz, they constitute the most important rock-forming minerals. The micas form another group of silicates of very varied composition, consisting chiefly of aluminium, potassium, magnesium, and iron, with a little fluorine and water. Closely allied to them are other silicates, such as beryl, leucite, tourmaline, chlorite, and glauconite.

Other salts are represented by borax or borate of sodium, nitre as nitrate of potassium and apatite, a phosphate of calcium with fluorine and chlorine.

Organic mineral matters are common in the form of amber and coal.

Of the foregoing minerals, practically only four enter largely into the formation of rocks: they are quartz, felspar, hornblende, and mica. The resulting rock formations have been divided by geologists into three principal kinds according to their mode of origin, namely the igneous, the aqueous or sedimentary, and the metamorphic.

Igneous Rocks.—These are all believed to have been derived from the original molten matter of the once fluid earth: some having solidified at a considerable depth, while others have been forced upwards and then cooled and solidified at or near the surface. These rocks contain a great number and variety of minerals: these latter being for the most part double silicates of great complexity. The minerals may be in a coarse crystalline condition as in granite, or indistinguishably mixed as in the basalts, or fused into a glass as in obsidian, or loose and open as in pumice, or stratified as in volcanic ash. These varieties of texture are mainly to be explained by the different conditions under which the rock has cooled. All the various minerals of igneous rocks are built up of silica, alumina, lime, oxide of iron, soda, potash, magnesia, and water. They exist chiefly as quartz, felspar, and mica. The first is pure silica; felspar is a silicate of aluminium and of potassium, sodium, or calcium. Unlike quartz, which is most durable, felspar is prone to break down under the influence of exposure to air and rain into clay, which is nothing more than an aluminous silicate. Mica, like quartz, is not very liable to chemical change, but, by continued friction, breaks into a fine scaly sand or dust. The other minerals of the igneous rocks are mostly silicates of calcium, magnesium, aluminium, and iron. Silica, either free or combined, being the most prominent constituent of the igneous rocks, its varying percentage is often made use of to classify them: those having above 60 per cent. being called *acidic*, and those having less, *basic*.

The more general classification of the igneous rocks is into the *Plutonic* or those coarse crystalline rocks which have cooled slowly far beneath the surface, and the *Volcanic* or the scoriaceous, glassy and compact rocks which have been cooled at or near the surface. These can further be subdivided, if necessary, into acidic and basic. Of the plutonic rocks, the chief type is granite, which forms a considerable portion of the earth's surface. The crystals of granite lie closely packed in a matrix of transparent quartz. The silica of the quartz and that existing in the felspar, mica, and other minerals of granite constitutes from 62 to 80 per cent. of the whole weight, so that it belongs to the acidic class. If hornblende is present in addition to the ordinary constituents of a granite, it is termed syenitic granite. The basic plutonic rocks are chiefly mixtures of felspars with hornblende, augite, or mica; many of them are green in colour, and are known technically as *diabase*, *gabbro*, *aphanite*, and *diorite*. A crystalline mixture of hornblende and felspar is called syenite.

Of the volcanic rocks, the chief are basalt, dolerite, trachyte, obsidian, pumice, and phonolite. The broken material emitted from volcanoes is called "ash," and when more or less solidified is called *tufa*. The half molten rocky material from volcanoes is the *lava*. This lava, when dense and columnar, as in Staffa, is *basalt;* if coarser, it is called *dolorite*. The term *trap* is given to certain dark basaltic lavas, which are found spread out in great sheets over large areas in the Deccan and Sweden.

Aqueous Rocks.—These are composed of small particles which are derived from the wearing away of other rocks and of matter which has been deposited from solution or suspension in water, or from organic materials. They are often called sedimentary rocks from their mode of formation, and are of four chief kinds, namely, the argillaceous, the arenaceous, the calcareous, and the organic.

Argillaceous rocks are the result of the sedimentary deposit of mud and clay, and consist largely of impure silicate of aluminium. The various claystone formations, such as the Lias, Oxford, Kimmeridge, Wealden, and London clays, are the products of these rocks: so are the *shales*, which are merely hardened and laminated clays.

Arenaceous rocks are those formed of sand or minute rounded grains of quartz. These grains, indifferently held together by clay, silica, iron oxides, or carbonate of lime, constitute the argillaceous, siliceous, ferruginous, and calcareous sandstones and grits. Conglomerates are rocks of this class, formed by pebbles or shingle cemented together, while a breccia rock is one composed of rough and angular fragments similarly cemented. Both the argillaceous and arenaceous rocks are essentially, in their mode of origin, sedimentary.

Calcareous rocks are those which are formed of the material which has been dissolved in water and deposited therefrom by chemical action. Of this class are the various limestones, which have been deposited from solution by loss of carbonic acid on exposure to the air. The deposition of carbonate of lime from aqueous solutions at the present time is familiar in the so-called petrifying springs, and in the growth of stalactites. Some limestones are formed of little spherical grains, like the roe of a fish; these are called *oolite*. When consisting of an admixture of carbonate of lime and carbonate of magnesia, limestones are termed *dolomites*. Another rock of this class is gypsum. Flints and chert are other instances of chemical action, by which the silica scattered through the chalk has been dissolved by percolating water, and then deposited as we now find it. By a somewhat similar process, large nodules of carbonate of lime, called *Kunkur*, are formed in beds of clay in parts of India. They contain some clay, and when ground up make a kind of cement.

Organic rocks are those aqueous rocks which consist mainly of limestones derived from the shells or other hard parts of marine organisms, and of carbonaceous beds formed of plants. Among the limestones of organic origin are the coralline and crinoidal limestones, consisting largely of the remains of corals, molluscs, and crinoids. In the same way originated the shell marls and shell sands, while chalk itself, being of marine origin, is composed mostly of the remains of Foraminifera. Of the organic rocks derived from plants, coal, peat, lignite, jet, plumbago, anthracite, and bitumen are conspicuous examples.

Metamorphic Rocks.—Any mass of rock which has been altered when *in situ*, as distinguished from that which has been worn away, broken up and deposited elsewhere, as a sedimentary rock, is said to be metamorphic. Of these metamorphic rocks, there may be said to be two groups: one, containing those rocks which have not been so altered as to prevent the recognition of their original condition, and the other, including those whose primitive state is quite obliterated by chemical and other changes. The first group embraces the slates, mica and marl slates, marble and quartzites; in which the original clay, limestone, and sandstone formation are respectively still discernible.

The second group comprises the true metamorphosed rocks. They are characteristic of Wales and the Highlands of Scotland, and are suggestive of the influence of subterranean heat, combined with great pressure and the presence of water, whereby they have become foliated or schistose. The most abundant rock of this class is *gneiss*, which is really a granite altered by pressure. The other schistose rocks are the various schists, such as mica-schist, hornblende-schist, talc-schist and others produced from sandy and clay deposits, the relative amount of either substance determining the character of the schist.

Formation of Soils.—From the foregoing geological survey it is clear that the igneous and metamorphic rocks are almost entirely silicates, while the softer aqueous or sedimentary rocks consist mainly of silicates, carbonates, and oxides. Changes of temperature, largely aided by frost, have cracked and broken up these various rocks mechanically. By the influence of rain and air, carbonic acid and oxygen have entered the interstices of the rocks and acted chemically upon their constituents. The carbonic acid, dissolved in water, has assisted in the disintegration of granites and basalts, by converting their contained felspar into a soluble carbonate, which, being readily carried off, has left a residue of clay behind: so that what was originally a hard granite rock has become a disintegrated mass of clayey gravel, representing the natural soil of a granite district. Basalt suffers in the same way, breaking up into a gritty clay containing nodular masses of greyish coloured stone, as noticeable on the moors of north Yorkshire. Upon the limestones, the carbonated waters have acted in a similar manner, slowly dissolving away the carbonate of lime and leaving undissolved the clay and flints. This clay with flints constitutes the natural soil of the chalk districts, while the clay without the flints is familiar in the limestone regions. Both by means of water and air, oxygen acts upon the various substances in the rocks, converting the carbonates and silicates of iron into oxides, and contributing not a little to the varying colours of different soils. In these and other ways the external surfaces of rocks become "weathered."

Generally speaking, the acid igneous rocks decompose into clay, silica, and alkaline carbonates, thus weathering into clayey soils which contain particles of quartz, felspar, and mica, as evidenced by the loams so commonly found over granites and schistose rocks. The basic rocks resolve largely into clay and carbonates of calcium, magnesium, and iron, yielding marls or coloured clays.

The formation of surface soils, from the weathering and decomposition of rocks, is by no means a purely chemical process caused by the direct action of rain and air, but is also in large part aided by the presence and action of both animal and vegetable life. From both animals and plants there is furnished, to the soil, matter, which not only adds to its bulk, but enriches it and renders it still more suitable for plant life. This is continually being removed by rain, which either runs off or through it, and, as continually, is replenished by the breaking up of the rocks below and the decaying vegetable matter above. The upper layers, in which organic matter predominates, are carried down by rain, and the lower and more mineral portions are brought to the surface by burrowing insects, worms, moles, and rabbits. In this manner the organic and inorganic matters of the earth are constantly being intermingled and renewed, and the soil both increased and improved. To these agencies must be added the constant action of wind and rain in moving soil from one part to another and the substitution of new surface soil by the upraising of a certain amount of material from deeper strata.

Being composed partly of inorganic matter derived from the subsoil by the process of weathering, and partly of the products of decomposition of animal and vegetable matter, most soils contain in abundance the compounds which plants require, such as nitrogen, lime, potash, soda, magnesia, silica, and phosphoric acid; but these substances are in an insoluble condition and only rendered assimilable by plants, after a slow conversion into soluble compounds by the agency of various forms of bacteria. This process, combined with the decomposition of vegetable remains, results in the formation of the so-called "humus." Very little is known with regard to the exact composition of humus. Some attempts have been made to separate it into constituent parts, and certain acids have been found, some of which, such as Crenic acid, $C_{12}H_{12}O_8$, are soluble in both water and alkalies: others, such as Humic acid, $C_{21}H_{24}O_{12}.3H_2O$, being insoluble in water but soluble in alkalies: whilst others again, such as Ulmic acid, $C_{40}H_{28}O_{12}.H_2O$, are insoluble in both water and alkalies.

The colour of humus is said to depend upon the nature of the acid present, ulmic acid giving a brown, and humic acid a black mould.

SOIL FEATURES WHICH INFLUENCE CLIMATE AND HEALTH.

There are certain general features of soil which materially influence both climate and health: they are, its Conformation and Elevation, the amount of Vegetation present upon it, its contained Air and Water, its Temperature and power for absorbing or retaining Heat, and lastly, the nature and number of its contained Micro-organisms.

Conformation and Elevation.—The relative amounts of hill and plain; the elevation of the hills; their direction; the angle of slope; the kind, size, and depth of valleys; the chief watersheds, and the direction and discharge of the water-courses; the amount of fall of plains, are the chief points to be considered.

Among the hills the unhealthy spots are enclosed valleys, punch-bowls and any spot where the air must stagnate, such as ravines or places at the head or entrance of ravines.

In the tropics especially ravines and nullahs are to be avoided, as they are often filled with decaying vegetation, and currents of air frequently traverse them. During the heat of the day the current of air is up the ravine, at night down it. As the hills cool more rapidly than the surrounding plains, the latter current is especially dangerous, as the air is at once impure and cold. The worst ravine is a long narrow valley, contracted at its outlet, so as to dam up the water behind it. A saddleback is usually healthy, if not too much exposed; so are positions near the top of a slope. One of the most difficult points to determine in hilly regions is the probable direction of winds; they are often deflected from their course, or the rapid cooling of the hills at night produces alteration.

On plains the most dangerous points are generally at the foot of hills, especially in the tropics, where the water, stored up in the hills and flowing to the plain, causes an exuberant vegetation at the border of the hills.

A plain at the foot of hills may be healthy, if a deep ravine cuts off completely the drainage of the hill behind it.

The next most dangerous spots are depressions below the level of the plain, and into which therefore there is drainage. Even gravelly soils may be damp from this cause, the water rising rapidly through the loose soil from the pressure of higher levels.

Elevation acts chiefly by its effect in lessening the pressure of the air, and in increasing the rapidity of evaporation. It has a powerful effect on marshes, high elevations lessening the amount of malaria, partly from the rapid evaporation, partly from the greater production of cold at night. Yet malarious marshes may occur at great elevations, even 6000 feet.

Vegetation.—The effect of vegetation on ground is very important. In cold climates the sun's rays are obstructed, and evaporation from the ground is slow; the ground is therefore cold and moist, and the removal of wood renders the climate milder and drier. The extent to which trees impede the passage of water through the soil is considerable.

In hot countries vegetation shades the ground and makes it cooler. The evaporation from the surface is lessened; but the evaporation from the vegetation is so great as to produce a perceptible lowering effect on the temperature of a place. Pettenkofer calculated that from an oak tree the evaporation equalled 212 inches, while the rainfall was only 25·6 inches; this shows how much water was abstracted from the soil, and how the air must have been moistened and cooled. Observations in Algeria have shown that *Eucalyptus globulus* absorbs and evaporates eleven times the rainfall; extremely malarious places being rendered healthy in this way in four or five years.

The hottest and driest places in the tropics are those divested of trees.

Vegetation produces also a great effect on the movement of air. Its velocity is checked; and sometimes in thick clusters of trees or underwood the air is almost stagnant. If moist and decaying vegetation be a coincident condition of such stagnation, the most fatal forms of malarious disease are produced. It may thus do harm by obstructing the movement of air; on the other hand, it may guard from the currents of impure air. The protective influence of a belt of trees against malaria is most striking.

In a hygienic point of view, vegetation must be divided into herbage, brushwood, and trees; and these should be severally commented on in reports.

Herbage is always healthy. In the tropics it cools the ground, both by obstructing the sun's rays and by aiding evaporation; and nothing is more desirable than to cover, if it be possible, the hot sandy plains of the tropics with close-cut grass.

Brushwood is frequently bad, and should often be removed. There is, however, evidence that the removal of brushwood from a marsh has increased the evolution of malaria, and that, like trees, brushwood may sometimes offer obstruction to the passage of malaria. It must also be remembered that its removal will sometimes, on account of the disturbance of the ground, increase malarious disease for the time; and therefore, in the case of a temporary camp in a hot malarious country, it is often desirable to avoid disturbing it. When removed, the work should be carried on in the heat of the day, *i.e.*, not in the early morning or in the evening.

W. North instances the case of Cisterna, where the removal of *macchia* (*i.e.*, brushwood, &c.), though long objected to on account of supposed protection from malarial currents, was the means of improving the healthiness of the district.

Trees should be removed with judgment. In cold countries they shelter from cold winds; in hot they cool the ground; in both they may protect from malarious currents. A decided and pernicious interference with the movement of air should be almost the only reason for removing them. In some of the hottest countries of the world, as in Southern Burmah, the inhabitants place their houses under the trees with the best effects; and it was a rule with the Romans to encamp their men under trees in all hot countries.

The kind of vegetation, except as being indicative of a damp or dry soil, does not appear to be of importance.

Ground Air.—The hardest rocks alone are perfectly free from air; the greater number even of dense rocks, and all the softer rocks, and the loose soils covering them, contain air. The amount is in loose sands often 40 or 50 per cent.; in soft sandstones, 20 to 40 per cent. The loose soil turned up in agricultural operations may contain as much as 2 to 10 times its own volume of air.

The nature of the air in soils has been examined by a good many observers; it is mostly very rich in carbon dioxide, is very moist, and probably contains effluvia and organic substances, derived from the animal or vegetable constituents, which have not yet been properly examined. Occasionally it contains carburetted hydrogen, and in moist soils, when the water contains sulphates, a little hydrogen sulphide may be found. It has been examined by Nichols in America, Fleck in Dresden, Fodor in Buda-Pesth, Lewis and Cunningham in Calcutta, and many others.

Pettenkofer was one of the first to point out the excess of carbon dioxide in ground air, as compared with that in atmospheric air. According to him, the amount increased with the depth from which the air was drawn, and was moreover much influenced by the season of the year, the greatest quantity, at a given depth, being obtained in July, and the least in January. This was at Munich. Fodor, at Buda-Pesth, and Fleck, at Dresden, obtained very similar results, their figures being:—

At a depth of 1 metre, 0·9 to 1·0 vol. of CO_2 per cent.
,, ,, 2 ,, 2·9 ,, 3·0 ,, ,, ,,
,, ,, 4 ,, 3·0 ,, 5·4 ,, ,, ,,
,, ,, 6 ,, 7·9 ,, 10·0 ,, ,, ,,

Both Pettenkofer and Fleck were of opinion that this carbon dioxide was due to the decomposition of organic substances, and that it might afford an approximate index of the degree of soil pollution. Fodor has, however, shown that a very foul soil, if at the same time permeable, contains less carbon dioxide than a cleaner but less permeable soil: and suggests that although the carbon dioxide is probably produced by the decomposition of organic matters, it does not afford so much a means of estimating the degree of pollution, as of the permeability of the soil.

Lewis and Cunningham, in their observations at Calcutta, found results somewhat similar to those of Fodor, the carbon dioxide being greatest in the lower strata examined. They considered that the fluctuation in the amount of carbon dioxide must be due to one or other of two causes: (1) variation in amount produced; (2) variation in amount accumulated, which would depend on the amount of soil-ventilation; and that this latter cause was the most operative in Calcutta. The carbon dioxide increased with the rainfall, the effect of the rain being to close the pores in the upper layers of the soil and so retain the carbon dioxide. Soil temperature they did not consider to have any effect. The composition of soil air differs at different times and seasons, the absolute and relative amounts of the constituents varying under varying conditions.

Just as the carbon dioxide increases so does the amount of oxygen decrease with the depth from which the soil air is withdrawn. Some figures given by Fodor gave from 18 to 21 per cent. of oxygen at a depth of 1 metre, and 18 per cent. at 4 metres. In some freshly manured moist soil, Boussingault found the percentage of carbon dioxide to be as much as 9·5, and that of oxygen only 10. From this it would seem that, on air passing into soil, its oxygen enters into chemical combination with carbon derived from animal and vegetable matter, and thus becomes replaced by an equal volume of carbon dioxide. However, this is not always the case, as occasionally the percentage amounts of O_2 and CO_2 together in soil air are such as to suggest the possible union of some of the oxygen with hydrogen to form water, and with nitrogen to form nitrates: while the carbon dioxide which is formed may dissolve in the water in the soil, or unite with ammonia and the earthy salts to form bicarbonates. On this point, some experiments have been made by us, which show that if air be driven through a cylinder, packed with ordinary moist earth, less carbon dioxide will be recovered from it, after passing through the soil, than was originally present in it. When dry sand was used, the air passed through it unaltered. Other observations made by Röller show that many of the differences between the atmosphere and ground air may be due to different soils having varying absorptive powers for different gases. Thus a rich loam absorbed much more nitrogen than oxygen, and no soil appeared to absorb either of these gases in exactly the same relative proportions in which they were mixed in the atmosphere.

Some observers have noted that, occasionally, the carbon dioxide in the ground air is greater in amount than corresponds to the oxygen absorbed from the atmosphere. Schlösing has explained this as being due to the vital action of putrefactive organisms: for if air, containing different amounts of oxygen, be drawn through earth containing putrefactive organisms, not only was the carbon dioxide largely increased, but oxygen was diminished along with a reduction of the nitrates, present in the soil, into nitrites and even ammonia. In this case the organisms had evidently used not only the atmospheric oxygen, but also abstracted some from the organic matters and nitrogen salts in the soil. This sequence of events further explains why increased amounts of carbon dioxide are found in the deeper earth layers, particularly after or during periods of warmth and moderate moisture, that is, at a time when organisms concerned in decomposition processes would be in a state of greatest activity.

The marked effect of rainfall and heat upon the amount of carbon dioxide in the soil has been emphasised by Lewis and Cunningham and ourselves, the increase of rainfall and warmth being quickly attended by an increase of carbon dioxide, while in dry cold weather the quantity of carbon dioxide is reduced. Such an increase after rain and heat is probably due to a blocking up of the pores of the superficial soil layers, synchronous with an increased production whereby an accumulation of carbon dioxide takes place in the deeper portions. The presence of much moisture in a soil is invariably coincident with a fall in the amount of carbon dioxide in the soil air owing to absorption by the water. Some daily variations of carbon dioxide in the ground air have been noticed, but appear to depend less upon processes of soil activity than on rain, wind, and changes of atmospheric pressure. These two latter do not appear to exert any very great influence, and are evidently secondary to rainfall as factors in the greater or less existence of carbon dioxide in soil air.

The *nitrogen* present in the ground air is almost constant, being the same as that in the atmosphere, namely, about 79 per cent. Besides oxygen, nitrogen, and carbon dioxide, the ground air contains about 85 per cent. of humidity, together with various products of fermentation and decomposition, such as ammonia, ammonium sulphide, hydrogen sulphide, and marsh gas: these latter, however, rarely existing in large amounts. Owing to the constant reduction, in the soil, of the various oxidised states of nitrogenous organic substances into ammonia, under the influence of bacteria, this gas, although present in the ground air, cannot be taken as an index of either pollution or putrefactive changes. Provided the air be taken from soils which have practically the same degree of permeability, the relative amounts of CO_2 found in it will furnish the best evidence as to their relative impurity: but if the permeability of soils vary, the amount of carbon dioxide in the soil air is not a reliable index of either purity or impurity.

The subterranean atmosphere thus existing in many loose soils and rocks is in continual movement, especially when the soils are dry; the chief causes of movement are the diurnal changes of heat in the soil, and the fall of rain, which must rapidly displace the air from the superficial layers, and, at a later date, by raising the level of the ground water, will slowly throw out large quantities of air from the soil. Fodor considers the temperature of the air, the ground temperature, the action of the winds, rainfall, barometric pressure, and level of ground water to be all influential in causing movement of the ground air, and consequent relative change in its constituents.

Local conditions must also influence the movement; a house artificially warmed must be continually fed with air from the ground below, and doubtless this air may be drawn from great depths. Coal gas escaping from pipes, and prevented from exuding by frozen earth on the surface, has been known to pass sideways for some distance into houses. The air of cesspools and of porous or broken drains will thus pass into houses, and the examination of drains alone often fails to detect the cause of effluvia in the house.

The unhealthiness of houses built on "made soils," for some time after the soils are laid down, is no doubt to be attributed to the constant ascent of impure air from the impure soil into the warm houses above.

To hinder the ascent of air from below into a house is therefore a sanitary point of importance, and should be accomplished by paving and concreting, or asphalting the basement, or, in some cases, by raising the house on arches off the ground. The improvement of the health of towns, after they are well paved, may be partly owing to lessening of effluvia, though partly also to the greater ease of removing surface impurities. In some malarious districts great benefit has been obtained by covering the ground with grass, and thus hindering the ascent of the miasm.

As a rule, it is considered that loose porous soils are healthy, because they are dry, and, with the qualification that the soil shall not furnish noxious effluvia from animal or vegetable impregnation, the rule appears to be correct. It is, however, undoubted that dry and apparently tolerably pure soils are sometimes malarious, and this arises either from the soils being really impure, or from their porosity allowing the transference of air from considerable distances. Even on the purest soils it is desirable to observe the rule of cutting off the subsoil air from ascent into houses.

The amount of air in soils can be roughly estimated, in the case of rather loose rocks, by seeing how much water a given bulk will absorb, which can be done by the following plan:—Weigh a piece of dry rock, and call its weight W: then weigh it in water and call this weight W_1: then take it out of the water saturated with moisture, and weigh it again; call this weight W_2. We then have—

$$\frac{(W_2 - W)100}{W - W_1} = \text{percentage of air.}$$

Example.—A piece of dry rock weighs 100 grammes (W); when weighed in water it weighs 60 (W_1); weighed out of water, but saturated, it weighs 110 (W_2): then $\frac{110 - 100}{100 - 60} = \frac{10}{40} = 0{\cdot}25$, and this multiplied by 100 gives 25 per cent. of porosity.

When the soil is loose, Pettenkofer adopts the following plan:—Dry the loose soil at 212° F. (100° C.), and powder it, but without crushing it very much; put it into a burette, and tap it so as to expel the air from the interstices as far as possible; connect another burette by means of an elastic tube with the bottom of the first burette and clamp it on close to the end of the latter; pour water into No. 2 burette, and then, by pressing the clamp, allow the water to rise through the soil until a thin layer of water is seen above it; then read off the amount of water used out of the second burette. The calculation—

$$\frac{\text{Amount of water used} \times 100}{\text{Cubic centimetres of dry soil}} = \text{percentage of air.}$$

Example.—30 c.c. of soil were put in the burette; it took 10 c.c. of water to reach to the top: then $\frac{10 \times 100}{30} = 33{\cdot}3$ per cent. of porosity.

Renk's plan is very simple. Take a measured quantity of soil, say 50 c.c., shaken well together, so as to represent its natural condition as much as possible, and put it into a 200 c.c. graduated glass measure: then pour in 100 c.c. of water, and shake well so as to expel all air. Allow it to stand a little, and read off the point at which the water stands. Suppose it stands at 125 c.c., then the 50 c.c. of soil and the 100 c.c. of water, when shaken together, only occupy a space of 125 c.c., the difference, 25 c.c., representing the bulk of air displaced from the 50 c.c. of soil: therefore $\frac{25}{50} \times 100 = 50$ per cent. of air or porosity in the sample of soil.

The examination of soil air can be best carried out by inserting into the soil leaden or iron tubes provided at their ends with perforated bulbs. To facilitate the introduction of these tubes, a hole must be dug, in the bottom of which broken bricks or large stones should be placed, and the bulbed ends of the tubes fixed at varying depths among them, the pit being afterwards filled and rammed in with the displaced soil. It is advisable that the disturbed earth be allowed to remain a month or more, before observations are made, so as to allow the soil to regain its ordinary condition. The tubes so placed in the earth should be next connected with an aspirator, capable of holding 2 litres of air: while intervening between the tubes and the aspirator must be arranged the usual appliances for the estimation of carbon dioxide, of oxygen, organic matter or micro-organisms in air. It is not necessary here to describe any of these procedures, as they are explained in another chapter: it is sufficient to point out that the essence of these arrangements is to be able to extract air from varying soil depths and then cause it to pass over or into certain reagents, contained in suitable apparatus, so as to complete the determination required.

Ground Water.—The water present in soils is divided into moisture and ground water. When air as well as water is present in the interstices the soil is merely moist. The ground water may be defined, after Pettenkofer, as that condition in which all the interstices are filled with water, so that, except in so far as its particles are separated by solid portions of soil, there is a continuity of water. Other definitions of ground water have been given, but it is in this sense it is spoken of here.

Moisture of Soil.—The amount of moisture depends on the power of the soil to absorb and retain water, and on the supply of water to the soil either from rain or ground water. With respect to the first point, almost all soils will take up water. Pfaff has shown that dried quartz sand in a filter can take up as much as 20 per cent. of water, and, though in the natural condition in the soil the absorption would not be so great, there is no doubt that even the hardest sands retain much moisture. After several months of long-continued drought, Church found a light calcareous clay loam subsoil to contain from 19 to 28 per cent. of water.

A loose sand may hold 2 gallons of water in a cubic foot, and ordinary sandstone may hold 1 gallon. Chalk takes 13 to 17 per cent.; clay, if not very dense, 20; humus, as much as 40 to 60, and retains it strongly. The so-called "cotton-soil" of Central India, which is derived from trap rock, absorbs and retains water with great tenacity; the driest granite and marbles will contain from 0·4 to 4 per cent. of water, or from 5 to 50 pints in each cubic yard.

The moisture in the soil is derived partly from rain, to which no soil is absolutely impermeable, as even granite, clay slate, and hard limestone may absorb a little. Practically, however, soils may be divided into the impermeable (unweathered granite, trap and metamorphic rocks, clay slate, dense clays, hard oolite, hard limestone and dolomite, &c.) and the permeable (chalk, sand, sandstone, vegetable soils, &c.). The amount of rain passing into the soil is influenced, however, by other circumstances—by the declivity and inclination of the soil; by the amount of evaporation, which is increased in summer; by hot winds; and by the rapidity of the fall of rain, which may be greater than the soil can absorb. On an average, in this country, about 25 per cent. of the rain penetrates into the sand rock, 42 per cent. into the chalk, and from 90 to 96 per cent. into the loose sands. The rest evaporates or runs off the surface by the lines of natural drainage. The rapidity with which the rain-water sinks through soil evidently varies with circumstances; in the rather dense chalks it has been supposed to move 3 feet downwards every year, but in the sand its movement must be much quicker.

The moisture of the soil is not, however, derived solely from the rain; the ground water by its own movement of rising and falling, by evaporation from the surface of the subterranean water, and by capillary attraction, makes the upper layers of the soil wet. By these several agencies the ground near the surface is in most parts of the world kept more or less damp.

Daubrée estimated the height to which water is raised by capillarity as follows:—

30 centimetres in sands.
60 ,, ,, calcareo-argillaceous soils.
150 ,, ,, clays and compact marls.

In the superficial soil layers, the capillary action appears to be greatest for clays and least for chalks: humus and sand occupying an intermediate position.

As regards the affinity of soils for water and their capabilities for moisture, a distinction must be made between the permeability and absorptive power of a soil. A permeable soil, by allowing water or moisture to pass through it, contributes to the supply of the ground water, while an absorptive soil really retains the moisture. Miers and Crosskey have explained the action of the soil in regard to water as being of a threefold nature. They say, it may act merely as a strainer allows fluid to pass through itself: it may take up water just as blotting paper takes up ink: or it may be saturated by water and retain it, as a sponge, immersed in water, is saturated by liquid which flows from it when the sponge is lifted out. This involves a distinction between *permeability*, *imbibition* and *saturation*: because, the amount of water which percolates through the soil is due to its permeability, that which is retained as moisture in the soil is due to its power of imbibition, while that lying in the subsoil, in the form of ground water, depends upon the saturation. Practically, the relation to water of a given soil depends upon all these three qualities, and according as the one or other is most prominent, so will the soil be drier or damper.

Thus, sandstones are very permeable but not absorptive, the same is the case with the limestones, chalk and schistose rocks. Generally speaking, soils which possess a great capacity for imbibition are not very permeable, and conversely the most permeable soils have the least storage capacity. The best test of permeability of a soil will be the rapidity with which percolation takes place through it. A number of experiments made indicate that water passes through clay the most slowly, and gradually increases in rapidity through marls, granitic soils, loams, limestone, coarse sand, basaltic soil, and fine sand. Warrington found that at Rothamsted only 7 inches of rain, out of an annual fall of 28 inches, percolated, during the year, through 3 feet of clayey gravel: while Prestwich relates that "on the chalk hills it takes four to six months for rain to pass from the surface to the line of water level at the depth of 200 to 300 feet, so that the heavy rainfall of winter is not felt in the deep springs for some months."

Absorption, being mainly dependent upon capillary action, is always greater for rocks or soils which consist of fine particles: the following table summarises a large number of observations:—

Granites	will absorb	from	0·1	to	0·4	per cent.	of water.
Shales	,,	,,	0·3	,,	1·5	,,	,,
Basalts	,,	,,	0·3	,,	3·0	,,	,,
Sandstones	,,	,,	0·5	,,	10·0	,,	,,
Dolomites	,,	,,	0·5	,,	5·0	,,	,,
Limestones	,,	,,	1·0	,,	16·0	,,	,,

If expressed as the proportion of the volume of water taken up to the volume of the soil, we get the following results:—

Humus,	70	per cent.
Clay,	60	,,
Fine limestone,	44	,,
Sand,	40	,,

Regarding the value of a rock or soil as a water-bearing stratum being mainly dependent upon its capacity for saturation, the following figures from Delesse are interesting:—

Sandstone	will	retain	29	per cent.	of water.
Chalk	,,	,,	24	,,	,,
Clay	,,	,,	20	,,	,,
Clay with chalk		,,	19	,,	,,
Basalt	will	retain	0·3	,,	,,
Granite	,,	,,	0·1	,,	,,

The determination of moisture in soil can be made by drying 10 grammes at a temperature of 110° C., then weighing, when the difference of the two observations will represent the amount sought. The quantity of moisture which a given soil sample is capable of taking up, may be determined by placing the previously dried soil under a bell-jar over water and noticing the resulting increase of weight.

The amount of actual moisture found in soils appears to vary with the depth and the amount of contained organic matter, being diminished as deeper layers are penetrated and as the quantity of organic material decreases. The moisture varies not only from year to year, but from month to month, reaching in Europe generally a maximum in May and then falling during the summer until late autumn. In the deeper soil layers, the maximum of moisture is not attained till midsummer. The minimum found by Fodor in Buda-Pesth at 1 metre was 5·9 per cent., while at 4 metres it was 3·2 per cent. Decomposition, in soil, ceases when the moisture falls below 1·5 per cent., but is most active when the amount is about 4 per cent. A sample of surface soil, taken at 6 inches, consisting of loose sandy loam, examined by one of us in India, contained but 2 per cent. of moisture.

The Ground or Subsoil Water.—The subterranean continuous water, known as *ground or subsoil water*, is at very different depths below the surface in different soils; sometimes it is only 2 or 3 feet from the surface, in other cases as many hundreds. This depends on the compactness or permeability of the soil, the ease or difficulty of outflow, and the existence or not of an impermeable stratum near or far from the surface. It is an error to look upon the ground water as a subterranean lake or sea, with an even surface like an ordinary sheet of water, for it is not necessarily horizontal, and in some places it may be brought nearer to the surface than others by peculiarities of ground. The water is in constant movement, in most cases flowing towards the nearest water-courses or the sea; the rate of movement has not yet been perfectly determined. In Munich, Pettenkofer reckons its rate as 15 feet daily; the high water in the Elbe moves the ground water in the vicinity at the rate of about 7 or 8 feet daily. Fodor gives the mean rate at Buda-Pesth as 53 metres (174 feet), with a maximum of 66 metres (216 feet) in twenty-four hours, reckoning by the rise of the wells following the rise of the Danube.

The rate of movement is not influenced solely by compactness or porosity of soil, or inclination. The roots of trees exert a great influence in lessening the flow; and, on the other hand, water runs off more rapidly than before in a district cleared of trees. The level of the ground water is constantly changing. It rises or falls more or less rapidly and at different rates in different places; in some cases its movement is only a few inches either way, but in most cases the limits between its highest and lowest levels in the year are several feet (in Munich about 10). In India the changes are greater. At Saugor, in Central India, the extremes of the soil water are from a few inches from surface (in the rains) to 17 feet in May. At Jubbulpore it is from 2 feet from the surface to 12 or 15. At Calcutta, Lewis and Cunningham found the water level to vary between 5 and 15 feet below the surface.

The *causes of change* in the level of the ground water are the rainfall, pressure of water from rivers or the sea, and alterations in outfall, either increased obstruction or the reverse. The effect of the rainfall is sometimes only traceable weeks or even months after the fall, and occasionally, as in plains at the foot of hills, the level of the ground water may be raised by rainfalls occurring at great distances. The pressure of the water in the Rhine has been shown to affect the water in a well 1670 feet away. The pressure of the Danube at Buda-Pesth is found to influence a well at a distance of 2700 feet (Fodor).

In a place near the Hamble River (Hampshire) the tide was found to affect the water of a well at a distance of 2240 feet, the well itself being 83 feet deep and 140 feet above mean water-level. A uniformly low ground water, say 15 to 20 feet, is most healthy, but a uniformly high ground water, say 3 to 5 feet, is preferable to one that is fluctuating, especially if the limits be wide. It must, however, be borne in mind that it is not the ground water itself that is the cause of disease, but the impurities in the soil which the varying level of the ground water helps to set in action.

Measurement of the Ground Water.—The height at which water stands in wells is considered to give the best indication of the height of the ground water. Pettenkofer uses a rod on which are fixed a number of little cups, and, when let down into the well and drawn up again, the uppermost cup which contains water marks, of course, the height of the water; the length of the cord or rod used for letting down the cups being known, the changing level of the well can be estimated to within half an inch. Some precautions are necessary in making these observations: if a rope is used it may stretch with use, or in a hot dry wind, or contract in wet weather, and thereby make the observation incorrect; local conditions of wells, proximity to rivers, &c., must be learnt, else what may be termed local alterations in a well may be wrongly supposed to mean changes in the general level of the ground water. It is necessary, therefore, to make the observations simultaneously in many wells and over a considerable district. The observations should be made not less often than once a fortnight, and oftener if possible, and be carried on for a considerable time before any conclusions are drawn.

Pettenkofer also uses a large float which is suspended by a chain travelling over a pulley: this supports an indicator at its other end, which marks the height on a fixed scale.

Method of rendering Soil Drier.—There are two plans of doing this,—deep drainage and opening the outflow. The laying down of sewers often carries off water by leaving spaces along the course of the sewers, but this is a bad plan; it is much better to have special drains for ground water laid by the side of or under the sewers. Deep soil drainage (the drains being from 8 to 12 feet deep and 10 to 20 feet apart) is useful in all soils except the most impermeable, and in the tropics should be carried out even on what are apparently dry sandy plains.

In some cases soil may be rendered drier by opening the outflow. This is an engineering problem which medical officers can only suggest. The clearing of water-courses, removal of obstructions, and formation of fresh channels are measures which may have an effect over very large areas which could not be reached by ordinary drainage.

Soil Heat.—Under this heading is involved the questions of the capacity of soils for both absorbing, retaining and giving off heat, as well as the facts regarding mere soil temperatures. It is a matter of common knowledge that certain soils are warmer than others, that is, they are more easily heated by the sun's rays, or in other words have a lesser or greater *specific heat*. The specific heat of any body is defined as being that amount of heat necessary to raise its unit mass through 1° C.: the unit of heat adopted being the quantity of heat needed to raise 1 kilogramme of water through 1° C. The specific heat of water is usually taken as unity, and on this basis, from the following table, it will be seen that the chief soils and their constituents have a distinctly lower specific heat than water, and that consequently all of them are more easily warmed than water.

Clay	has a	specific	heat of	0·160
Quartz	,,	,,	,,	0·188
Felspar	,,	,,	,,	0·190
Granite	,,	,,	,,	0·192
Calcite	,,	,,	,,	0·204
Mica	,,	,,	,,	0·205
Slate	,,	,,	,,	0·207
Limonite	,,	,,	,,	0·221
Limestone	,,	,,	,,	0·245
Loam	,,	,,	,,	0·259
Basalt	,,	,,	,,	0·270
Sand	,,	,,	,,	0·275
Marl	,,	,,	,,	0·284
Humus	,,	,,	,,	0·600

Complementary to the foregoing, may be taken the two following tables, quoted by Lloyd from experiments made by Liebenberg of Halle.

Gain of Heat by Soils.

	Original Temperature.	After ½ hour.		After 1 hour.		After 2 hours.	
		2 cm.	5 cm.	2 cm.	5 cm.	2 cm.	5 cm.
Lime sand,	21° C.	29° C.	27°·5 C.	32° C.	31°·5 C.	36°·5 C.	37°·0 C.
Tertiary clay,	21°	30°	27°·5	33°	30°·0	36°·3	35°·0
Tertiary sand,	21°	30°	28°·0	33°	32°·5	37°·5	36°·5
Marl,	21°	31°	28°·5	34°	32°·5	39°·0	37°·5
Meadow loam,	21°	32°	27°·5	37°	36°·0	40°·5	38°·5
Rich loam,	21°	32°	29°·0	36°	34°·0	41°·5	39°·5
Basalt,	21°	33°	28°·5	35°	33°·0	42°·0	38°·0
Water,	21°	26°	26°·0	29°·5	29°·5	31°·0	31°·0

Loss of Heat by Soils.

	Original Temp.	After ½ hour.	After 1 hour.	After 2 hours.
Coarse sand,	41°·25 C.	29°·75 C.	24°·25 C.	19°·75 C.
Fine sand,	41°·75	28°·25	23°·25	18°·75
Marls,	40°·00	27°·50	23°·00	18°·50
Loams,	40°·00	27°·00	22°·00	18°·00
Clay,	39°·50	26°·00	21°·50	18°·00

With regard to the heat retaining power of some soils, the following are the results of Schübler's observations:—

Power of retaining Heat, 100 being assumed as the standard.

Sand with some lime,	100·0	Clayey earth,	68·4
Pure sand,	95·6	Pure clay,	66·7
Light clay,	76·9	Fine chalk,	61·8
Gypsum,	72·2	Humus,	49·0
Heavy clay,	71·11		

These tables all show that not only does sand warm much more rapidly than clay, but also that the presence of organic matter in any soil causes it to possess a relatively greater power of absorbing heat. These facts are probably due to the peculiar behaviour of water to heat. Water is both a bad absorber and bad radiator of heat, hence soils which contain much water, such as a damp clay, have a higher specific heat than dry porous soils, like sand, and consequently warm slowly and are often spoken of as "cold soils." This is in accordance with everyday experience.

The rapidity with which soils radiate heat is not necessarily equal to their power of absorbing it, but will depend somewhat on their colour and the kind and thickness of the vegetation growing upon them. It is notorious that dark materials always absorb more radiant heat than light ones: "it has been found, for instance, that with the same exposure to the sun, a white sand attained a temperature of 43° C., while a black sand rose to 50° C."

Generally the radiating power is more rapid than the absorbing: soils cool more rapidly than they heat. Some of the marshes in Mexico cool so rapidly at night that the evolution of malaria is said to be stopped, and the marsh is not dangerous during the night. Jourdanet states that while a thermometer marked zero on the ground, it recorded 14° C. at a distance of 16 feet above the ground. Vegetation and herbage greatly lessen the absorption of heat by a soil, at the same time making radiation more rapid. On the Orinoco, a naked rock has been known to have a temperature of 48° C., while an adjacent rock covered with grass had a temperature of but 30° C.

Not only does the amount of radiation differ in different soils, but a change is produced in the heat by the kind of soil. The remarkable researches of Tyndall have shown that the heat radiated from granite passes through aqueous vapour much more readily than the heat radiated by water (though the passage is much more obstructed than in dry air). In other words, the luminous heat rays of the sun pass freely through aqueous vapours and fall on water and granite; but the absorption produces a change in the heat, so that it issues again from water and granite changed in quality.

Besides the excess of heat absorption over heat radiation, it is probable that soils obtain a considerable amount of heat by virtue of the chemical actions which are constantly taking place within them; "it having been proved by numerous observers that the growth of plants is always accompanied by a rise in temperature, which again is related to the rapidity of their vital processes." The heat liberated by the condensation of gases may, too, be a not inconsiderable source of warmth.

It will be readily understood, from the above considerations, that the temperature of the soil is but rarely that of the atmosphere, but more often higher: and, too, that the earth's temperature is different in different places. Fodor was one of the first, from his observations made at Buda-Pesth, to point out that the surface soil is warmer by day and colder by night than the air, but that the subsoil reaches its maximum and minimum heat later than the surface soil, so that it is colder in summer but warmer in winter than the superficial layers. His observations give the following results:—

Average	maximum	temperature, at	½ to 1 metre	in depth, was found	in	August.
,,	,,	,,	2 metres	,,	,,	September.
,,	,,	,,	4 ,,	,,	,,	October.
,,	minimum	,,	½ to 1 metre	,,	,,	January or Feb.
,,	,,	,,	2 metres	,,	,,	April.

Fodor's results and those of others indicate the greatest range of temperature in the superficial soil: at 18 inches below the surface there occurs in Europe a variation of from 15° to 20° C. below the monthly mean, while at 10 feet deep the variation is as little as from 3° to 5° C.

There is a marked difference in the manner in which the *surface* soil temperatures follow variations in the atmospheric heat, as compared with the temperatures of the deeper layers. While the temperature of the surface soil will quickly respond to small changes in heat of the air, that of the soil below the surface follows even great variations of air temperature but slowly. Thus, after a series of cold or warm days, it will be three or more days before the soil temperature, at a depth of half a metre, will accommodate itself to that of the air. At greater depths the stability of the soil temperature is even greater.

The sun's rays would appear to cause two currents of heat in soil: one wave is diurnal, the heat passing down in temperate climates to about 4 feet in depth during the day, and receding during the night, the depth, however, varying with the nature of the soil and with the season: the other wave is annual, the amplitude of which diminishes with the depth till it ceases to be perceptible. Forbes has shown, from observations made in Edinburgh, that the annual variation is not appreciable lower than 40 feet below the surface, and that under 24 feet the changes of temperature are small through the year. The depth at which the annual variation ceases, or where the temperature is constant, depends on the conductivity and specific heat of the soil: but particularly on the difference between the summer and winter temperatures. The rate at which the annual wave of heat is propagated downwards is so slow, that at Edinburgh, at a depth of 24 feet, the highest annual temperature does not occur till January, and the lowest not till the middle of July: thus reversing the seasons at this depth. At Greenwich, at 25½ feet, these phases of the annual temperature occur on November 30th and June 1st. Some observations, made in the Punjab, showed that at 20 feet the annual maximum was reached in September and the minimum in March. According to Everett, the heat of the earth's surface is not influenced by the flow of heat from below upwards, but is determined entirely by atmospheric conditions. The temperature gradient averages an increase of heat downwards of 1° F. for each 50 feet roughly: which makes the soil heat gradient five times steeper than that of air. The soil temperature gradient is steepest beneath gorges and least so beneath ridges: hence the underground isothermals (annual) are flatter than the uneven surfaces above them. The increase or extension of heat through any cubic area of soil is about equal to the product of the temperature gradient by the conductivity, so that it includes convection by the percolation of water as well as conduction proper: as a result of this, in comparing different strata of soil, the heat gradient varies in the inverse ratio of the soil conductivity.

In Calcutta, Lewis and Cunningham found that the temperature of the soil varied with the season. In hot weather the thermometer stood highest in the air, next highest in the upper stratum of the soil, and lowest in the lower stratum. In cold weather the conditions were exactly reversed, the air being coolest and the lowest stratum of soil the hottest. During rain, however, these relations were not constant.

Since the effect of cold, generated by nocturnal radiation, mostly accumulates on the earth's surface, while the effects of solar radiation are spread to some height by ascending currents from the heated ground, it might be expected that the mean annual temperature of the soil surface would be lower than that of the air resting on it: this is precisely what is found to be the case. On the other hand, the deeper layers of the earth are often warmer than the atmosphere, and do not display the same extremes of heat as does the air. This is seen in the case of deep springs which get their source from depths greater than that to which the annual variation of soil heat penetrates, and have in consequence a constant temperature throughout the year, and further, if they come from a depth much greater, they give a close approximation to the mean annual temperature of the place.

Reflection of Light.—This is a matter of colour; the white glaring soils reflect light, and such soils are generally also hot, as the rays of heat are also reflected. The effect of glare on the eyes is obvious, and in the tropics this becomes a very important point. If a spot bare of vegetation, and with a white surface, must be used for habitations, some good result might be obtained by colouring the houses pale blue or green.

The effect of soil temperature upon disease is undoubtedly important, more particularly with regard to malaria, cholera, and epidemic diarrhœa. These relations will be considered later on, when discussing the influence of soil generally to special diseases.

Estimation of Soil Temperatures.—No difficulty should be experienced in making these observations. One or more shafts or tubes should be bored into the soil to the required depth: the sectional diameter of these tubes may vary from 2 to 8 inches. Into the tubes, boards or blocks of wood should be made to fit, carrying the thermometers at suitable depths; the opening or mouth of the tube being closed with an accurately fitting cap or plug. The observations should be taken at the same hour every day, the thermometers immediately returned into the soil, care, of course, being taken, before so doing, to raise the registering index of the minimum, and to depress that of the maximum instrument well above and below the temperature of the soil.

Micro-organisms in Soil.—It has for some years been known that ordinary garden soil and agricultural humus contained large numbers of micro-organisms belonging to the Schizomycetes and other allied groups of the lower Fungi. Schlösing and Muntz in 1877–78, and Warington about the same time, showed that the process of nitrification that takes place in soils is a fermentative process, excited and carried on through the agency of a minute organism, just as ordinary fermentation is carried on by *torula.* Miquel in 1879 attempted to estimate the number of germs present in soils of different kinds. Since then, Koch, Fränkel, Flügge, the Franklands, and other observers have pursued the subject, which opens out a large field for investigation of great importance: these researches have yielded results from which some conclusions may be drawn, though at the present stage of the inquiry this should only be done with caution.

The existence of micro-organisms in soil is not surprising, when one considers that in many kinds of ordinary soil all the conditions necessary for their growth and multiplication are present, namely, a supply of nutritive substance derived from the decomposition of organic matter, with moisture, access of air, and a suitable temperature. All of these conditions are commonly found in the superficial much more than in the deeper layers of the soil, and it is accordingly in the former rather than in the latter that microbes are found to exist in the greater numbers: below 12 to 15 feet in depth they are comparatively few. The greater the organic pollution of the soil, the greater the number of microbes present; the most suitable conditions of moisture and temperature no doubt vary in regard to different species, neither dryness nor complete saturation, nor the extremes of heat and cold, being favourable to the development of many forms at present investigated. The actual numbers of germs found, or calculated, by different observers vary very considerably, and are perhaps of not much importance, but there is a pretty general agreement in regard to these two points: (1) the larger the amount of organic matter in the soil, the greater the number of micro-organisms; (2) whatever the nature of the soil, the number of micro-organisms diminishes as the depth increases.

All forms of bacterial life have been found to be present in soil: in the moist and superficial layers, micrococci are the more numerous, while in the drier and deeper portions, bacilli are present in the largest numbers. As Flügge has shown, some species are markedly prominent, and are found in the most varied places, while others occur in only limited areas. It is probable that large numbers and kinds of bacilli are also present in the soil in the form of spores. Practically, all the micro-organisms found in soil may be divided into the *saprophytic* and the *pathogenic.*

The former probably includes a large number of species, which up to the present have not been differentiated; according to Arnould, no more precise distinction can be drawn than between those which *oxidise*, and those that *de-oxidise* or *reduce*. Of these the oxidisers are the most numerous and important, including those through whose agency the process of nitrification takes place; this, though originally supposed to be the work of one specific "nitrifying ferment," is in all probability effected by several different forms, not as yet distinguished from each other by specific characters. The *butyric ferment* of Pasteur (*Clostrydium butyricum*), which is a reducing bacterium, is likewise now considered to be not one but several species; other observers have described other reducing forms. Possibly the same species may be at one time an oxidiser, at another a reducing ferment.

The pathogenic bacteria occur with such frequency in the earth that no material produces infection so easily as soil. Well-known pathogenic inhabitants of the soil are the bacilli of malignant œdema, of infective tetanus, the bacillus septicus agrigenus, and the anthrax bacillus. With soil, too, are probably often associated Eberth's bacillus of enteric fever, the malarial plasmodium, the vibrios of cholera, some forms of pneumococci (Sherrington), and an as yet not isolated microbe connected with the occurrence of epidemic summer diarrhœa. The local and seasonal variations in the distribution of some infective diseases led Pettenkofer and others to believe that the soil had a specific influence on the development and spread of infective germs, and that there was a constant connection between soil and epidemics. The negative results of direct experiments and a fuller knowledge of the fate and behaviour of various bacteria in soil have rendered the general acceptation of this view to be impossible. Our present knowledge indicates that the pathogenic micro-organisms are not, as a rule, propagated in soil, because the saprophytes naturally existing therein find the conditions more favourable for their development, and overcome the pathogenic species in the struggle for existence. Koch and others have tried to cultivate *Bacillus anthracis* in various kinds of soil, but without success; in soil previously sterilised, however, this species has been made to undergo development, the conditions obviously being very different from those that exist under any natural circumstances.

Speaking generally, bacteria meet with unfavourable nutritive conditions in the soil, and their multiplication occurs only very exceptionally even in impure soil.

Flügge considers that on the surface of the soil pathogenic bacilli may find such conditions of moisture and temperature as are favourable to their germination and the production of new bacilli; but that they will speedily cease to exist, the vegetative form being easily overcome by saprophytes. The deeper layers of the soil, on the other hand, are favourable for the preservation of the spores of pathogenic organisms, though not for their multiplication; it is because they do not develop, but remain in the spore form, the temperature and other surrounding circumstances being unsuitable to germination, that they are preserved, vitality being maintained, though dormant.

Soyka's experiments with anthrax bacilli indicate that, in their case at least, the soil exercises no marked or specific influence on the formation of spores. Observations made with other pathogenic forms similarly show the soil to be deficient in any special power of furthering spore formation. The preservation of non-spore-bearing bacteria in soil has been explained by Soyka as likely to often occur, because in that medium they are rarely likely to become completely dried, even in the driest of soils, owing to the layer of aqueous vapour which so tenaciously surrounds the elements of the soil. The length of life of micro-organisms in the soil depends almost entirely on the amount of moisture present. Peat appears to be very hostile to many forms of bacteria; why so, is not precisely known, but is very generally attributed to the presence of complex acids. Even granting the frequent preservation of pathogenic bacteria in soil, it must be remembered that this preservation is not an exclusive attribute of soil, and that, in the case of the infective diseases, this action or want of action of the soil can but rarely influence the spread of epidemics.

Much interest attaches to the question, how do the preserved bacteria spread from the soil to man? The action of winds and the blowing about of bacteria-laden dust is only conceivable from the superficial layers of very dry soils. In some countries, notably in the East, and especially where excreta are superficially dug into or carelessly spread upon the ground, wind action probably is a more potent factor in the spread of disease than is generally recognised. In this country and Europe generally the possibility of a detachment and carrying away of soil bacteria by currents of air is only present in the latter end of summer, or in autumn, and quite absent when rain renders the outer surface of the earth moist.

In estimating the value of the ground water and the water derived from it for drinking and other purposes, as means of distributing soil bacteria, we must take into consideration the enormous capacity of soil for retaining, as it were in a mesh, even such minute bodies as bacteria. The soil is, in fact, an excellent microbic filter and "where there is a thick layer of soil above the ground water, this mode of transport cannot come into play"; but where the ground water is only separated by thin layers of loose soil from the surface, or when fissures or cracks permit a ready communication between cesspools and wells, then the bacteria will pass from the soil to man. Although the soil acts as a good filter, holding back most of the organisms, Dempster has demonstrated that it is possible for cholera commas to be carried through two feet and a half of porous soil by a current of water. Occasionally micro-organisms may be conveyed from the soil to the domestic economy by articles of food which grow in the soil or by animals, but such modes of transference must obviously be the exception rather than the rule.

The most important result of the presence of micro-organisms in soil appears to be the carrying on of a process of oxidation of the dead organic matter that finds its way into the ground, the process of *nitrification* that has already been alluded to; the nitrogen of organic bodies is first turned into ammonia, and this is successively changed into nitrites and nitrates. That this action was due to some property residing in the soil itself was shown by the experiment of Schlösing; if a weak solution of ammonia is applied to a mixture of calcined sand and chalk and freely exposed to the air, no oxidation will take place, even after several weeks; if then a morsel of garden soil be added, in a few days nitrites and nitrates will be detected. This action is entirely arrested by the introduction into the soil of vapour of chloroform, which paralyses all fermentative organisms. Hoppe-Seyler, Fleck, and other observers consider the process to be a purely chemical one, not needing the presence of any living agent; but the fermentative theory, promulgated by Schlösing and Muntz and Warington, has the sanction of Wollny, Fodor, Soyka, and others. The nitrifying power of different soils varies very considerably, depending partly on the nature of the soil itself, partly on the amount of ferment present (this in turn depending both on the number and nature of the micro-organisms), and being affected also by conditions of temperature and moisture. It appears to be of the first necessity that the soil should be alkaline, the carbonates of potash and lime being the most usual constituents, and after these, lime and magnesia; a quartz sand without lime is unfavourable to nitrification. The most favourable temperature is 37° C. The soil must be moist, and must also be penetrated by air; the successful purification of sewage by the method of intermittent downward filtration, as compared with filtration from below upwards, depends upon this; by the latter method the access of air is prevented and nitrification retarded. Along with the oxidation of nitrogenous organic matter into nitric acid proceeds the oxidation of organic carbon into carbonic acid, the one action being in fact the complement of the other.

THE COMPARISON OF DIFFERENT SOILS.

In examining the influence upon health of the soil round any dwelling, it is probable that the immediate local conditions are of more importance than extended geological inquiries: it is, so to speak, the house and not the regional geology which is of use. Still the general geological conditions, as influencing conformation and the movement of water and air through and over the country, are of great importance. The healthiness of a soil depends chiefly on the following factors:—(1) considerable slope and permeability, so that water runs off readily and regularly, rendering both the soil and the air above it dry; (2) vegetation not excessive; (3) absence of organic emanations; (4) purity of water-supply. In reference to these points, the different soils can be thus critically examined.

The Granitic, Metamorphic, and Trap Rocks.—Sites on these formations are usually healthy; the slope is great, water runs off readily; the air is comparatively dry; vegetation is not excessive; marshes and malaria are comparatively infrequent, and few impurities pass into the drinking water.

When these rocks have been weathered and disintegrated, they are supposed to be unhealthy. Such soil is absorbent of water; but evidence as to the effect of disintegrated granite or trap is really wanting.

In Brazil the syenite becomes coated with a dark substance, and looks like plumbago, and the Indians believe this gives rise to "calentura," or fever. The dark granitoid or metamorphic trap or hornblendic rocks in Mysore are also said to cause periodic fevers.

The Clay Slate.—These rocks precisely resemble the granite and granitoid formations in their effect on health. They have usually much slope; are very impermeable; vegetation is scanty; and nothing is added to air or to drinking water.

They are consequently healthy. Water, however, is often scarce; and, as in the granite districts, there are swollen brooks during rain, and dry water-courses at other times, swelling rapidly after rains.

The Sandstones.—The permeable sandstones are very healthy; both soil and air are dry; the drinking water is, however, sometimes impure, and may contain large quantities of chlorides, especially in the New Red Sandstone when rock salt abounds. If the sand be mixed with much clay, or if clay underlies a shallow sand-rock, the site is sometimes damp.

Carboniferous Formations.—The hard millstone grit formations are very healthy, and their conditions resemble those of granite. The drinking water is generally pure and fairly soft.

The Limestone and Magnesian Limestone Rocks.—These so far resemble the former that there is a good deal of slope and rapid passing off of water.

Marshes, however, are more common, and may exist at great heights. In that case the marsh is probably fed with water from some of the large cavities, which, in the course of ages, become hollowed out in the limestone rocks by the carbonic acid of the rain, and form reservoirs of water.

The drinking water is hard, sparkling, and clear. Of the various kinds of limestone, the hard oolite is the best, and magnesian is the worst; and it is desirable not to put stations on magnesian limestone if it can be avoided.

The Chalk.—The chalk, when unmixed with clay and permeable, forms a very healthy soil. The air is pure, and the water, though charged with calcium carbonate, is clear, sparkling, and pleasant. Goitre is not nearly so common, nor apparently calculus, as in the limestone districts.

If the chalk be marly, it becomes impermeable, and is then often damp and cold. The lower parts of the chalk, which are underlaid by gault clay, and which also receive the drainage of the parts above, are often very malarious; and in America some of the most marshy districts are on the chalk.

Gravels of any depth are always healthy, except when they are much below the general surface, and water rises through them. Gravel hillocks are the healthiest of all sites, and the water, which often flows out in springs near the base, being held up by underlying clay, is very pure.

Sands.—There are both healthy and unhealthy sands. The healthy are the pure sands, which contain no organic matter and are of considerable depth. The air is pure, and so is often the drinking water. Sometimes the drinking water contains enough iron to become hard, and even chalybeate. The unhealthy sands are those which, like the subsoil of the Landes, in south-west France, are composed of siliceous particles (and some iron) held together by a vegetable sediment.

In other cases sand is unhealthy, from underlying clay or laterite near the surface, or from being so placed that water rises through its permeable soil from higher levels. Water may then be found within 3 or 4 feet of the surface; and in this case the sand is unhealthy and often malarious. Impurities are retained in it, and effluvia traverse it.

In a third class of cases the sands are unhealthy because they contain soluble mineral matter. Many sands (as, for example, in the Punjab) contain much magnesium carbonate and lime salts, as well as salts of the alkalies. The drinking water may thus contain large quantities of sodium chloride, sodium carbonate, and even lime and magnesian salts and iron. Without examination of the water it is impossible to detect these points.

Clay, Dense Marls, and Alluvial Soils generally.—These are always to be regarded with suspicion. Water neither runs off nor runs through; the air is moist; marshes are common; the composition of the water varies, but it is often impure with lime and soda salts. In alluvial soils there are often alternations of thin strata of sand and sandy impermeable clay; much vegetable matter is often mixed with this, and air and water are both impure. Vast tracts of ground in Bengal and in the other parts of India, along the course of the great rivers, are made up of soils of this description, and some of the most important stations even up country are placed on such sites.

The deltas of great rivers present these alluvial characters in the highest degree, and should not be chosen for sites. If they must be taken, only the most thorough drainage can make them healthy. It is astonishing, however, what good can be effected by the drainage of even a small area, quite insufficient to affect the general atmosphere of the place; this shows that it is the local dampness and the effluvia which are the most hurtful.

Cultivated Soils.—Well-cultivated soils are often healthy, nor at present has it been proved that the use of manure is hurtful. Irrigated lands, and especially rice fields, which not only give a great surface for evaporation, but also send up organic matter into the air, are hurtful. In Northern Italy, where there is a very perfect system of irrigation, the rice grounds are ordered to be kept 14 kilometres (= 8·7 miles) from the chief cities, 9 kilometres (= 5·6 miles) from the lesser cities and the forts, and 1 kilometre (= 1094 yards) from the small towns. In the rice districts of India this point should not be overlooked.

Made Soils.—The inequalities of ground which is to be built upon are filled up with whatever happens to be available. Very often the refuse of a town, the cinders or dust-heaps, after being raked over and any saleable part being removed, are used for this purpose. In other cases chemical or factory refuse of some kind is employed. The soil under a house is thus often extremely impure. It appears, however, that the organic matters in soil gradually disappear by oxidation and removal by rain, and thus a soil in time purifies itself. The length of time in which this occurs will necessarily depend on the amount of impurity, the freedom of access of air, and the ease with which water passes through the soil. In the soil at Liverpool, made from cinder refuse, vegetable matters disappeared in about three years; textile fabrics were, however, much more permanent; wood, straw, and cloth were rotten and partially decayed in three years, but had not entirely disappeared. In any made soil it should be a condition that the transit of water through its outlet from the soil shall be unimpeded. The practice of filling up inequalities is certainly, in many cases, very objectionable, and should only be done under strict supervision.

In a tabular form, the various soil formations can be conveniently classified, thus:—

Soils in order of Healthiness.

	Slope.	Permeability to water.	Emanations into air.	Substances into water.
Primitive and metamorphic rocks (when unweathered),	Great usually.	Slight.	None.	Few.
Clay slate,	Do.	Do.	Do.	Do.
Millstone grit. Hard oolite formations,	Moderate.	Do.	Do.	Do.
Gravels and loose sands, without impermeable subsoils,	Slight.	Great.	Slight.	Variable.
Chalk (not marly),	Moderate.	Do.	Do.	Lime salts; a little magnesia.
Sandstones (old and new),	Do.	Variable, but usually considerable.	Do.	Variable, often great; alkaline and earthy salts; organic matter.
Limestones (old and new),	Considerable.	Moderate.	Do.	Rather considerable; lime salts.
Magnesian limestone, dolomite, &c.,	Moderate.	Do.	Do.	Considerable; lime; magnesia.
Sands with impermeable subsoils,	Slight.	Arrested by subsoil.	Considerable.	Variable, often great; alkaline salts; some lime.
Clays, marls, mixture of sand and clay, most alluvial soils,	Do.	Slight.	Do.	Often great; alkaline and earthy salts; organic matter.
Marshes (when not peaty),	Do.	Do.	Do.	Great; salts; organic matter.

SOIL IN RELATION TO SPECIAL DISEASES.

There are certain diseases of both animals and man, with the etiology of which the soil or the conditions of its contained air, water, and micro-organisms, from time to time, have appeared to bear some connection. The diseases are—anthrax, calculus, cancer, cholera, epidemic diarrhœa, diphtheria, dysentery, enteric fever, goitre, lead poisoning, malaria, malignant œdema, phthisis, rheumatism, rickets, tetanus, and yellow fever. If recent statements are correct, possibly to these must be added the bubonic plague, the suspected specific bacillus of which has been observed by Yersin as present in soil in Hong-Kong. While in the case of several nematoid worms known to be parasitic to man, it is probable that the soil constitutes their normal habitat, in at least one stage of their existence.

Anthrax.—Known in man, under the forms of malignant pustule and woolsorter's disease, this is a specific affection communicable to human beings directly or indirectly from the lower animals, especially the herbivora. Of all the pathogenic micro-organisms, the specific bacillus of this disease is probably the one whose history and characters have been best worked out. The anthrax bacilli are straight, slightly bent or curved rods, of a comparatively large size, having blunt or square ends and tending to adhere by their extremities so as to form long chains or filaments in the interior of some of which bright granules appear. These granules are spores, which, under certain favourable conditions, are capable of giving rise to the parent bacillary forms. The spores are much more resistant to external and unfavourable circumstances than the bacilli, being specially able to withstand considerable heat and drying. Besides, by the formation of spores, anthrax bacilli can multiply by a process of fission. The chief importance of the connection of anthrax with soil lies in the fact that the disease is specially prevalent in certain countries among animals grazing upon damp soils, rich in humus during the hotter months of the year. The infection of these animals is derived from the presence of anthrax bacilli in or on the soil surface, derived from a previous case of the disease, either from discharges of a diseased animal or from the dead carcass of one which has been either carelessly buried or left to putrefy on the surface. Pasteur has suggested that, after the burial of an animal dead from anthrax, a development of bacilli into spores can take place in the soil, and that these spores, being swallowed by earth worms, may in turn be carried to the surface so as to be capable of infecting animals grazing thereon. Owing to anthrax bacilli never forming spores except in the presence of free oxygen and a certain temperature, this suggestion of Pasteur's has been severely criticised, but it is quite probable that there is a sufficient amount of oxygen in the soil pores to bring about sporulation, especially if we remember that not only are animals often opened for examination after death but also the carcass is, as a rule, dragged along the ground before burial, causing effusion of liquid, crowded with the specific bacilli, into the surface soil.

The remedy for this sequence of events appears to be the immediate burial of the carcasses of animals dying of anthrax, *unopened* and *deeply*, when the bacilli will not only fail to produce spores but be themselves killed by the putrefactive bacteria in the course of a short time. There, however, remains the danger of a possible infection of the soil from discharges of moribund animals and the subsequent dissemination of the bacilli and their resulting spores over fields by rain or flood. Their access to drinking water in this way is not unknown, accompanied by the infection of human beings as well as of animals.

Calculus.—One of the oldest and most universal theories concerning the causation and prevalence of stone in the bladder, associates its frequency and endemicity in certain parts of the world with the subsoil water,—not from any peculiar variations in either its level, or its quantity, but rather from its quality. In so much, the chemical and mineral ingredients of a water depend on the peculiarities of the soil through which it passes, we are justified and driven to entertain the proposition that this disease is, in some way, associated with soils belonging to certain geological formations. The view that certain properties inherent in the drinking water, particularly hardness, were the real cause in the formation of calculus has been brought forward by many observers, notably by Prout and Cadge, to explain the prevalence of the disease in Norfolk and the Eastern counties of England; by Roos in Russia; by Clot Bey in Egypt; and by Balfour in India. While admitting the general strength of the arguments advanced and the imposing array of cases and figures brought forward by these writers, we are still unable to ignore the fact that the force of their arguments is much vitiated by the endemic prevalence of calculus in many places, notwithstanding the use of a comparatively pure soft water, free from lime salts: while, in other parts, where lime exists largely in the water, the disease is either rare or altogether absent.

In India, where the disease is common enough, experience shows that the cause of it cannot be discovered in the hardness of the water. The evidence from China on this point is probably the most marked; there the disease is extremely frequent, but a Chinaman rarely drinks plain cold water; the universal beverage is tea, in which the water has been previously boiled and nearly all lime in it precipitated. Again, both in Egypt and Central Africa, no connection seems to exist between the disease and any special quality of the water. Referring to Europe generally, writers testify, particularly from the Alp region, that there are many localities with very hard water and, at the same time, remarkably free from stone; as well as other places much subject to calculus, but whose water is either drawn from rain cisterns or from lime-free freshets. On the same point, Polak, quoted by Hirsch, says of Persia, "The disease is met with equally on the marshy ground by the Caspian, where the drinking water is brackish, and in association with the highly calcareous and sedimentary waters of Demarsend, Lavistan, and Mehelet, or the waters of Hamaden, issuing from volcanic ground, or the saline water of Koom."

Apart from mere questions of water analysis, the more we survey the distribution area of the disease, the more complex does its relation to soil appear. Thus, in support of the view held by some that chalk soils are peculiarly conducive to this affection, we find it to be extensively prevalent on the calcareous and dolomitic soil of the basins of the Don and Volga; on the chalk soil of eastern English counties; on the Jurassic limestone of the Swabian Alps; in the limestone districts of Cremona and Brescia; and on the Jurassic limestones of Canada; and the recent limestone of the United States. On the other hand, we find the disease is equally indigenous upon other kinds of soil, such as the basaltic trap and tufoid formations in the Deccan and Mauritius; on the alluvial soil of Canton; on the transition rocks in Cheshire and North Wales; and the carboniferous rocks of Yorkshire, with the clay sand near Ostend and Dunkirk. Not only do we find these discrepancies, but others in the fact that many parts of England, Switzerland, and the West Indian Islands, whose soil belongs to the recent chalk and limestone formations, are relatively, if not quite, exempt from the malady. In the face of these facts, one is forced to think that neither the soil itself nor the qualities which it gives to the water percolating through or issuing from it have any true influence upon either the causation or prevalence of calculous diseases; but rather, that the real etiological factors in the affection, so far from being sought for in any exterior influence, whether climatic or telluric, must, on the contrary, be looked for in certain habits of life and nutrition, or in congenital and acquired states of individual metabolism.

Cancer.—As the result of various writers', more particularly of Haviland's, inquiries into the geographical distribution of disease in Great Britain, an increased regard has been attached, in recent years, to the part played by telluric and topographical conditions in the etiology of cancer. Haviland, by constructing a series of "disease maps" from an analysis of the statistics available from the Registrar-General's office, states that cancer shows "an infrequency in places characterised by elevated sites and limestone formations, or even by sites subject to floods, but within the immediate influence of calcareous rocks," but betrays a high mortality in districts "associated with flooded, low-lying, and clayey areas." He cites the Thames valley as a typical cancer district in all respects. Further, by assuming that cancerous diseases are due to a micro-parasite and that since certain pathogenic organisms are inhabitants of the soil, Haviland is of opinion that there is a probability that the organisms concerned in cancer production also exist in the soil, thriving more especially in the alluvial earth. Recently, D'Arcy Power has endeavoured to favour the production of carcinoma in animals by exposing them in various ways to the influence of soil seeded with minced cancerous tissues. He employed a soil which fulfilled all the conditions required by Haviland for the successful propagation of cancer, assuming, for the sake of experiment, that the cancer germ existed, and that a part of its life was passed in earth. His results were entirely negative, both as to the propagation of cancer from cancer, and as to the probability of the soil having anything at all to do with its etiology. Although there is much which is suggestive in Haviland's views, we are compelled, in the face of the fact that cancer prevails in both Norway and Mexico, mostly on the higher lands, to regard his data as insufficient for the indication of any true connection between soil conditions and cancer prevalence: and even if true for England and Wales cannot be regarded as universally applicable.

Cholera.—The earliest writers upon this disease emphasised its remarkable preference for particular places: while the history of each successive epidemic implies, besides an importation of the contagium, certain local conditions which may be either general sanitary defects or peculiarities of climate and soil. It is now very generally accepted that the particulate contagium of cholera is the specific micro-organism called the comma bacillus. This grows in and liquefies alkaline gelatin, but not at all in a distinctly acid medium. Its morphological and biological characters are sufficiently distinct to render its differentiation easy. Whether it is by this particular organism *alone*, or whether it is only when in conjunction with some other, as yet unknown, microbe that the symptoms of cholera are generated, the general belief prevails that cholera, in this country at least, is mainly spread by means of the drinking water, though dissemination may occur in other ways, more particularly from an "excrement sodden earth" which fouls not only water but air. On the Continent, especially in Germany, much importance has been attached to movements of the ground water in the diffusion of cholera. This has been mainly due to the teachings of Pettenkofer, who maintained that cholera never prevails, as an epidemic, where the soil is impermeable to water, or where the soil water does not violently fluctuate in level. Pettenkofer admits the presence of a specific germ in the soil, which he considers is only able to virulently manifest itself when the soil has been rendered suitable, as when the ground water, after having risen to a higher level than usual, begins to fall again. This sequence of events is quite conceivable, by either the assumption that the sudden rise and fall in ground water level carries into wells some organic cholera-producing matter from the soil, which otherwise could not gain access to water supplies: or by assuming that the cholera micro-organism, if present in the upper soil layers, is merely awakened into activity by warmth and moisture, and subsequently becomes diffused into the atmosphere, as a drying zone of soil forms on the fall of the soil water. The latest utterances of Pettenkofer emphasise this latter view, for he says, the rise and fall of ground water are but an "index of the humidity or moisture of the porous and permeable soil which overlies the ground water." Fodor, at Buda-Pesth, has demonstrated an association of soil moisture and heat, as indicated by the fluctuations of ground water and rise in temperature, with cholera prevalence. Pfeiffer has also noted a direct relation between soil temperature at a depth of 3 to 6 feet, associated with soil moisture, and the prevalence of cholera epidemics.

Although these views as to the connection between cholera outbreaks and variations in soil heat and levels of soil water have not received much confirmation in England, still Lewis and Cunningham's observations, in Calcutta, indicate some inverse relation between conditions of water level and cholera prevalence. The level of the ground water in Calcutta is highest in September (minimum of disease), lowest in May (maximum of disease), and therefore accords closely with the inverse relation affirmed by Pettenkofer. On the other hand, no such relation was found between the cholera curve and those of soil temperature, and of the amount of carbon dioxide in soil air.

It has been alleged that (for India at least) no widespread epidemic of cholera can occur unless during or after rain. This can be readily understood if we assume, with Pettenkofer, that soil moisture, as distinguished from absolute dryness or saturation, heat, aëration, the presence of the specific germ and filth are the essential earth conditions for the spread of cholera. On the other hand, rainfall, sufficient to saturate the soil, will tend to arrest the disease, however high the temperature may be, owing chiefly to the micro-organisms being carried further from the surface where they are no longer among favourable surroundings. If rain merely moistens a previously dry and foul soil, the other conditions being present, it may induce an outbreak. Given a moist soil, prolonged heat and drought may establish conditions most conducive to cholera. It is readily intelligible, from these considerations, that low-lying and crowded districts invariably suffer more severely from cholera, during epidemics, than those at higher levels and more sparsely peopled. The former have usually not only to contend with their own local impurities, but, not infrequently, also with those carried into them by the drainage of ground water from places above them. A low level in itself, however, is not sufficient for the epidemic extension of the disease unless combined with a comparatively high temperature of both air and soil.

It must not be overlooked that, unless these various agreements between cholera curves and curves of soil heat, moisture, and ground water levels are to be regarded as mere coincidences, an essential factor to explain their association with cholera prevalence is the presence in the soil itself of the specific germ. Assuming this to be the vibrio known as the "comma bacillus," it is interesting to find that in no cholera epidemic has this micro-organism been found in, or isolated from the soil; though cholera commas have been repeatedly demonstrated to be present in sand placed in filters in India. To those familiar with the countless numbers of bacteria present in even comparatively clean soils, and the difficulties experienced in obtaining pure fractional cultures of particular forms from impure growths, this non-isolation from, and failure to find in, soil samples the cholera vibrio will not be surprising. Though this micro-organism has not been found in soil, many observations have been made regarding its behaviour and fate when introduced into soil samples. Experimental facts indicate that choleraic comma bacilli are, under ordinary circumstances, somewhat feeble in the struggle for existence; and when introduced into soil and water, of varying qualities, so long as these retain their natural conditions, tend to disappear, mainly owing to the influence exerted on the commas by other fungi and schizomycete organisms. Cunningham's experiments, made with garden humus kept moist under a bell jar, show a survival of cholera commas for some forty days. If the earth were much fouled, as by mixture with fæces, the commas were not recoverable later than five to nine days: if the fæces, before mixture with the soil, were boiled, the commas were found as late as the 26th day. Dempster's experiments indicate that (1) in dry soils, evaporation not prevented, comma bacilli were alive on the 3rd but dead on the 4th day, in white sand, in yellow sand, and in garden earth; (2) with a moist soil, evaporation not prevented, they were alive on the 7th day in white sand, and on the 33rd day both in yellow sand and garden earth; (3) when evaporation was almost prevented, they were alive on the 28th day in white sand, and on the 68th day in yellow sand and garden earth; (4) in dried soil they did not live longer than one or two days; (5) in white crystal sand, evaporation allowed, the commas were dead on the 30th day, the moisture present being 0·66 per cent.; when evaporation was prevented, they were alive on the 174th day, the sand still containing 7·1 per cent. of moisture; (6) in peat, comma bacilli were invariably dead in twenty-four hours, irrespective of the amount of moisture present. The degree of moisture is, therefore, a factor of the greatest importance in regard to the retention of vitality of these organisms in soil, and this may be the explanation in part of the endemic and epidemic prevalence of cholera. In Lower Bengal the soil is always moist, and cholera is endemic, but is lessened during the heavy rains when the soil becomes saturated; in the Punjab the soil is dry, and epidemics do not occur unless some amount of rain has fallen; in the one case the rains hinder, in the other they favour the appearance of cholera. The difficulty which comma bacilli appear to have in surviving in such media as earth or water appears to be mainly due to their inability to form spores or otherwise assume a resistant form. It is necessary in this connection, however, to remember that, among the many comma bacilli obtainable from cholera dejecta, there is, in all likelihood, a plurality of species which do not behave uniformly in water, soil, and other media. By a due appreciation of this fact, it is probable that many experimental inconsistencies may be explained: especially as both Nicati and Reitsch have shown that cholera bacilli are capable of existing three months in such foul water as that of the port of Marseilles.

The general evidence indicates that the specific bacteria of cholera discharges are capable of a much longer existence in the superficial soil layers than has hitherto been supposed; and consequently it is specially necessary to guard against pollution of the soil, and through it against the probable contamination of both water and air. In India, all the evidence points to the soil as playing a very large part in the diffusion of cholera, chiefly as affording a nidus in which the comma bacilli can retain their vitality, if not actually multiply, for long periods. The soils in which this sequence of events seems particularly to occur, are the loose and partially moist sands in the beds of rivers, and along the sides of tanks and other bodies of water used for bathing and laundry purposes. While the connection between soil conditions and cholera prevalence appears to be true for some localities, particularly its areas of endemic prevalence, the evidence is not sufficiently strong to warrant its universal application; in fact, as will be discussed in a subsequent chapter, the diffusion of the disease is largely dependent upon other factors than soil states.

Diarrhœa.—In especial relation to that peculiar form of diarrhœa which is apt to prevail epidemically in summer and autumn, a considerable amount of evidence has been brought forward of late years to associate its connection with life processes of micro-organisms present in the superficial soil layers, but as yet not satisfactorily isolated. It is of very general knowledge that diarrhœa mortality is low in places built upon solid rock, but high where the soil is porous and loose, also upon sand or a thick surface mould. Gravel or coarse sand varies in its relation to the disease mortality and prevalence in proportion as the loose elements or stones vary. The more gravel approaches to sand in its fineness, or to rock in its coarseness, so its relation to diarrhœa appears to be greater or less. Clay soils do not appear to be, in themselves, specially favourable to a high diarrhœal mortality. The marls are either favourable or unfavourable to diarrhœal prevalence in proportion as they are loose and permeable on the one hand, or plastic and stiff on the other.

Ballard, who was one of the first to indicate any possible connection between soil states and diarrhœa in this country, thinks that the presence of much organic pollution renders a soil distinctly more favourable to a high diarrhœa mortality than it might otherwise be: such organic fouling need not be of a fæcal or excremental nature. For these reasons, diarrhœal mortality and prevalence are apt to be high where dwellings are built upon made ground, upon the refuse of towns, upon reclaimed areas, or upon the sites of old market gardens, and in places where the earth beneath and around is polluted by collections of liquid filth in cesspits, or where sewage has soaked into it from imperfect drains, or from the surface of the ground. It is the opportunities for the collection of organic filth in the fissures of certain kinds of rocks that seem to impart to them, when built upon, a diarrhœal character. In discussing the influence of moisture of a soil, Ballard remarks that excessive wetness and complete dryness of soil appear to be both unfavourable to diarrhœa prevalence. The degree of habitual moisture, specially favourable, is that amount which, while being marked, is not sufficient to preclude the free admission of air between the constituent physical elements of the soil. Such a degree of dampness occurs when the subsoil water stands sufficiently near the surface to maintain by capillary attraction the dampness brought about by previously greater nearness of the water to the surface: or when the soil, as in the case of marls, contains sufficient of the clayey element to imprison some of the water saturating it at some time previously. The requisite degree of soil dampness may be produced by floods, or from habitual surface soakage, as from leakage of conduits, sewers, and drains.

One of the most important soil conditions indicated by Ballard, as influencing the prevalence of diarrhœa in England, was the temperature of the soil.

As the result of many years of observation, regarding the relationship between diarrhœa prevalence and the earth temperature at depths of 1 foot and 4 feet from the surface, he says that "the summer rise of diarrhœal mortality does not commence until the mean temperature recorded by the 4-foot earth thermometer has attained somewhere about 56° F., no matter what may have been the temperature previously attained by the atmosphere or recorded by the 1-foot earth thermometer." The maximum mortality from diarrhœa appears not to occur until quite a week after the 4-foot thermometer attains its maximum mean, and declines gradually with the decline of the temperature recorded by the same thermometer. The heat of the atmosphere and of the more superficial soil layers appear to exert but a subsidiary influence upon diarrhœa prevalence.

Very similar results were obtained by the late Dr Tomkins, who, at Leicester, for several years recorded the temperature of the soil at 1-foot and 4-feet levels during the warmer months. His observations showed that it is not till the heat of the earth at a depth of 1 foot has reached 60° F., and remains some 4° lower than this at 4 feet, that diarrhœa begins to prevail to any marked extent. Tomkins, however, was disposed to regard the 1-foot temperature as the more significant.

Speaking generally, both Ballard and Tomkins express a belief that epidemic diarrhœa, as observed in England, is due to a soil-bred organism, which, at times, escaping from the earth becomes air-borne, and thence gains access to the human body by food or drink. This organism has not been isolated so far, neither is there any definite evidence forthcoming from either the Continent or the tropics which causally connects epidemic diarrhœa with soil conditions. We are only too well aware that fermenting and decomposing food, especially milk, may cause diarrhœa, and that, since these processes are mainly the result of bacterial action, these latter may be regarded as the fundamental causes of the disease. But it is open to doubt whether sufficient evidence exists to show that these organisms ordinarily reside in, or are at all dependent upon conditions of, the soil, to permit our forming a working hypothesis upon these lines.

Diphtheria.—All accounts of diphtheria show a tendency on the part of this disease to recur in the same districts year after year. The question naturally suggests itself, are the reappearances due to a revival of the contagium derived from previous outbreaks in the same place, or to some favouring condition which the place offers for the development of infection derived from some other quarter; and have these favouring conditions any dependence upon the character and state of the soil? As far back as 1858, Greenhow reported to the Medical Department of the Privy Council that diphtheria was especially prevalent on cold, wet soils. Later in 1881, Airy describes the localities affected as "for the most part cold, wet clay lands," but he adds "there is evidently great variety in the soils on which diphtheria can prevail, for it is found in full force on the chalk downs of Kent, on the loamy sands and clays of the Sussex weald, on the alluvium and boulder clay of Essex, on the marls of the new red sandstone, and on the slopes of the slate rocks of Wales." Similar evidence was forthcoming at the Hygienic Congresses of London and Buda-Pesth.

An analysis of the innumerable reports upon outbreaks of diphtheria in various parts of Europe indicates that the geological features of the affected districts appear to play a less important part in the incidence of the disease than does soil dampness. This is especially well shown by Kelly and Barnes in their accounts of the epidemics occurring in Sussex and the Eastern counties respectively. The latter shows that in five parishes, comprising 1813 inhabitants, on a dry gravelly soil, only one outbreak of diphtheria occurred in eleven years; whilst in twenty-seven other parishes, with 1400 people living on a subsoil of clay having a percentage of water in it as high as 90 per cent., no less than 48 outbreaks occurred in the same period. These figures show the relative proportion of outbreaks to inhabitants as being 1 in 1800 on dry soil, and 1 in 300 on wet.

A very interesting series of facts dealing with the inter-relationship between diphtheria prevalence at Maidstone and movements of the subsoil water are given by Adams. His observations, extending over nine years, show that a strict concordance may be traced between soil dampness and diphtheria on the one hand, and absence of diphtheria and soil dryness on the other. But the dampness and dryness of the soil depend upon the rise and fall of the ground water and have their appropriate seasons: so long as the order of this occurrence is preserved, health is maintained. As long as the soil is well washed by the winter's high tide and afterwards dried and aërated during the summer's low tide, all goes well : but so soon as these salutary movements are arrested or their order disturbed, diphtheria prevails, reaching its acme of prevalence when stagnation at a relatively high level is most complete. For the conception of this relationship between the movements of the subsoil water and the prevalence of diphtheria, it is assumed that the germ of the disorder resides in or upon the soil, and is liable to be displaced and dispersed along with the subsoil air. Adams maintains that the two chief agencies concerned in the discharge of the soil air into the atmosphere we breathe are reduction of atmospheric pressure, which acts by aspiration, and rainfall, which operates by compression. Probably the latter is by far the more effectual, though both may often act in concert. The way rainfall operates, especially when sudden and copious, is as follows:—"The outside uncovered soil, receiving the rain, becomes temporarily sealed by moisture, and the underlying imprisoned ground air is driven downwards and laterally beneath protected parts, such as are sheltered by buildings, and so finds an easy way of escape upwards through the unwetted surfaces that underlie buildings. Therefore, the tendency for ground air to be forced into dwellings depends upon the relative proportion that the uncovered bears to the covered area."

In connection with the foregoing generalisations, it is interesting to note the actual behaviour of the diphtheritic contagium in soil.

The true bacillus of diphtheria is now recognised to be that first described by Löffler: but we have no actual proof that this micro-organism is either an ordinary or even occasional resident of the soil, or that it becomes air-borne in sewer gas or soil emanations. Experiments show that pure cultures of this bacillus, when mixed with garden soil, constantly moistened short of saturation and kept in the dark at a temperature of 14° C., will retain their vitality for more than ten months. They die out from moist soil, kept at 26° C., in about two months: from moist soil, at 30° C., in seventeen days, and from dry soil at the same temperature within the week. False membranes from cases of diphtheria, when placed in soil under similar conditions, appear to retain their specific infectivity for slightly shorter periods. In the laboratory, absolute soil dryness is as distinctly antagonistic to the vitality of the diphtheritic bacillus as soil dampness is favourable.

These experimental results explain to a large degree the general absence of diphtheria throughout the plains of India, and its endemic prevalence in the Indian hill stations and Europe generally. The peculiar connection of subsoil water levels with diphtheria prevalence, as emphasised by the experience of Maidstone, is to be largely explained by the influence which they have upon the greater or less degree of soil dampness. Both statistically and experimentally, we find that a damp soil favours the life and development of the diphtheria bacillus: while prolonged submersion and drought kill it. In the incidence of epidemic diphtheria, we are justified in regarding, in country places at least, constant soil moisture as a chief factor; while possibly, in the case of urban outbreaks, mere soil dampness is subsidiary to other more potent causes.

Dysentery.—Owing to the curious analogy which exists between the geographical distribution of dysentery and malarial fevers, and to its endemicity, if not epidemic diffusion in certain places, often within narrow limits, a strong feeling has grown up that telluric influences and general states of the soil are of very special importance in its production. A glance at the literature of its wide geographical distribution seems to show that dysentery can prevail independently of elevation and ground configuration, but this conclusion is much vitiated by the transparent manner in which all older writers have included and at times made interchangeable with this disease, all forms of diarrhœa and not a few fevers. When we look into details, and rigidly adhere to the question of the presence or absence of true dysentery, we find that, in both tropical and sub-tropical latitudes, the disease tends to prevail most on low-lying, damp lands presenting much decay of animal and vegetable matter.

In the tropics, the essential character of the areas in which dysentery prevails in its worst form is a markedly damp and porous soil, coupled with heavy rainfall, and a high subsoil water level. In England, dysentery has, for many years, been counted among the rarer diseases: when it did prevail, it was only in the low-lying, damp localities in which intermittent fevers were common. Since the same have been drained, dysentery, with paludal fevers generally, has become an infrequent affection. The case of Millbank Prison is an instance where small outbreaks of the disease were of constant occurrence, and very generally attributed to emanations from the soil on which the prison stood, consequent on the decomposition of organic matter. It is very probable, however, not only in the case of the tropics but also in regard to Millbank Prison, that the water-supply rather than the soil air is the determining factor in disease production. That soil, laden with the products of decomposing sewage or other filth, may by its emanations play an important part in causing dysentery, is shown by the account given by Fagge of a series of epidemics which occurred in the Cumberland and Westmoreland Asylum during 1864, 1865, and 1868: due apparently to the persistent spreading out of the sewage of the institution upon adjacent land. Conolly Norman describes a similar case as occurring at the Richmond Asylum, near Dublin, in 1886–87.

Taken in conjunction with the fact that the precise cause or virus of dysentery is largely an unknown quantity: that the disease tends to particularly prevail during war, famine, and other occasions of malnutrition, it is probable that conditions of soil are only indirectly the cause or occasions of dysentery. Particularly is it so in India, and the tropics generally, where, while a wet soil is not itself a cause of the disease, it becomes indirectly so as influencing the type of climatic conditions. The same holds good for the epidemic occurrence of dysentery under similar conditions in higher latitudes. These conclusions are not subversive of nor inconsistent with the view that the specific virus of dysentery may be, after all, a soil resident—and gaining access to the human subject either by aërial emanations or through the medium of drinking water and food; but until its identity and life-history have been, more or less, established, one must withhold from any more absolute conclusion than that the disease may be conveyed by persons from infected places to other localities, and that dysentery appears where dysentery has been before: also, that as in cholera or enteric fever, there may be an organism given off in the dejecta, which finds in the soil a suitable nidus for its preservation and propagation.

Enteric Fever.—The evidence which has been advanced in favour of a connection between this disease and soil is very similar to that which has been discussed in special reference to cholera and diphtheria. Pettenkofer's observations on the wells of Munich led Buhl to the discovery that in that city there is a very close relation between the height of the ground water and the prevalence of enteric fever: the outbreaks of enteric fever occurring when the soil water was lowest, and especially when, after having risen to an unusual height, it had rapidly fallen. The observations have been further extended by Pettenkofer with the same results. The point has been also numerically investigated by Seidel in Munich and Leipzig for the years 1856–64 and 1865–73, and from a mathematical consideration of the numbers he concludes that, according to the theory of probabilities, it is 36,000 to 1 that there is, in each period, a connection between the two occurrences. Other observations in Germany are confirmatory, but in this country the connection has not been traced. In some outbreaks of enteric fever the ground water has been rising and not falling. Fodor says that at Buda-Pesth the rise of enteric fever mortality accompanies the rising ground water, and the two fall together. In other instances the attacks have been traced to impure drinking water or milk, or to personal contagion, and the agency of the ground water has appeared to be quite negative. Buchanan has quoted a case in which the sinking of the ground water and the outbreak of fever were coincident, and yet the connection was, so to speak, accidental, for the efficient cause of the outbreak was the pollution of the drinking water with enteric evacuations. And he also points out that when the ground water has actually been lowered in certain English towns by drainage operations, enteric fever has not increased as it should do, according to theory, but has diminished, owing to the introduction of pure water from a distance. He thus thinks that, while a connection between the prevalence of enteric fever and sinking of the ground water may be admitted to exist, it is indirect, and that the true cause of the fever is the impurity of the drinking water. Pettenkofer has replied to this view, and denies, from actual analysis, the fact of the contamination of the drinking water in enteric outbreaks.

The observations of Pettenkofer, and the case of the barracks at Neustift, recorded by Buxbaum, are certainly in favour of the opinion that a direct connection may exist in some cases between the sinking of the ground water and outbreaks of enteric fever; but the frequency and extent of the connection remains to be determined, and in this country, at any rate, the other conditions of spread of enteric fever appear to be far more common.

Criticising these views of Pettenkofer's, Ranke has pointed out that no enteric fever exists in the neighbourhood of Munich but what is imported from Munich itself, although both the soil and ground water are the same. Munich has a soil consisting of fine sand, with a peculiar power of holding nitrogenous substances: it is largely honeycombed with cesspools, from which more than 90 per cent. of the contents soak into the surrounding soil, and, as the streets are well paved, the houses of the town constitute the only outlets for the foul soil air. A very similar argument, together with some very interesting facts concerning the prevalence in Dublin of enteric fever, have been brought forward by Sir C. A. Cameron. For some years a persistent occurrence of this disease has existed in Dublin, which cannot be accounted for either by polluted water, milk, or food, and which has not very sensibly decreased even after an improvement in the water-supply. Sir C. A. Cameron attributes this prevalence to the practice, which has been in use in Dublin for years, of storing excreta in pits, so that the soil has become thoroughly saturated with the specific organisms of the disease: these, he thinks, are carried into the atmosphere by displacements of ground air. According to him, the ratio of cases to population, living in Dublin, on a loose porous gravel soil for the ten years, 1881–91, was 1 in 94: while the ratio for those living on stiff clay was but 1 in 145. "This is what we should expect, since the movements of the ground air are much greater in loose porous than in stiff clay soils."

Baldwin Latham endeavours to show that the healthiest periods (*i.e.*, as regards immunity from enteric fever, &c.) are those when the ground water is high; whereas low ground water periods, especially when an exceptionally low period occurs, are the most unhealthy. As a rule, however, he says that the state of the ground water is an indication of the future health rather than of the present, the most unhealthy time being when percolation commences after the lowest ground water period. Thus enteric fever deaths at Croydon (1837–86) are fewest in June, and increase steadily to a maximum in January. This corresponds to the observations of Durand-Claye in Paris (1865–69 and 1872–81), who has shown that the deaths from enteric fever are at their lowest in June, and at their highest from August to November. These run in some measure contrary to Pettenkofer's views.

No pronounced relation has been found between the death-rate or prevalence of enteric fever and the temperature or putrefactive activity of the soil.

Assuming that there is some connection between oscillations of the ground water or movements of the ground air and enteric fever, it is necessary to realise the entrance and existence within the soil of a specific germ. This is now accepted as being the Eberth-Gaffky bacillus. No experiments have as yet demonstrated the presence of this particular microbe in soil, under ordinary circumstances: but many observations have been made which show the possibility of this micro-organism existing for considerable periods of time under certain conditions of warmth and moisture. Dempster's experiments show, working on a dry soil, where evaporation was allowed to take place, that in white crystal sand, the bacilli can be found, after mixture, up to the ninth day; in yellow sand up to the eighteenth day; and in garden earth up to the fourteenth day. On the moist soils, on the other hand, the following were the results: in moist white crystal sand, the enteric bacilli were alive on the twenty-third day; in yellow sand and in garden earth, on the forty-second day. On soils which had been specially dried, the bacilli were only found up to the seventh day. Experiments made with peat show that on this soil, these bacilli do not survive longer than twenty-four hours. Our own observations, made with various soils brought from the tropics and belonging to the loose, sandy marls, show that under conditions of medium moistness, enteric bacilli can live in such soil at least five weeks, but that when the soil was allowed to become dry, the bacilli could not be found after the third week. Uffelman has found that in garden earth enteric bacilli remain alive some twenty-one days; in white sand for seventy days. Graucher and Deschamps have kept them alive in moist soil for four months. Karlinski has found that these bacilli remain alive in putrid fæces for as long as three months.

Although a vast amount of evidence has accumulated, which indicates the specific contamination of food and drink as the most frequent channel of infection for enteric fever, still it must not be overlooked that dried enteric excreta, particularly when superficially buried in dry sandy soil, may be carried by the air and distributed as dust upon food. This is a point of importance in connection with the maintenance and management of the dry earth closet system in hot countries, like India: where possibly it is a not infrequent way in which enteric fever is spread. Copeman quotes a curious case from Von Giett, which illustrates how the soil may constitute a nidus, in which the enteric germ may lie dormant for an indefinite period. "A man who had acquired enteric fever elsewhere brought it to a village. His evacuations were buried in a dung-heap. Some weeks later five persons engaged in removing some of the dung were attacked by the disease: their discharges were sunk deep in the heap. At the end of nine months, it was completely cleared out by two workmen, one of whom fell ill of enteric fever and died."

Notwithstanding the discordance of the facts noted from various localities in reference to the connection between the action of either ground water or air and enteric fever prevalence, a few authenticated cases, like the foregoing, taken in conjunction with results of laboratory experiments, which show the possibility of the specific bacilli being able to remain alive some time in earth, make it difficult to deny the importance of the soil as a possible breeding-place of the enteric germ.

Goitre.—The view that some causal connection exists between this disease and soil is based upon the marked influence which locality bears to its endemic prevalence: coupled with the fact that healthy persons, coming into goitrous places from non-goitrous localities, not unfrequently contract the disease after a longer or shorter stay: while, on the other hand, removal from goitrous centres has been found to be one of the most certain means of either overcoming the disease or preventing its further development. From time to time, three states of soil have been credited with causative influences upon this affection: these are, altitude and configuration, dampness, and geological origin.

The general area of distribution of goitre shows that the disease is very largely, though not exclusively, endemic in mountainous districts. The observations, made chiefly by Sansome, that in these endemic mountainous districts the disease prevailed the most in the deeply-cleft valleys receiving little sunshine and wind, and possessing a damp or marshy soil, gave rise to a generally current belief that a wet soil had some peculiar influence upon its causation. Though it is true the disease does largely prevail in valleys and on damp, wet soils, still from its frequent occurrence in wide and open valleys and on plains which are dry, this wet soil, the degree of elevation or the configuration of the ground, cannot be seriously regarded as etiological factors.

As to whether any connection exists between the endemic occurrence of goitre and soil mineral constituents, has been a question hotly argued by many writers; particularly by those who regarded its cause to lie in the habitual use of water containing certain substances, such as calcic carbonate, magnesia, or even metallic sulphides. Inasmuch as the presence of these minerals in the water depends on the ground from which it springs or over which it flows, it is natural to conjecture that goitre must be associated in its endemic form with limestone, dolomite, or metalliferous soils. Boussingault was apparently the first to call attention to the significance of a limestone soil in his researches upon the endemicity of the disease in the

Cordilleras of New Granada, and after him came several others, to be followed eventually in 1859 by M'Clelland's work in the district of Kumaon in Oudh and the Himalayan slopes. Similar investigations made in Savoy by Billet show that the endemicity of the disease became most marked on the limestone, magnesia, and gypsum formations. Other observers, notably Grange in Europe, with Gray and Greenhow in India, all confirmed and amplified these conclusions: laying, however, particular stress upon the magnesia, the maximum amount of disease, according to them, being found on a soil of dolomite or magnesian limestone. This magneso-limestone soil theory of the origin of goitre has been fiercely combated by Thomson and Saint Lager, who have called attention to the fact that although in New Zealand the greater part of the native population live upon the magnesian limestone, goitre and cretinism are entirely unknown among them. Saint Lager advanced the view that goitre is only endemic in regions with metal-yielding rocks, and that its occurrence depends essentially upon the presence of iron and copper pyrites, and that its prevalence on soils containing magnesia is explicable by the fact that such soil is particularly liable to contain those metallic sulphides. This view has lately found support in the inquiries of Lebour on the distribution of goitre in England. Unfortunately for the full acceptance of these views, in the very districts of France in which iron sulphides occur in the largest quantity, endemic goitre is conspicuous by its absence, while the disease is endemic in many parts of that country where not a trace of any metal can be discovered in the soil.

In the face of these conflicting theories, it is impossible to come to any definite conclusion that goitre has or has not any relation to soil conditions: the problem must be still regarded as awaiting solution.

Lead-poisoning.—It is well known that some drinking waters drawn from certain areas have a remarkable capacity for dissolving lead from the pipes by which they are distributed. These waters are commonly obtained from moorlands or high gathering grounds where peat is more or less plentiful: and, too, are characterised by an acid reaction, while the non-lead-solving waters are, on the other hand, neutral or faintly alkaline. Knowing the richness of peaty soils in complex acids, described under the names of crenic, ulmic, humic, and apocrenic acids, it is believed that the source of the acid, found to be present in lead-solving waters, is the soil through and from which the water is gathered. Unfortunately, very little is known of this water acidity, as the amount is always small; but the actual acid found in the water of the service pipes is not invariably the same as that to which the acidity on the gathering grounds is due, some chemical decomposition apparently taking place as it passes through the mains. Some have suggested the acid to be sulphuric acid, produced by the oxidation of iron pyrites in the shale, so frequently found under peat beds: in support of this view the evidence is not strong, while in favour of the opinion that it is one of the earth acids may be mentioned that, where peat is most abundant, the acidity is greatest. Evidence is slowly accumulating which is very suggestive of the acid being a product due to the growth of micro-organisms in soil or water. That such might be the case was suggested by Power in 1887, since which date experiments have been made by Houston, which, without being absolutely conclusive, are confirmative of the belief that some micro-organisms are obtainable from peaty soils, whose growth is accompanied by the formation of an acid, capable of dissolving lead. Further observations are, however, required before the subject can be considered to be properly understood.

Malaria.—A moist soil influences greatly the development of the agent, whatever it may be, which causes the paroxysmal fevers. The factors which must be present to produce this agent are heat of soil (which must reach a certain point = isotherm of 65° F. of summer air temperature), air, moisture, and some impurity of soil, which in all probability is of vegetable nature. The rise and fall of the ground water, by supplying the requisite degree of moisture, or, on the contrary, by making soil too moist or too dry, evidently plays a large part in producing or controlling periodical outbreaks of paroxysmal fevers in the so-called malarious countries. The development of malaria may be connected either with rise or with fall of the ground water. An impeded outflow which raises the level of the ground water has, in malarious soils, been productive of an increase of paroxysmal fevers. In the making of the Ganges and Jumna Canals the outflow of a large tract of country was impeded, and the course and extent of the obstruction was traced by Dempster and Taylor by the almost universal prevalence of paroxysmal fevers and enlarged spleens in the inhabitants along the banks. The severe and fatal fever which prevailed in Burdwan, in Lower Bengal, for a number of years, appears to have been in part owing to the obstruction to the natural drainage from mills and from blockage of water-courses. In some cases relative obstruction comes into play; *i.e.*, an outfall sufficient for comparatively dry weather is quite inadequate for the rainy season, and the ground water rises. At Pola, in Istria, for example, there are no marshes, but in the summer sometimes half, sometimes 90 per cent., of all cases are malarious; the reason is, that a dense clay lies a little below an alluvial soil, and the only exit for the rain is through two valley-troughs, which cannot carry off the water fast enough in the wet season, from February to May.

The opposite result, viz., an increased outflow lowering the subsoil water, has been observed in drainage operations, and very malarious places have been rendered quite healthy by this measure, as in Lincolnshire, and many parts of England. The case of Boufaric, in Algeria, is a good instance. Successive races of soldiers and colonists had died off, and the station had the worst reputation. Deep drainage was resorted to; the level of the ground water was lowered less than 2 feet. This measure, and a better supply of drinking water, reduced the mortality to one-third.

Although no definite relation has been shown to exist between the carbon dioxide in soil air and malaria, rainfall, on the other hand, appears to bear a direct relationship to the disease, the malaria curve generally falling during rain, but generally rising as dry weather sets in. The differences of density in the soil air appear to bring about an escape of the malarial miasm into the atmosphere, rather than do currents of atmospheric air by aspirating the soil. It is owing to its rarity, as compared with that of the air above, that the ground air tends to rise into the atmosphere towards evening: and it is after sundown, when the atmosphere is very generally polluted by ground air, that malarial infection most often occurs. These facts suggest the improbability of the malaria germ being present in the dust on the earth's surface, but rather that it is contained in the ground air below the surface: the frequency of malarial infection following digging up of soil largely confirms this.

There is little evidence to show that malaria is caused by any mineral constituents of the ground, more particularly as it prevails upon soils of such widely different composition as alluvial, sandy, or ferruginous earths, as well as upon soils formed from the weathering of metamorphic rocks.

If we accept the microbian origin of the disease, a malarious soil will depend not on the nature of its inorganic constituents but upon the presence of those conditions which favour the life of the specific organisms and bring about their aërial diffusion. These organisms are probably allied to the flagellate protozoa and have been described by Laveran, Marchiafava, Celli, Richards, Councilman, and Osler as the *plasmodium malariæ*. It is an amœboid-like body, which appears to separate out the pigment of the red blood-corpuscles. Its spores, which eventually form, are found only in the spleen and give rise to fresh amœbæ. These pass into the blood, causing renewed fever, the nature of the attack being determined by the rapidity with which the different stages take place. So far, this micro-organism has not been found in the soil, nor indeed has it even been cultivated outside the human body.

With regard to so-called **malarious soils**, the following geological formations are more particularly known to be associated with the evolution of the agent which causes periodical fevers.

Marshes.—Except those with peaty soils, those which are regularly overflowed by the sea (and not occasionally inundated), and the marshes in the southern hemisphere, and some American marshes, which, from some as yet unknown condition, do not produce malaria.

The characters of well-marked marshes are a large percentage of water, but no flooding; a large amount of organic matter (10 to 45 per cent.) with variable mineral constituents; silicates of aluminum; calcium, magnesium, and alkaline sulphates; calcium carbonate, &c. The surface is flat, with a slight drainage; vegetation is generally abundant.

The analyses of the worst malarious marshes show a large amount of vegetable organic matter. A marsh in Trinidad gave 35 per cent.; the middle layer in the Tuscan Maremma 30 per cent. The organic matter is made up of humic, ulmic, crenic, and apocrenic acids—all substances which require renewed investigation at the hands of chemists. Vegetable matter embedded in the soil decomposes very slowly; in the Tuscan Maremma, which must have existed many centuries, if not thousands of years, many of the plants are still undestroyed. The slow decomposition is much aided by heat, which makes the soil alkaline from ammonia (Angus Smith), and retarded by cold, which makes the ground acid, especially in the case of peaty soils.

It would now seem tolerably certain that the growing vegetation covering marshes has nothing to do with the development of malaria.

Alluvial Soils.—Many alluvial soils, especially, as pointed out by Wenzel, those most recently formed, give out malaria, although they are not marshy. It is to be presumed, that the newest alluvium contains more organic matters and salts than the older formations. Many alluvial soils have a flat surface, a bad outfall, and are in the vicinity of streams which may cause great variations in the level of the ground water. Mud banks also, on the side of large streams, especially if only occasionally covered with water, may be highly malarious; and this is the case also with deltas and old estuaries.

The soils of *Tropical Valleys, Ravines, Nullahs.*—In many cases large quantities of vegetable matter collect in valleys, and, if there is any narrowing at the outlet of the valley, the overflow of the rains may be impeded. Such valleys are often very malarious, and the air may drift up to the height of several hundred feet.

Sandy plains, especially when situated at the *foot of tropical hills*, and covered with vegetation, as in the case of the "Terai" at the base of some parts of the Himalayan range. In other cases, the sandy plains are at a distance from hills, and are apparently dry, and not much subjected to the influence of variations in the ground water. The analysis of such sand has not yet been properly made, but two conditions seem of importance. Some sands, which to the eye appear quite free from organic admixture, contain much organic matter. Fauré has pointed out that the sandy soil of the Landes in south-west France contains a large amount of organic matter, which is slowly decomposing, and passes into both air and water, causing periodical fevers. This may reasonably be conjectured to be the case with other malarious sands. Then, under some sands, a few feet from the surface, there is clay, and the sand is moist from evaporation. Under a great heat a small quantity of organic matter may thus be kept in a state of change. This is especially the case along the dried beds of water-courses and torrents; there is always a subterranean stream, and the soil is impregnated with vegetable matter. In other cases the sands may be only malarious during rains, when the upper stratum is moist.

North points out that the Roman Campagna, so notorious for the extreme prevalence of malaria, is by no means a plain in the ordinary acceptation of the word, but is broken up into valleys, into which run streams liable to frequent flooding and depositing large quantities of silt; and that underlying the surface soil there is frequently an almost impervious layer of tufa, full of saucer-like depressions, which hold water and render the soil with which they are filled and hidden, wet and boggy.

He attributes to the local climatic conditions, produced by these local peculiarities of configuration of the soil, the prevalence of malaria, which is in so many cases limited to a sharply circumscribed area.

Certain *hard rocks* (*granitic* and *metamorphic*), especially when weathered, have the reputation of being malarious; more evidence is required on this point. As Friedel justly remarks of Hong-Kong, it is not the disintegrated granite, *per se*, which causes the fever, but the soil of the woods and dells, and the clefts in the rocks, which is derived from the granite, and soon filled with a cryptogamic vegetation.

The *magnesian limestone* rocks which have been subjected to volcanic action have also been supposed to be especially malarious, but the evidence has not been yet corroborated.

Iron Soils.—Sir Ranald Martin directed attention to the fact that many reputed malarious soils contain a large proportion of iron. No good evidence has been adduced that this is connected with malaria, but the point requires further examination. The red soil from Sierra Leone, which contains more than 30 per cent. of oxides of iron, shows nothing which appears likely to cause malaria. The peroxide of iron is a strong oxidising agent, readily yielding oxygen to any oxidisable substance, and regaining oxygen from the air. It may, therefore, assist in the oxidation of vegetable matter in an iron soil.

In certain cases attacks of paroxysmal fever have arisen from quite *localised* conditions unconnected with soil, which seem, however, to give some clue to the nature of the process which may go on in malarious ground.

Friedel mentions that in the Marine Hospital at Swinemünde, near Stettin, a large day-ward was used for convalescents. As soon as any man had been in this ward for two or three days, he got a bad attack of tertian ague. In no other ward did this occur, and the origin of the fever was a mystery, until, on close inspection, a large rain cask full of rotten leaves and brushwood was found; this had overflowed, and formed a stagnant marsh of 4 to 6 square feet close to the doors and windows of the room, which on account of the hot weather were kept open at night. The nature of the effluvium was not determined.

Malignant Œdema.—This is a fatal disease of mice, guinea-pigs, and rabbits. In man it is commonly spoken of as progressive gangrenous emphysema, being chiefly observed after compound fractures or wounds, and characterised by a rapidly-spreading œdema in which the subcutaneous tissues, commencing at or near the injury, get distended with a clear reddish fluid containing bubbles of gas. The frequency of this affection following injuries or wounds into which earth had passed or come into contact, early drew attention to the connection between it and soil. Its infective agent is now known to be a bacillus morphologically similar to that of anthrax, but differing from it in being anaerobic. The œdema bacillus appears to be widely distributed, being found in the most varied putrid substances, in the bodies of decomposing animals, in fæces, and in every specimen of earth which has been impregnated with putrefying matter. These bacilli are particularly found in garden earth, after recent manuring, where they appear to be able to pass through their characteristic cycle of development as saprophytes.

Phthisis.—In some way which is not clear, a moist soil produces an unfavourable effect on the lungs: at least in a number of English towns which have been sewered, and in which the ground has been rendered much drier, Buchanan showed that there had been a diminution in the number of deaths from phthisis. Bowditch of Boston, U.S.A., and Middleton of Salisbury, noticed the same fact some years previously. Buchanan's evidence is very strong as to the fact of the connection, but the nature of the link between the two conditions of drying of soil and lessening of certain pulmonary diseases is unknown. The following table shows the amount of change in the death-rate from phthisis in twenty-four of the towns visited and reported on by Buchanan in 1865–7, and published in Simon's ninth and tenth reports to the Privy Council:—

Town.	Previous Death-rate per 10,000 from Phthisis.	Degree of Change in Death-rate from Phthisis.		Influence of Sewage Works on Subsoil.
		In Total Population.	In Females between 15 and 55.	
Salisbury,	44	– 49 p. c.	?	Much drying.
Ely,	32	– 47 p. c.	?	Ditto.
Rugby,	28	– 43 p. c.	– 48 p. c.	Some drying.
Banbury,	26	– 41 p. c.	– 36 p. c.	Much drying.
Worthing,	30	– 36 p. c.	– 41 p. c.	Some drying.
Macclesfield,	51	– 31 p. c.	– 22 p. c.	Much drying.
Leicester,	43	– 32 p. c.	– 16 p. c.	Drying.
Newport,	37	– 32 p. c.	– 13 p. c.	Local drying.
Cheltenham,	28	– 26 p. c.	– 25 p. c.	Some drying.
Bristol,	33	– 22 p. c.	18 p. c.	Ditto.
Dover,	26	– 20 p. c.	– 18 p. c.	Local drying.
Warwick,	40	– 19 p. c.	– 10 p. c.	Some drying.
Croydon,	...	– 17 p. c.	?	Much drying.
Cardiff,	34	– 17 p. c.	?	Ditto.
Merthyr,	38	– 11 p. c.	– 12 p. c.	Some recent drying.
Stratford,	26	– 1 p. c.	– 4 p. c.	Some local drying.
Penzance,	30	– 5 p. c.	0	No change.
Brynmawr,	28	+ 6 p. c.	– 8 p. c.	No notable change.
Morpeth,	30	– 8 p. c.	+ 12 p. c.	No change.
Chelmsford,	32	0	+ 11 p. c.	Slight drying.
Penrith,	39	– 5 p. c.	+ 27 p. c.	No change.
Ashby,	25	+ 19 p. c.	– 10 p. c.	Some drying.
Carlisle,	32	+ 10 p. c.	+ 11 p. c.	Drying.
Alnwick,	28	+ 20 p. c.	+ 36 p. c.	No drying.

The importance of these observations appeared to be so great that Buchanan was directed by the Privy Council to make a special investigation in the three south-eastern counties, Surrey, Kent, and Sussex, for the purpose of determining whether any relation could be traced between the prevalence of consumption and the state of the soil as regards moisture. In instituting this comparison, Buchanan classified the several districts as having mainly soils *permeable* by moisture, or soils of such a character that water was unable to escape from them, so that they might be called *retentive.* He then massed the fifty districts into which these counties were divided into five groups of ten each, according to the greater or less prevalence of phthisis in them, and in this way he obtained the following table:—

Groups of Districts.	Proportion of Population per 1000 residing on	
	Permeable Soils.	Retentive Soils.
A. With least phthisis,	909	91
B. With next least phthisis,	877	123
C. Middle as to phthisis,	795	205
D. With more phthisis,	792	208
E. With most phthisis,	642	358

An exact comparison between retentive and permeable soils in regard to the prevalence of phthisis was afforded by a limited area, the Wealden, which in part is formed by the Weald clay, in part by the Hastings beds of alternate sands and clays. There are, indeed, no districts wholly of sand to contrast with others wholly of clay; but there are great differences in the proportion of the two soils in different districts. How closely these correspond with differences in the consumption death-rate appears from the following table, in which the districts are arranged in order of the death-rate from phthisis, those being placed highest in which it is least. Where there are gravels over the Weald clay, the figure is divided between the last two columns, it being presumed that they occupy an intermediate position.

District in Order of Phthisis Death-Rate.	Percentage of Population Resident on						Total on	
	Higher Beds, mostly Lower Greensand.		Weald Clays.		Hastings Beds.		Sands and Half Gravels over Weald Clay.	Clays and Half Gravels over Weald Clay.
	Sands.	Clays.	With Gravel.	Without Gravel.	Sands.	Clays.		
Hastings,	...	...	...	...	95	5	95	5
Cranbrook,	...	...	1	6	84	9	84	16
East Grinstead,	...	...	...	12	82	6	82	18
Tunbridge,	...	1	24	7	64	4	76	24
Hambledon,	49	...	20	31	...	...	59	41
Battle,	...	...	...	...	80	20	80	20
Rye,	...	4	...	...	79	17	79	21
Maidstone,	43	1	45	11	...	...	66	24
Cuckfield,	21	1	...	25	48	5	69	31
Uckfield,	...	...	...	1	82	17	82	18
Hailsham,	...	...	...	34	61	4	61	38
Ticehurst,	...	...	...	...	67	33	67	33
Tenterden,	...	...	...	29	42	29	42	58
Horsham,	...	...	...	56	44	...	44	56
Petworth,	30	...	...	70	...	...	30	70

Buchanan's conclusions have been subjected to much criticism, notably by Kelly, the Medical Officer of Health for East Sussex, who has expressed doubts of there being any intimate relation between dampness of the soil and phthisis. He finds that in the years 1861–70, the order in which the several districts have to be placed in regard to their death-rates from phthisis is different from that given by Buchanan for 1851–60. He points out that most of the impervious beds are to the north of the South Downs, and that consumption seems most common in places which are bleak and exposed as well as damp. He insists on the fact that in West Sussex (as indeed throughout England and Wales) there has been of late years a great decrease in the mortality from consumption, although there has been no change in the drainage of Sussex. Kelly is inclined to attribute it mainly to the progress which has taken place in the social state of the rural population. These more recent inquiries, when contrasted with Buchanan's earlier ones for the same localities, do not so much indicate the earlier conclusions to be wrong, as that all varieties of soil being now equally healthy, the cause of the phthisis which still occurs has to be sought for in other directions than soil dampness.

It is probable that dampness is merely one of the many factors which are concerned in causing a predisposition to phthisis. On low-lying, damp soils colds and catarrhs are notoriously more common than on high and dry situations, and the tubercle bacillus, which is the exciting cause of phthisis, finds a favourable nidus in these cases. We have no reason to think that soil in any particular condition affords a more favourable medium for the preservation of the bacillus than do other materials. Even admitting that soil dampness may favour the prevalence of phthisis by tending to lessen the resistance of the individual to the specific bacillus, it is obvious that many other conditions, such as overcrowding, poverty, ill-feeding, and general neglect of children, may all equally exercise a powerful influence on phthisis mortality.

Rheumatism.—In respect of soil influences it is necessary to make a distinction between chronic rheumatism and acute rheumatism or rheumatic fever. It is well known that the chronic rheumatic diseases prevail most in deep and damp valleys, along sea-coasts, the shores of rivers, and in places which are much exposed to wind. Whatever connection chronic rheumatism and allied affections may have to soil states, is probably only in so far as altitude, configuration, and physical characters of the soil affect the climate of particular places. Of all soil conditions, dampness is that which will be most likely to predispose to chronic rheumatism, because it makes a locality cold; and this is particularly likely to occur on clays in low-lying districts. Beyond this general statement we cannot go.

As relates to acute rheumatism or rheumatic fever, the facts are not so simple. The tendency of modern thought is to regard rheumatic fever as a specific febrile disease dependent upon a specific micro-organism. A study of its epidemic prevalence shows that, at intervals of a few years, rheumatic fever tends to prevail epidemically. These epidemics occur in or just following years of sparse rainfall. This produces its effect by its influence in causing a warm and dry subsoil, usually with an exceptionally low ground water. From this point of view, rheumatic fever is essentially a soil disease, having close relationships with erysipelas and other septicæmic diseases. The explanation of the epidemic prevalence of rheumatic fever, as well as erysipelas and puerperal fever, lies in the favouring influence of a dry and warm subsoil on the specific contagia of the three diseases. Whether these contagia are alternately parasitic and saprophytic, or each case implies a fresh infection from the soil, is still doubtful. It is noticeable that the conditions of soil producing rheumatic fever and chronic rheumatism appear to be almost exactly opposed to each other. The seasonal distribution of the two diseases is also dissimilar.

Rickets.—Although most authorities are agreed that this disease is primarily a disorder of nutrition, the outcome of either hereditary taint or defective and improper food in early life, still the remarkably definite relation which rickets appears to bear to climate has induced some writers to think it is in some manner dependent on the nature of soil. Hirsch has very clearly shown how countries, with a cold and wet climate subject to frequent changes in weather, are, if not the exclusive home of rickets, at least its headquarters. Oppenheim, arguing from its frequency on marshy plains or in valleys, has suggested that it is in some way related to malaria: especially as it is rarely met with where the soil is dry or at great altitudes. It is doubtful whether these facts are anything more than coincidences: even if not so, much more evidence must be produced before the soil can be rightly regarded as in any way directly influencing the etiology of rickets.

Tetanus.—Formerly, a distinction was made between a traumatic and an idiopathic form of this disease; but at the present time, the belief prevails that tetanus only results from traumatic infection. The agent which produces this affection is, like that of malignant œdema, an anaerobic bacillus, frequently present in garden and other soil. Nicolaier was the first to demonstrate that when soil from gardens, roads, or fields was subcutaneously inoculated into guinea-pigs and mice, symptoms identical with tetanus were induced. The researches and experiments of Bassano have demonstrated the wide distribution of the tetanus germ in soil, besides indicating that neither climate nor meteorological conditions have much influence on the life of these micro-organisms. The extensive presence of the tetanus bacilli in soil explains why tetanus is more common after wounds on the hands and feet than on any other part of the body; and why it is more frequent amongst children who play about bare-footed than amongst adults. Gardeners and grooms are especially liable to it. The peculiar frequency with which grooms and others, in contact with horses, are attacked with tetanus has induced Verneuil to think that the disease is of equine origin: and that horse dung is the most potent source of tetanus dissemination. Verneuil's views are largely supported in France, although negative evidence comes from the New Hebrides to the effect that though horses are unknown, yet tetanus is very common there. In regard to this controversy as to the equine origin of tetanus, Nocard has aptly remarked "to pretend that the tetanic action of soil is due to the dung of horses, more than to that of oxen or sheep, is to say that tetanus is more frequent in the country than in the towns, where horses are much more numerous, a statement absolutely contrary to the facts." Although we cannot accept the equine theory of the origin of tetanus, we must take care not to err too much the other way and attribute its causation exclusively to soil. We must admit, the evidence points to the soil as being the chief medium of conveying infection, still the tetanus bacillus can exist in or on other articles and places, such as the coat of a horse or other animal, in hay, on a rusty nail, or on surgical and veterinary instruments.

Yellow Fever.—The whole history of yellow fever goes to show that though at one time and another its diffusion has been wide, still its native habitat is much less extensive. The extent of its diffusion indicates an independence of geological origin of soil. On the other hand, the prevalence of the disease along the banks of tropical rivers, which are dry at certain periods, and in the low parts of tropical sea-ports, particularly those abutting on or overhanging harbours, stagnant waters, or foul foreshores, clearly defines the existence of a porous, loose, and periodically saturated soil as being a constant concomitant of yellow fever.

No evidence appears to be available regarding the microscopic life present in soils of these kinds, neither are there any data which show that soil temperature, taken alone, has any bearing upon the occurrence of this peculiar disease in its endemic home. Although we do not know exactly what is the infective agent of yellow fever, yet, judging from its analogy to other infective diseases, such agent is in all likelihood a micro-organism : and that this microbe is a soil resident is suggested by a curious incident which occurred near Lima in 1880. A number of troops were engaged in throwing up an earthwork, which involved the digging up of an old cemetery, in which victims of an antecedent epidemic had been buried. Within a week over 50 per cent. of those engaged upon the work were attacked by yellow fever.

The philosophical and remarkable theory regarding the peculiar origin of this disease, as elaborated by Creighton from the forgotten writings of Audouard, has a direct interest and bearing upon the connection between the affection and soil processes. The Audouard-Creighton theory of the evolution of yellow fever is that its advent into the world coincided with the rise of the slave trade, and that its habitat has been and is the ports of debarkation of these slaves. It is perfectly well known, from the writings of both Lind and Bancroft, that the slaves on the slave ships did not suffer from yellow fever, but much from dysentery. According to Audouard, yellow fever originated at all its endemic centres from the filth of the slave ships, which filth was the putrid dysenteric discharges of the sick negro. Regarded in this light, yellow fever has been given us in the dejecta of another race, which, brought in considerable quantities in the bilges of ships to ports, has there been discharged into harbour mud and soil. The scourings of these ships, fermenting and multiplying in the harbour and shore mud, has generated a specifically poisonous virus which has been only too readily carried from harbour to harbour. In connection with this view, it is curious to note the fact that yellow fever is most persistent at places where there has been least cleansing of harbours, beach, or foreshore by the natural action of the tides, or where much stagnation of the harbour water exists, as in places like Havana, Port Royal, Bridgetown, and Port-au-Prince.

Though up to the present the isolation and identity of the yellow fever poison has not been made, still there is much to make us regard it as being essentially a mud or soil-contained poison, and the mud or soil, where it has accumulated for a time, continues to be an endemic focus of the disease. Until we know more as to what is the nature of the yellow fever virus, we must leave it an open question as to how far the soil acts as only a nidus for it, or how far it exercises any specific influence on its growth and spread. As in the case of the other infective diseases, it is probable that the soil only furnishes a suitable medium in which the yellow fever poison may remain and multiply, and that, of itself, the soil is quite devoid of any special vitalising influence upon the cause of the disease.

THE BACTERIOLOGICAL EXAMINATION OF SOIL.

It has already been indicated that most soil samples are exceedingly rich in bacteria: the majority of these, as agents of putrefaction and nitrification, play a distinctly beneficial part in nature: a few others, which are pathogenic to both animals and man, appear to be possessed of less obvious advantages. Though the presence of even large numbers of micro-organisms in an earth sample is not necessarily an indication of its being either unsuitable for a building site, or as a source of water-supply, still the recognition and differentiation of various species, in some cases, is important. Such a procedure is obviously one of considerable difficulty, involving great care and patience: and before anything of a pathogenic nature could be definitely stated to be present or not, necessitates the isolation of various colonies, the application of various methods of culture, staining and even experimental inoculations on animals.

To obtain a cultivation of the microbes in soil, a sample of the latter must be first dried and then triturated. It may then be shaken up with distilled water, and from this a drop transferred to sterilised bouillon or gelatin. Again, a small quantity, after drying and trituration, may be sprinkled over the surface of nutrient gelatin prepared for a plate cultivation. In another method, the gelatin is liquefied in a test-tube, the powdered earth added, evenly distributed throughout the medium, and from it a plate culture made. In such a plate culture, by means of a suitably ruled glass plate and divided into centimetre squares, it is easy to count the number of colonies which develop in a given area, and from them calculate the number of bacteria that were originally present in the given sample of earth. For the differentiation of particular species, the individual colonies should be examined by cover glass preparations, and by fractional cultivation upon gelatin, potatoes, and other media.

A more difficult procedure is to aspirate the ground air from different soil depths and then cause it to pass slowly over the surface of gelatin, whereby such micro-organisms as may be present attach themselves and eventually develop upon the nutrient medium, where they can be subsequently examined.

THE PHYSICAL AND CHEMICAL EXAMINATION OF SOIL.

Though more often required for agricultural than for hygienic purposes, a complete examination of a soil should include the following points:—

Mechanical Condition.—The degree of density, friability, and penetration by water should be determined both in the surface and subsoil. Deep holes, 6 to 12 feet, should be dug, and water poured on portions of the soil. Holes should be dug after rain, and the depth to which the rain has penetrated observed. In this way the amount of dryness, the water-level, and the permeability can be easily ascertained.

The surface or subsoil can also be mechanically analysed by taking a weighed quantity (100 grammes), drying it, and then picking out all the large stones and weighing them, passing through a sieve the fine particles, and finally separating the finest particles from the coarser by mixing with water, allowing the denser particles to subside, and pouring off the finer suspended particles. The weight of the large stones, plus the weight of the stones in the sieve and of the dried coarser particles, deducted from the total weight, gives the amount of the finely divided substance, which is probably silicate of aluminum.

Temperature.—The temperature at a depth of 2 or 3 feet, at two to four o'clock in the afternoon, would be an important point to determine in the tropics, and also the temperature in early morning.

Hygroscopic Moisture.—Place 5 grammes of air-dry oil in a flat-bottomed and tared platinum dish: heat in an air bath to 45° C. for eight hours: cool and weigh: repeat the heating, cooling, and weighing at intervals of an hour till constant weight is found, and estimate the moisture by the loss of weight. Weigh rapidly to avoid absorption of moisture from the air.

Water Holding Power.—In the throat of a clean 3-inch glass funnel place a very small filter, just large enough to prevent the soil from running through the stem: wet the filter and add 100 grammes of the air-dried soil: from a burette pour water on the soil, till it is thoroughly wet and a few drops pass through: let it stand undisturbed till no more water flows from the soil, the funnel being covered with a glass plate to prevent evaporation. Return the water which has filtered through to the burette. The number of c.c. taken up by the soil will show the percentage capacity of the soil to hold water. In using this process, in order to secure uniform results, the soil should be simply poured into the funnel and not pressed or packed in any way. The soil should not be handled or shaken.

Capillary Power.—This is determined by filling a long glass tube with soil, placing the lower end in water, and marking the height to which the water ascends, as shown by the changed colour of the soil in the tube.

Volatile Matter.—The platinum crucible and 5 grammes of soil, used to determine the moisture, are heated to low redness. The heating should be prolonged till all organic material is burned away, but below the temperature at which alkaline chlorides volatilise. Moisten the cold mass with a few drops of a saturated solution of ammonium carbonate, dry, and heat to 65° C., to expel excess of ammonia. The loss in weight of the dry soil represents organic matter, water of combination, salts of ammonia, &c.

Water-soluble Materials.—To prepare a water extract of the soil, a percolator of glass or tin may be employed. It should be large enough to hold 1 kilogramme of soil. Pour sufficient ammonia-free distilled water on the soil to moisten it all, and let the whole stand undisturbed for half an hour, then add more water till a litre of filtrate is secured. If the soil extract is cloudy, filter through a plain filter.

Soluble Solids.—Evaporate 100 c.c. of the filtrate to dryness in a tared dish: each gramme of residue will represent 1 per cent. of water soluble matter. Test this dry residue for nitrates by pouring over it 10 c.c. of pure H_2SO_4, holding in solution 4 mgms. of brucine sulphate.

Chlorides.—Titrate 100 c.c. of the filtrate or soil extract with standard deci-normal silver nitrate, adding a few drops of a solution of K_2CrO_4 as an indicator.

Sulphates.—Precipitate these from 100 c.c. of the soil extract with $BaCl_2$, in the presence of a few drops of HCl. Reserve the rest of the soil extract for a subsequent quantitative estimation of nitrates.

Acid-soluble Materials.—Place 10 grammes of air-dried soil in a 200 c.c. glass flask, add 100 c.c. of pure HCl, insert the stopper, wire it securely, place in a steam bath, and digest for thirty-six hours at the temperature of boiling water. Pour the contents of the flask into a small beaker, wash out the flask with distilled water, add the washings to the contents of the beaker, and filter through a washed filter. The residue is the amount insoluble in hydrochloric acid. Add a few drops of HNO_3 to the filtrate, and evaporate to dryness on the water bath: take up with hot water and a few drops of HCl, and again evaporate to complete dryness. Take up as before, and filter into a litre flask, washing with hot water. Cool and make up to 1 litre. This solution may be marked "A." The residue is soluble silica.

Ferric and Aluminium Oxides.—To 100 c.c. or 200 c.c., according to the probable amount of iron present, of the solution "A," add NH_4OH to alkaline reaction (avoiding excess) in order to precipitate ferric and aluminic oxides and phosphates. Expel the excess of ammonia by boiling, allow to settle, decant the clear solution through a filter, add 50 c.c. of hot distilled water, boil, settle, and decant again. After pouring off all the clear solution possible, dissolve the residue with a few drops of HCl with heat and add just enough NH_4OH to precipitate the oxides. Wash by decantation with 50 c.c. of distilled water, and then transfer all the precipitate to the filter and wash with hot distilled water till the filtrate becomes free from chlorides. Save the filtrate and washings, which may be marked solution "B." Dry the precipitate and filter at 45° C., transfer the precipitate to a tared crucible, burn the filter and add the ash to the precipitate, heat the whole red hot, cool, and re-weigh. The increase of weight, minus the ash of the filter and the phosphoric acid (to be determined subsequently), represents the weight of the ferric and aluminium oxides.

Ferric Oxide.—Precipitate 100 c.c. of solution "A" with NH_4OH, wash the precipitate with hot water, dissolve while wet in dilute H_2SO_4: reduce by the addition of granulated zinc, free from iron, and estimate ferric oxide by a standard solution of $KMnO_4$. To prepare the potassium permanganate solution, dissolve 3·156 grammes of pure crystallised permanganate in a litre of distilled water, and preserve in a ground glass stoppered bottle shielded from the light. Standardise from time to time this permanganate solution with pure ferrous sulphate. This method of estimating iron depends upon the fact that $KMnO_4$, in the presence of a ferrous salt, oxidises to the ferric state. The solution made as above after addition of the zinc is one of a ferrous salt: as the $KMnO_4$ falls into this solution, a pink blush is formed, but disappears on stirring as long as a ferrous salt remains unoxidised to ferric. As soon as all is oxidised to the ferric state, the pink remains permanent. Knowing, after standardisation, the oxidising value of each c.c. of $KMnO_4$ in terms of Fe_2O_3, this, multiplied by the number of c.c. used, gives the amount of ferric oxide in 100 c.c. of solution "A" or 1 gramme of air-dried soil.

The weight of ferric oxide, so found, deducted from the total weight of ferric and aluminium oxides, with corrections for filter ash and phosphoric acid, will give the weight of alumina in 1 or 2 grammes of soil, according as 100 or 200 c.c. of solution were originally taken.

Phosphoric Acid.—Take another 100 c.c. of solution "A" and neutralise with ammonia, and add about 15 grammes of dry ammonium nitrate. Next precipitate, by adding 50 c.c. of molybdic solution, made by dissolving 100 grammes of molybdic acid in 400 c.c. of ammonia, the solution then being poured into 1250 c.c. of nitric acid. Filter, and wash with a solution of ammonium nitrate, made by dissolving 200 grammes of the salt in water and then made up by further additions to 2 litres. The precipitate on the filter is then dissolved in ammonia and hot water, washed into a beaker, making a bulk of not more than 100 c.c. This solution is nearly neutralised with HCl, cooled, and then magnesia mixture run in slowly, accompanied by vigorous stirring. After fifteen minutes, add 30 c.c. of ammonia, filter the precipitate which forms, wash with dilute ammonia, ignite, and weigh. The magnesia mixture is made by mixing 110 grammes of crystallised magnesium chloride, 280 grammes of ammonium chloride, and 700 c.c. of ammonia, and then making up to 2 litres.

Manganese.—Concentrate solution "B" to 200 c.c. or less: add NH_4OH to alkalinity: add bromine water and boil: as the bromine escapes, allow to cool somewhat, add more ammonia and bromine and heat again. This process is continued until the manganese is completely precipitated, which it will be in about an hour; the solution is filtered while warm, the precipitate well washed, dried, ignited, and weighed. Estimate as Mn_3O_4.

Lime.—If no manganese is precipitated, add to solution "B," or to the filtrate and washings from the last procedure, 20 c.c. of a strong solution of NH_4Cl and 40 c.c. of a saturated solution of $(NH_4)_2C_2O_4$, to completely precipitate all the lime as oxalate, and convert the magnesia into soluble magnesium oxalate. Heat to boiling, and let stand for six hours till the calcium oxalate settles clear, decant on to a filter, pour 50 c.c. of hot distilled water on the precipitate, and again decant on to a filter, transfer the precipitate to the filter, and finally wash it free from all traces of oxalates and chlorides. Dry and ignite the precipitate, weigh and estimate as CaO: carefully moisten with H_2SO_4, heat gently and weigh as $CaSO_4$.

Magnesia.—Concentrate the filtrate and washings from the last procedure to 200 c.c., place in a half-litre flask, add 30 c.c. of a saturated solution of Na_2HPO_4 and 20 c.c. of concentrated ammonia, cork the flask and shake violently, till crystals form, then set the flask to cool. Filter off the clear liquid through a tared Gooch filter, transfer the precipitate to the filter, and wash with dilute ammonium hydrate (1 to 3) till the filtrate is free from phosphates; dry and ignite the crucible, to form magnesium pyrophosphate. The increase of weight × 0·36024 = MgO.

Sulphuric Acid.—Evaporate 200 c.c. of solution "A" nearly to dryness to expel the excess of acid: then add 100 c.c. of distilled water, boil, and add 10 c.c. of a solution of $BaCl_2$ and continue the boiling for five minutes. When the precipitate has settled, pour the clear liquid on to a tared Gooch filter, treat the precipitate with 50 c.c. of boiling water, and transfer the precipitate to the filter, and wash with boiling water till the filtrate is free from chlorides. Dry the filter and ignite. The increase in weight is barium sulphate, which × 0·412 = SO_4 in 2 grammes of air-dry soil.

Potash and Soda.—To another 200 c.c. of solution "A" add $BaCl_2$ in slight excess, and make alkaline with ammonia to precipitate sulphuric and phosphoric acids, ferric oxide, &c. Then precipitate the calcium and barium by $(NH_4)_2C_2O_4$. Evaporate the filtrate and washings to dryness, heat to decompose oxalates and expel ammonia salts, dissolve in 25 c.c. of distilled water, filter and wash the precipitate: add to the filtrate and washings 10 c.c. of baryta water and digest for an hour. Filter and wash the precipitate, add ammonium carbonate to the filtrate to complete precipitation of the baryta, filter and wash this precipitate. Evaporate the filtrate and washings in a tared dish, gently ignite residue to expel ammonia salts, cool and weigh. The increase of weight represents chlorides of sodium and potassium in 2 grammes of soil.

If the potassium chloride be separated and estimated by platinic chloride, and its weight subtracted from the weight of the chlorides of potassium and sodium, the difference will represent sodium chloride.

Nitrogen of the Soil.—The nitrogen compounds in the soil may be placed in three classes:—(1) The nitrates and nitrites, existing as soluble salts; (2) ammonia, or organic nitrogen easily converted into ammonia; (3) the humus nitrogen, or the inert nitrogen of the soil.

Active Soil Nitrogen.—For reducing the nitrates to ammonia, and at the same time to bring ammonia salts and organic nitrogen into a condition for separation by distillation, the best material is sodium amalgam. This may be readily prepared by placing 100 c.c. of mercury in a half litre flask, covering the warmed mercury with melted paraffin, and dropping into the flask at short intervals pieces of metallic sodium the size of large peas (taking care that the violence of the reaction does not project the contents from the flask), till 6·75 grammes of sodium have combined with the mercury. The amalgam contains 0·5 per cent. of sodium, and may be preserved indefinitely under the covering of the paraffin.

To estimate the active soil nitrogen, weigh 50 grammes of air-dried soil and place it in a clean mortar. Take 200 c.c. of ammonia-free distilled water, rub up the soil with a part of the water to a smooth paste, transfer this to a flask of 1 litre capacity, washing the last traces of soil into the flask with the rest of the water. Add 25 c.c. of the liquid sodium amalgam, and shake so as to well distribute the amalgam through the soil. Insert a stopper with a valve, and set aside in a cool place for twenty-four hours. Pour into the flask 50 c.c. of milk of lime, and distil on a sand bath 100 c.c. into a flask containing 20 c.c. of deci-normal sulphuric acid, and titrate with deci-normal soda solution, using dimethyl orange as an indicator. Estimate the nitrogen of the ammonia found as active soil nitrogen.

If the ammonia produced is too small in amount to be readily estimated volumetrically, determine the ammonia by Nesslerising the distillate.

Estimation of Nitrates in the Soil.—When it is desired to estimate separately the nitrates in the soil, the following method may be used. Evaporate 100 c.c. of a soil extract to dryness: dissolve the soluble portion of the residue in 100 c.c. of ammonia-free water, filtering out any insoluble residue, place the solution in a flask, and add 10 c.c. of liquid sodium amalgam, insert stopper with valve, set aside in a cool place to digest for twenty-four hours, add 50 c.c. of milk of lime, distil and titrate as above, finally estimating the nitrogen as N_2O_5. If the amount of nitrates is small, Nesslerising may be substituted for titration.

An approximate estimation of the nitrates may be made by evaporating a measured quantity of a soil extract, say 5 c.c., on a porcelain crucible cover, having first dissolved a minute fragment of pure brucine sulphate in the soil extract. When dry, pour over the residue concentrated H_2SO_4, free from nitrates, and observe the colour reactions produced. A simple pink indicates about the two-thousandth part of a milligramme, reckoned as KNO_3; a pink with faint reddish lines about the three-thousandth of a milligramme; a reddish colour about a four-thousandth part, and a distinct red a five-thousandth part of a milligramme. Blank experiments to test the acid and the brucine will be required before confidence can be placed in such estimations.

Total Nitrogen of Soil.—The total nitrogen of soils may be determined by the usual combustion with soda-lime, but this process is often unsatisfactory because of the large amount of material required when the organic matter or humus is small in amount.

A modification of the Kjeldahl method is more easy to carry out and gives equally satisfactory results. Place 20 grammes of soil in a Kjeldahl flask, and add 20 c.c. of H_2SO_4 (free from ammonia) holding in solution 1 gramme of salicylic acid. If the soil contain much lime or magnesia in the form of carbonate, more acid may be needed, enough being added to secure a strongly acid condition of the flask contents. Add gradually 2 grammes of zinc dust, and mix by shaking. Heat to boiling in a sand bath and boil for ten minutes. Add 1 gramme of mercury and continue boiling for one hour, adding 10 c.c. of H_2SO_4 if the flask contents are likely to become solid. Cool, and wash out the soluble matter with 200 c.c. of pure water, leaving the heavy earthy materials. Rinse the residue with another 100 c.c. of water and add this to the first washing. Place this soluble acid extract in a litre digestion flask, add 35 c.c. of a solution of potassium sulphide, and shake to secure intimate mixture. Introduce a few fragments of granulated zinc, pour in 75 c.c. of a saturated solution of caustic soda, connect the flask with a condenser, and distil 150 c.c. into a flask containing 20 c.c. of deci-normal sulphuric acid and titrate with deci-normal soda solution. Enter the nitrogen obtained from the ammonia produced in this operation as total soil nitrogen.

The difference between the total soil nitrogen and the active soil nitrogen will express the inert nitrogen of the soil.

Carbon Dioxide.—Introduce 5 grammes of soil into a small wide-mouthed flask and moisten with a little water. A short test-tube is filled two-thirds with HCl and introduced so that its top rests against the shoulder of the flask, and that no acid escapes. A perforated cork with two tubes is now attached. One tube reaches to the bottom of the flask and extends well above the cork and is itself closed by a small cork. The other tube, which does not extend much below the cork of the flask, is bent thrice at right angles, and finally fitted into a wider tube 8 inches long and drawn to a point at its further end. This tube has a plug of cotton wool at either extremity, the intermediate space being filled with small fragments of neutral calcium chloride, previously well dried. The whole apparatus is now weighed. After weighing, the flask is slightly inclined, so that a little acid flows out of the tube: it is then mixed with the soil by gentle agitation: this is repeated until the soil ceases to effervesce. The flask is then warmed: when nearly cold, the small cork in one of the tubes is removed, and air slowly drawn through the apparatus by suction applied to the piece of india-rubber tubing attached to the open end of the calcium chloride tube: this is continued until all the carbon dioxide has been removed: the little cork is now replaced, and the apparatus, when quite cold, weighed: the loss in weight is carbon dioxide. Some practice is needed to get fairly exact results with this apparatus.

The following table gives the analyses of several kinds of soil, as made by different observers: they are of interest, as showing how one soil may differ from another in composition.

	Lincolnshire Fen Soil. (Wilson.)	Bedfordshire Loam Soil. (Voelcker.)	Gloucestershire Stiff Clay Soil. (Voelcker.)	Essex Marl. (Voelcker.)	Maltese Chalk Marl. (Playfair.)	Punjab Alluvium.
Moisture, .	17·73	19·61	15·53	3·51	7·62	3·06
Organic matter and combined water,	23·40	8·85	3·62	10·50	9·33	4·56
Ferric oxide,	4·89	6·35	1·76	5·36	1·11	3·32
Alumina,	4·18	3·43	1·70	2·19	3·26	7·43
Lime,	1·95	0·48	0·74	17·62	23·77	1·60
Magnesia,	0·21	0·46	0·60	0·25	0·53	...
Potash, . .	0·11	0·33	0·27	0·62	0·55	...
Phosphoric acid,	1·20	0·22	0·38	0·77	0·90	0·44
Sulphuric acid,	0·15	0·14	...	0·04	0·12	0·52
Carbon dioxide,	0·72	...	...	0·92	...	...
Chlorine,	0·03	0·05	...	0·07	0·03	0·91
Silica and insoluble matter,	45·43	60·08	75·40	58·15	52·78	78·16
	100·00	100·00	100·00	100·00	100·00	100·00

BIBLIOGRAPHY AND REFERENCES.

Adams, "On the Relationship between Diphtheria and Movements of the Ground Water," *Proc. 8th Internat. Congress of Hyg. and Demog.*, Buda-Pesth, 1894. Airy, *Proc. Internat. Med. Congress*, 1881. *A. M. D. Reports*, various papers, notably in years 1871, 1872, 1873, 1882, 1885. Arnould, "Les Micro-organismes dans le sol," *Annales d'Hygiene*, 1885.

Ballard, Local Government Board, *Report of Med. Officer*, 1888. Barnes, *Brit. Med. Journ.*, vol. ii., 1888. Baumgarten, *Studien über die Absorptionsfahigkeit der Bodenarten*, München, 1889. Beare, *Proc. Instit. of Civil Engineers*, 1892, pp. 341–369. Bird, *Manual of Geology*, Lond., 1894. Brewer, "On the Origin and Constitution of Soils," *Connecticut State Bd. of Agricul.*, 1877–8. Buchanan, *9th and 10th Rep. Med. Off. Privy Council*, 1866–7. Buhl, *Zeitsch. f. Biologie*, Bd. i. p. 1. Burdon-Sanderson, *Report on Health of Liverpool.*

Cameron, *Trans. Roy. Acad. of Med. in Ireland*, vol. vi., 1888. Copeman, Article on "Soil," in Stevenson and Murphy's *Treatise on Hygiene*, vol. i., 1892. Cunningham, *13th Ann. Rep. of San. Comm. with Govt. of India*, 1878 ; also in *Sci. Mem. of Med. Offs. of Army of India*, Calcutta, Parts iii. and iv., 1888–9.

Daubrée, *Les Eaux Souterraines*, Paris, 1887. De Chaumont, *Lectures on State Medicine*, 1875. Delesse, "Durée des pavés et des grés," in *Ann. des Ponts et Chaussées*, vol. v., 1854. Dempster, "Influence of Different Kinds of Soil on the Cholera and Typhoid Fever Organism," *Brit. Med. Journ.*, i., 1894, pp. 1126 and 1140.

Ebermayer, *Die physical Einwerkungen des Waldes auf Luft u. Boden*, Berlin, 1875. Everett, *Report of British Association*, 1879.

Fodor, *Hygienische Untersuchungen über Luft, Boden, und Wasser*, Braunschweig, 1882. Forbes, *Edin. Meteor. Reports*, 1883–4–7. Frankland, *Zeitsch. f. Hygiene*, Leipzig, 1889, vi. p. 373.

Hirsch, *Geograph. and Historical Pathology*, New Sydenham Soc., 1886. Hunt, *Chemical and Geological Essays*, Lond., 1879.

Kelly, *Proc. Brit. Med. Assoc.*, 1886.

Latham, *Transac. Sanit. Instit.*, 1886. Lewis, *Physiol. and Patholog. Researches*, Lond., 1888. Lloyd, *Science of Agriculture*, Lond., 1884.

Miers and Crosskey, *The Soil in Relation to Health*, Lond., 1893.

Nichols, *Sixth Rep. of Massachusetts Board of Health*, 1875. North, "Lectures on Malarial Fevers," *Brit. Med. Journ.*, vol. i., 1887.

Pettenkofer, *Zeitsch. f. Biol.*, 1871, vii. p. 395 ; also *Die Boden und sein Zusammenhang mit der Gesundheit des Menschen*, Berlin, 1882. Pfaff, *Zeitsch. f. Biol.*, Bd. iv. p. 249. Poore, "The Living Earth," *Lancet*, vol. ii., 1890. Prestwich, *Geological Conditions affecting the Water Supply to Houses and Towns*, Oxford, 1876.

Ransome, "Soils and Sites," *Health Lectures*, Lond., 1884–5. Reuk, "Uber die Permeabilität des Bodens für Luft," *Zeitsch. f. Biol.*, München, 1879, xv. p. 205.

Smolensky, "Uber den Kohlensäuregehalt der Grundluft," *Zeitsch. f. Biol.*, 1877, xiii. 383. Soyka, "Der Boden," *Handb. d. Hyg.*, Leipzig, 1887 ; also *Zeitsch. f. Hyg.*, 1887, ii. p. 96.

Tomkins, *Brit. Med. Jour.*, 1889, ii. p. 180.

Warington, *Journal of Chem. Soc. Lond.*, 1884, vol. xlv. Wolffhügel, "Uber den Kohlensäuregehalt im Geröllboden von Münschen," *Zeitsch. f. Biol.*, xv. p. 98. Wollny, *Der Einfluss der Panzendecke auf der Physic Eigenschaften des Bodens*, Berlin, 1877.

CHAPTER IX.

HABITATIONS.

"WHOEVER considers carefully the record of the mediæval epidemics, and seeks to interpret them by our present knowledge of the causes of disease, will surely become convinced that one great reason why those epidemics were so frequent and so fatal was the compression of the population in faulty habitations. Ill-contrived and closely packed houses, with narrow streets, often made winding for the purposes of defence; a very poor supply of water, and therefore a universal uncleanliness; a want of all appliances for the removal of excreta; a population of rude, careless, and gross habits, living often on innutritious food, and frequently exposed to famine from their imperfect system of tillage,—such were the conditions which almost throughout the whole of Europe enabled diseases to attain a range, and to display a virulence, of which we have now scarcely a conception. The more these matters are examined, the more shall we be convinced that we must look, not to grand cosmical conditions; not to earthquakes, comets, or mysterious waves of an unseen and poisonous air; not to recondite epidemic constitutions, but to simple, familiar, and household conditions, to explain the spread and fatality of the mediæval plagues."

GENERAL CONDITIONS OF HEALTH.

The diseases arising from faulty habitations are in great measure, perhaps entirely, the diseases of impure air. The site may be at fault; and from a moist and malarious soil excess of water and organic emanations may pass into the house. Or ventilation may be imperfect, and the exhalations of a crowded population may accumulate and putrefy; or the excretions may be allowed to remain in or near the house; or a general uncleanliness, from want of water, may cause a persistent contamination of the air. On the other hand, these five following conditions insure healthy habitations:—

1. A site dry and not malarious, and an aspect which gives light and cheerfulness.
2. A pure supply and proper removal of water; by means of which perfect cleanliness of all parts of the house can be insured.
3. A system of immediate and perfect sewage removal, which renders it impossible that the air or water shall be contaminated from excreta.
4. A system of ventilation which carries off all respiratory impurities.
5. A condition of house construction which insures perfect dryness of the foundation, walls, and roof.

In other words, perfect purity and cleanliness of the air are the objects to be attained. This is the fundamental and paramount condition of healthy habitations; and it must over-ride all other conditions. After it has been attained, the architect must engraft on it the other conditions of comfort, convenience, and beauty.

The inquiries which have been made for many years in England have shown how badly the poorer classes are lodged, both in town and country, and how urgent is the necessity for improvement. Various Acts have been passed for the purpose of improving the condition of the dwellings of the working classes, but either from lack of energy in carrying out their provisions, or from the difficulty of proving that a dwelling is injurious to health unless it is in extremely bad condition, these Acts have had hitherto only partial effect.

In towns, density of population has a direct influence on the mortality of its inhabitants. Ogle, in the Supplement to the 45th Annual Report of the Registrar-General, illustrates the connection between the aggregation of the population and the death-rate, and clearly shows that after the density has reached a certain degree of intensity, it begins to exert an appreciable effect. Russell also points out the evils connected with overcrowding, and shows that Aberdeen, with a population of 13·6 per cent. living in one room, has the lowest death-rate of eight of the large Scotch cities, and that this rises *pari passu* with the diminution in the size of the average house, until we reach Glasgow with 24·7 per cent. of its population living in one room, and the highest death-rate. Back-to-back houses illustrate very clearly the effect of density of population, involving as they do deficient light and ventilation and imperfect sanitary arrangements. Tatham has shown that at Salford the mortality from all causes, from pulmonary diseases, from phthisis, and from the seven chief zymotic diseases taken together, as well as from diarrhœa alone, increases *pari passu* with the proportion of back-to-back houses. "The more crowded a community, the greater, speaking generally, is the amount of abject want, of filth, of crime, of drunkenness, and of other excesses, the more keen is the competition and the more feverish and exhausting the conditions of life; moreover, and perhaps more than all, it is in these crowded communities that almost all the most dangerous and unhealthy industries are carried on. It is not so much the aggregation itself, as these other factors which are associated with aggregation, that produce the high mortality of our great towns or other thickly populated areas."

Farr states that it is proved beyond doubt that if the population be the same in other respects, an increase of density implies an increase of mortality; and he gives five groups of cases, showing the varying mortality with density of population.

Where the population was 86 persons to 1 square mile, the mortality was 14, 15, or 16 per 1000. Where the population was 172 persons to 1 square mile, the mortality was 17, 18, or 19 per 1000. Where the population was 255 to 1 square mile, the mortality was 20, 21, and 22 per 1000. Where the population was 1128 persons to 1 square mile, 23, 24, or 25 per 1000. Where the population was 3399 persons to a square mile, the mortality was 26 per 1000 and upwards.

The later returns of the Registrar-General for England and Wales prove that where crowding exists it is a source of ill-health. There is also another factor which commonly accompanies overcrowding, and which reacts upon the community in the form of increased morbidity and mortality rates, and that is an abnormally high birth-rate. In the slums of large cities, and crowded dwellings, there are invariably high birth and death rates. The following tables illustrate this fact:—

Table of Six Densely Populated Towns, 1892.

Town.	Population.	Persons per acre.	Birth-rate per acre.	Death-rate per 1000.
London,	4,263,294	57·1	30·9	20·6
Liverpool,	513,790	98·6	34·7	24·7
Plymouth,	85,610	58·3	29·1	18·8
Bolton,	116,261	48·4	32·7	22·8
Manchester,	510,998	40·0	33·7	23·8
Salford,	210,058	38·9	35·9	24·6
Averages of the six towns,	...	56·88	32·83	22·55

Table of Six Towns not so Densely Populated, 1892.

Town.	Population.	Persons per acre.	Birth-rate per 1000.	Death-rate per 1000.
Croydon, .	106,152	11·8	26·5	15·8
Huddersfield,	96,599	8·2	23·0	18·1
Norwich,	102,736	13·7	30·5	20·0
Halifax,	84,097	22·3	25·9	19·5
Bradford,	219,262	20·3	27·2	18·0
Oldham,	134,221	28·4	29·1	22·0
Averages of the six towns,	...	17·45	27·03	18·90

In the Report to the Local Government Board by Ballard, upon the causation of the annual mortality from diarrhœa, he shows that, among the more important conditions influencing diarrhœal mortality, aggregation of the population favours, and dispersion over an area disfavours, diarrhœa, and that density of buildings, of whatever kind, upon an area promotes diarrhœal mortality.

Sites.—In towns and villages, the sites of additional or substituted dwellings are generally fixed irrespective of the advice of anyone. In the case of isolated dwellings, however, where selection can be made, adverse conditions in the site may render the best designed and best built structure unhealthy. It is therefore desirable to know what to select, or at least understand what to avoid in making a selection. The question involves the following considerations:—

1. The aspect or exposure to wind, light, and air.
2. The ground or soil on which it is proposed to build.
3. The surroundings of the site.

Aspect and shelter have each their bearing on the salubrity and equality of temperature. While the situation should afford a free circulation of air about the dwelling, it is advisable to avoid exposure to a prevailing cold wind, and it may be necessary even to secure shelter from this by means of a belt of trees or some rising ground. But neither aspect nor shelter has an influence so great as the condition of the ground or soil beneath and surrounding the dwelling.

Dryness of site is essential to both these advantages. A damp subsoil for the foundation of a house is known to favour the prevalence of disease, and is, perhaps, one of the most fruitful sources of impurity of air in dwellings. Wherever possible, the soil or ground itself ought to be porous, such as gravel or sand, which allows the water to run freely away, or chalk, which retains but comparatively little moisture, and does not cause dampness to collect about the house. The next best soils on which to build are rocks, such as granites, clay slates, limestones, or sandstones; nearly all these have a good slope, and are easily drained. The loams and stiff clays are not, as a rule, good soils for building purposes, as, unless well drained, they are apt to hold water; if, however, adequately drained, these are not necessarily unhealthy.

In these soils numerous drains are requisite to overcome the retentive properties which such soils possess. The greater the number, the better will that purpose be fulfilled. In free soils, *i.e.*, sand, gravels, and chalk, as a rule, no advantage is gained by multiplying drains beyond the minimum number that will lower the subsoil water, and they should be as far removed from buildings as possible. Pure chalk forms a healthy site, being permeable; but if the chalk be mixed with clay (marl), or be underlaid with clay, it becomes impermeable and damp. If of any thickness and not situated in a hollow, gravel beds make good building sites.

The worst soils are the shallow beds of gravel or sand lying on clay; these are frequently water-logged and proportionately bad; the same remark applies to reclaimed lands near the mouths of rivers and the so-called alluvial lands, which consist of soils that are really the deposit or sludge from rivers. Alluvial tracts are almost invariably unhealthy, owing not only to their dampness, but also to the large quantity of organic matter which they contain. These soils and sites are peculiarly liable to produce chronic rheumatism, ague, and various forms of malarial fever, as well as catarrhs and neuralgia.

If the site is artificially made, care must be taken to see that the subsoil is free from organic pollution of any kind. In the low-lying parts of towns and cities, or where the subsoil has been excavated for sand or gravel, the place is used frequently as a tip for rubbish of all kinds until the level is raised to a sufficient height to allow of its being utilised for building purposes.

From a report made by Parkes and Burdon-Sanderson on the sanitary condition of Liverpool, experiments, having for their object to ascertain what the effect of time had been on the organic matters which, together with cinder refuse, had been used to fill up inequalities of ground, tended to show that the process of decay of all the most easily destructible matters, including vegetable refuse, is completed in three years; but it is very doubtful if modern methods of investigation would not prove that this limit of time is far too short to allow such a site to be built upon, unless the whole ground surface or site of such building be asphalted or covered with a layer of concrete cement or some other impermeable material.

This concrete should be 6 inches thick: its component parts should be ballast, consisting of broken stone, gravel or burnt clay of a clean description and Portland cement of the best quality, in the proportion of five of ballast to one of cement, with enough sand to fill up interstitial spaces. It is desirable to cover the ground forming the base of the dwelling with concrete extending from one outside wall to the other. This will not only prevent dampness and "ground air" rising from the underlying soil into the house, but it will also prevent any liquid refuse sinking into the ground to pollute the soil beneath. As a rule, cellars under houses add to their healthiness, especially if properly built on an impervious flooring and adequately ventilated.

In all sites it is important to notice the distance of the ground water from the surface. If this water is too near the ground level, the site will be damp: it ought never to be nearer the surface than 8 feet, and, if possible, should be at least 15 or 20 feet below the ground line. Whenever ground is water-logged, owing to want of an outlet, whether the soil be an open gravel or dense clay, it will afford a bad site, unless the subsoil water is lowered by drainage to such a sufficient depth as not only to reduce evaporation, but to prevent the rising of moisture up to the cellar floors and the foundations of the dwelling.

There is reason to believe that frequent and sudden changes of water-level are specially unhealthy, and where these occur the place will not be a good site.

Statistics for many years go to show that where the ground water level has been lowered and the soil made drier, there the public health has improved. Buchanan, in his report upon the influence of sewage works on the public health, states that the general death-rate of Newport in South Wales was reduced 23 per cent., while phthisis was reduced 32 per cent. At Cardiff the general death-rate was reduced 24 per cent. and the death-rate from phthisis 17 per cent. At Salisbury the general death-rate was reduced 9 per cent., and that due to phthisis 49 per cent.

The most essential points to be sought for in regard to a choice of site for building purposes are as follows :—

1. A moderately elevated spot, so that a fall from the building may be secured in one direction at least, sheltered from the north and east, but not so shut in as to impede the free circulation of air round and over it.

2. The site should, if possible, be upon a porous soil, such as gravel and sand, care being taken to see that the subsoil is sufficiently permeable to secure thorough drainage, either naturally or artificially. When a house *must* be built on a retentive soil great precaution must be taken effectually to drain the subsoil and to obviate the dampness of the site as much as possible by the use of concrete.

3. The ground water should not be nearer the surface than 8 feet, and not subject to either great or sudden fluctuations.

4. The surface soil and subsoil, no matter what their nature, should be clean and not fouled by either sewage or refuse.

5. The site must also be chosen that sufficient facilities shall be secured for drainage and water-supply.

Construction of Dwellings.—The foundations ought to be sufficiently solid and deep enough in the ground to give firmness to the building. When the ground is soft, or a solid foundation cannot be reached, the walls should be built upon a solid platform of concrete or stone, which should be at least four times as broad as the walls. The bases of the walls themselves should be expanded into what are called *footings*, the lowest course of which should be at least twice the breadth of the wall. The height of the footings ought not to be less than two-thirds of the wall thickness. To prevent moisture from rising up the walls of dwellings, it is now usual to build them on a layer of concrete. In addition to this base of concrete, it is necessary to have a layer of impervious material, *i.e.*, *a damp-proof course* within the wall itself. The proper height at which to insert a damp-proof course in external walls is a few inches above the natural ground line, and in internal walls on a level with the bottom of the concrete. Damp-proof courses are made of different materials. Sometimes a double course of slates bedded in cement is used: sometimes a layer of sheet lead is placed throughout the whole length of the walls; perforated stoneware tiles embedded in cement have also been applied to the same purpose; these have the double advantage of not only preventing the uprising of moisture, but they also act as a means of ventilating the spaces between the ground beneath and the joists of the floor.

All dwellings possessing basement floors under the level of the natural surface of the ground should have outside areas or dry passages between the ground and their walls. This can usually be secured by digging away the earth on the outside to below the level of the floor so as to form a dry area. As an alternative plan to this, a device recommended by the Local Government Board in their Model Bye-laws may be employed; this consists in making the wall hollow up to a point above the ground level, and then inserting two damp-proof courses, one at the bottom of the hollow, and below the floor level, the other at the top of the hollow, and, therefore, above the outside ground level. By this means the inner wall is quite shut off from the soil. Both these arrangements are shown in fig. 65.

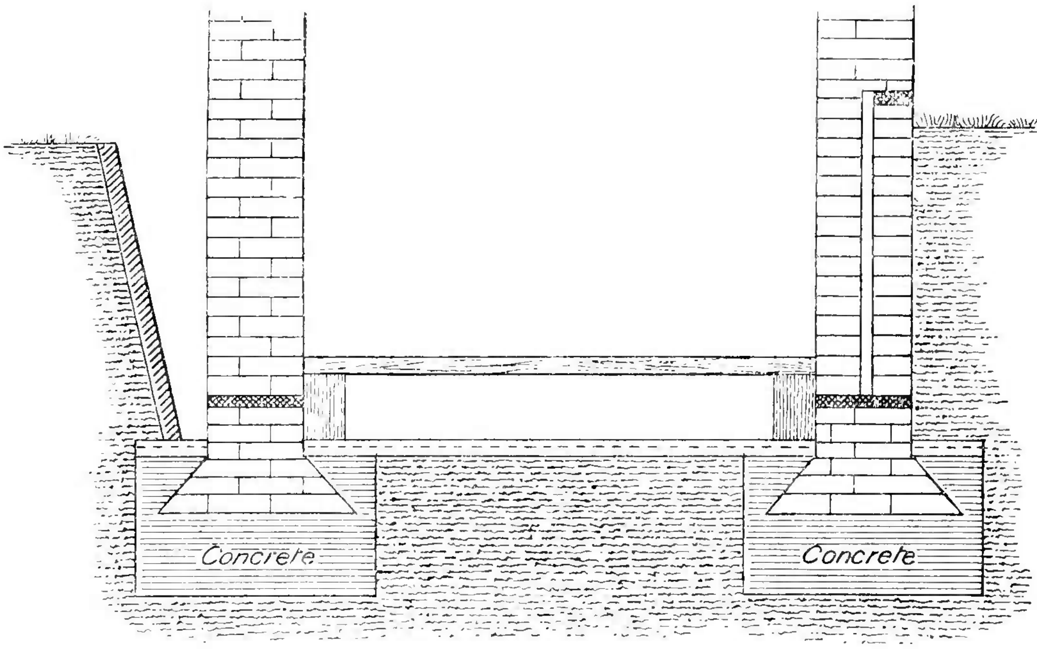


Fig. 65.

The materials generally used for the construction of walls of dwelling-houses are bricks, stones, and wood. Bricks are made from three kinds of earth, namely, pure clays, marls, and loams. Pure clay consists chiefly of alumina and silica; marls are clays having a considerable amount of lime in them; while the loams are light and sandy clays. Few bricks are made solely from any one of these earths, but rather from an admixture of all three. Bricks are burnt in kilns or clamps. Kiln-burnt bricks are more uniform in quality than clamp-burnt: the latter have part of the fuel mixed with the clay, and traces of it can be detected in the bricks after they are burnt. A good brick should be regular in shape, well burnt, of a uniform colour, and when struck give a clear metallic ring. A good ordinary brick should not weigh less than about 5 lb, and usually measures 9 inches long, $4\frac{1}{2}$ inches broad and $2\frac{1}{2}$ inches thick $= 101\frac{1}{4}$ cubic inches. The dimensions vary slightly in Scotland and Ireland. Ordinary bricks absorb about one-sixth of their weight of water; very hard bricks, such as the blue Staffordshire, about one-fifteenth or one-twentieth. So porous are ordinary bricks that both rain and air can be easily driven through them; in fact, so much is this the case that it is desirable in all dwellings that the outer walls should, if of brickwork, be at least a brick and a half thick (14 inches), so that in addition to the bricks there may be in the structure of the wall itself a layer of mortar. Mortar is a compound of one part of lime with three parts of clean sharp sand made up with fresh water. Sand is added to check shrinkage, either in drying or by absorption of carbonic acid from the air. Bricks are superior to any other material for house walls.

Two kinds of stone are generally used for house building; they are sandstone and limestone. Sandstone has been described as sand made into a cake with clay, lime, and oxide of iron. It is the varying amount of this latter which gives the various colours to it, such as red, yellow, and grey sandstone. Limestone is rock composed mainly of carbonate of lime. Like bricks, stone is both porous and absorbent of water, but in a less degree.

No woodwork should be placed in a wall except where it is necessary for carrying the floors or roof, or for fixing the fitments of a building, and then it should be so arranged that the shrinking or decay of the wood will not affect the strength of the wall. When the ends of flooring or other timbers are placed in the wall for support, they should rest on stone templates, and space for ventilation should be left all round them: the wall above must not rest upon them.

Wood enters largely into the construction of the inner fittings of all dwellings. In its natural state it is very absorbent, and the unavoidable cracks and crevices admit both air and water. The chief kinds used are ash, beech, oak, elm, pine, and larch. The first four differ from the latter in being free from turpentine. Good timber should be close and straight grained, free from cracks and dead knots, and well seasoned.

The walls of all dwelling-houses should be most carefully built from the foundations upwards, whether of brick or stone, with a layer of mortar not only between each course, but under the first course and well fitted into the vertical joints. Bricks are laid in beds or courses, and are usually spoken of as being bonded together.

English bond is the strongest and simplest for all ordinary work. The heading and stretching courses generally alternate, but not necessarily. No bricks in the same course should break joint with each other.

Flemish bond shows headers and stretchers alternately in each course. It is not so strong as English bond, but gives a better appearance, as a smoother face can be shown on both sides.

The thickness of the external walls of dwelling-houses is determined by the size of the building, more particularly by its height. According to the Model Bye-laws of the Local Government Board, the minimum thickness should be as follows:—When a wall is not over 25 feet in height, if it does not exceed 35 feet in length and do not comprise more than two stories, it shall be 9 inches for its whole height, but if it do comprise more than two stories or exceed 35 feet in length, it shall be 13½ inches below the topmost story and 9 inches for the rest. When walls are over 25 feet high and not exceeding 35 feet in length, they should be 13½ inches thick below the topmost story and 9 inches for the rest; but if they be longer than 35 feet, then they must be 18 inches thick for the height of one story, then 13½ inches thick for the rest of the height below the topmost story, and 9 inches thick for the rest of its height. Walls over 35 feet high must be 18 inches thick for the first two stories and 13½ inches for the rest. If over 50 feet in height, walls should be 22 inches thick for the height of one story, then 18 inches for the next two stories, and finally 13½ for the rest of the height.

Walls built of cut stone need be no thicker than those of brick, but if of rough stone or flint and boulders, they should be at least one-third thicker. Walls made of both brick and stone are not uncommon; the chief point about them is the need of careful bonding together of the two elements. Occasionally walls are made of concrete either rammed down in layers, or else built of concrete blocks well cemented together. Wood is at times used in making the upper part of the outer walls of houses; when so employed, it needs to be backed with at least 4½ inches of brickwork and well bonded together.

Owing to the absorbent and porous nature of all these materials, special care must be taken that outer walls constructed of them do not admit damp, especially when in positions much exposed to rain and wind. Different means are adopted for resisting the effects of driving rain; in some parts, vertical slating of the external walls is used, while in other places plain tiles are substituted, and present a much more agreeable appearance.

Hollow external walls are almost sure preventives against damp, and by their adoption in exposed localities the dwelling is not only rendered drier, but is made warmer in winter and cooler in summer. They consist of two thicknesses of brickwork separated by an air space of 2 or 3 inches, with a carefully devised admission of outer air, which should circulate through the hollow spaces. The two thicknesses should be tied together by bonding ties of iron; bricks are not recommended for this purpose, for any existing outside moisture can be absorbed by the end of the brick, and through it conveyed inwards, thus neutralising the benefit that would otherwise be derived. A damp-proof course is needed at the top of exposed walls, such as parapets and chimneys; this is usually provided by finishing the top of the wall either with a stone or letting it project an inch or two over the side, or else having an impervious damp-course laid in the wall or chimney at its junction with the roof.

During the building of house walls, care should be taken that the chimney flues are properly constructed. They should be made as straight as possible and separate one from another. The circular form is the best, as it is easy to clean, and the draught is more regular through it. They should contain no woodwork, and may with advantage be lined with a casing of sheet iron, an arrangement which not only disconnects the flue from the house structure, but favours cleansing and the maintenance of an up-draught. All chimneys should be higher than surrounding buildings, so that they may be in no way sheltered when the wind is in a certain direction, nor a down-draught set up.

Defects in roofs of buildings are a frequent cause of dampness. The more common materials used in making roofs are slates and tiles, and less often, thatch, wood, zinc and corrugated iron. Slates should be hard yet not brittle, free from streaks or flaws and give a metallic ring when struck. They should not absorb more than 5 per cent. of water in twenty-four hours. If stood half their depth in water for several hours, the moisture should not rise to the top. They should be uniform in size, thickness, and colour, roughish and not greasy on the surface, free from white iron pyrites, and from large crystals of yellow pyrites; if of poor quality they are apt to scale and readily break away. Tiles, like bricks, are made of clay, but need more careful drying and burning. They should be hard and as little absorbent of water as possible. Thatch forms a warm and dry roof, but is very liable to be infested by birds and vermin; the danger from its liability to fire is great, and on this account it is seldom used. Wood is also used, but is open to the same objection. Zinc and corrugated iron are not suited for dwelling-houses; they are extremely hot in summer and cold in winter. In all buildings it is important to see that there is a framework sufficiently strong to bear the weight of the material and in addition a certain amount of snow; in England this is not likely to accumulate to a greater depth than 6 inches and may be taken at 5 ℔ per superficial foot of horizontal surface. The effect of wind has also to be provided for, and this may be taken at 50 ℔ per square foot on the surface perpendicular to its direction. Rankine states that the maximum observed in Great Britain is 55 ℔.

The framework is usually made of wood. The angles of roofs for different coverings are as follows:—Zinc, 4°; large slates, 22°; ordinary slates, 26°·3; pantiles, 24°; thatch of straw, 45°; plain tiles, 45°. House roofs should always be covered with boarding laid at right angles to the rafters, and, if possible, some non-conducting material between this and the slates, such as "Slag-felt," which not only makes the house cooler in summer, but warmer in winter. Laths are nearly always substituted for boards in roofs; this should not be, as they are much less satisfactory. When slates are used they should be fastened to the boards with zinc nails; composition nails are sometimes used but the heads break off. If iron nails are used they should be galvanised, or boiled in linseed oil.

The part of each slate exposed to view is called the *gauge*. The *lap* is the distance which the lower edge of any course overlaps the slates of the second course below, measuring from the nail hole; it should not be less than 2 inches, but 3 inches is better. The flatter the pitch the greater the lap required. Tiles are often fastened with wooden pegs or hung on two special projections. Zinc and iron roofs are laid nearly flat in widths, with their edges overlapping to allow for expansion and contraction. The gutters round chimneys and party walls where they join the roof are frequent places for leaks; they all should be made of lead, the edges of which should pass well into the brickwork; cement, if used for this purpose, is liable to crack. The eaves of roofs are finished in different ways. If eaves-boarding is used, they should come out some distance beyond the walls, and be provided with a gutter so as to throw off the rain well away from the house. These gutters should be made of cast iron: for an ordinary roof they may be 5 inches deep with a slope of 1 in 10 inches; but they are usually fixed horizontally for appearance sake, and must then be larger than is necessary to carry off the water. The gutters should discharge into rain pipes made also of cast iron, 4 inches in internal diameter and placed at intervals of 50 feet. These rain-water pipes should discharge into properly ventilated rain-water tanks, or over a drain covered by a grating. They should never be directly connected with drains or sewers, neither should they be placed with their heads just below bed-room windows, more particularly when they empty into a tank.

For the inner walls of a house, the use of plaster of a coarse quality covered by a thin layer of a finer kind is almost universally adopted to cover the internal wall surfaces; this surface is generally papered. This practice has many disadvantages; the plaster, being porous, absorbs the moisture of the internal air, and with it any organic matters present in the air of inhabited rooms; while paper, unless varnished, cannot be washed, and much dirt sticks to it. The flock papers and their cheap imitations are particular offenders in these respects. Limewashing is preferable to unglazed and flock papers; in all cases where it is necessary to repeat limewashing, the wall should be first scraped and the old coat thoroughly removed.

Floors are best made of impervious materials which can be washed. Wood, stone, or tile constitute the chief. Stones or tiles are suitable for sculleries and passages, but are cold for kitchens and living-rooms. Wood makes the best flooring, particularly if of hard wood, such as oak or teak laid as parquet flooring. These, however, are very expensive. The ordinary wood floor is generally made of deal. If made of deal, a floor can be well laid down, provided that care be taken to tongue and groove the planks which constitute it. Cracks and crevices in floors should be avoided, as the enclosed space below, between them and the ceiling of the next room, is apt to become a huge receptacle for dirt of all kinds. In the commonest description of floors, the edges of the boards are merely placed true and the boards are laid side by side as close as possible and then fixed by one or two nails driven into each joist. Their edges are then said to be *plain* or *butt-jointed.* This mode of laying boards is only tolerable in inferior buildings, as open joints invariably occur, owing to the unavoidable shrinkage of the boards. The *grooved* and *tongued* joint consists of forming a groove or channel along the edge of one board, and a projection or tongue which resembles a continuous tenon to fit it on the edge of the other board, each board having a groove on one edge and a tongue on the other. When face-nailed, each board should have two nails where it crosses the joist. Skirtings are employed to hide the joint between the walls and floor boards. They should, where possible, be of tiles, iron or cement, but if of wood, they ought to be let into a groove in the floor, a device which will serve to prevent draughts coming through, and also the accumulation of dust in the holes and cracks which are invariably formed by the shrinking of the joints and skirtings.

When rooms in consecutive stories are only separated by a single floor, measures must be taken to prevent the passage of sound and smell. "Slag-felt," a patent preparation of slag-wood, has remarkable properties of deadening sound; it further has the advantage of being fire-proof and does not harbour vermin. "Pugging," which generally consists of plasterers' rubbish, saw-dust, tan, chopped straw, dried moss, &c., is objectionable, and should not be used for obvious reasons.

It remains now to consider a few of the chief points as to the design and arrangement of dwelling-houses. The chief object should be to make every use of the whole space in order to get as much accommodation and comfort as possible. If possible, rows of houses should run north and south, and all square buildings should have angles in these directions, so as to get some sunlight in every room. In many modern houses the most frequent error is perhaps the cramped space allowed for halls and staircases. Plenty of space should be given for them, as, with ventilating windows at the top, they constitute the central ventilation of the house. All the rooms should be so placed as to get light and air directly from the outside; and if there be any passages or lobbies they should be similarly lighted and aired. No room or closet which is not in direct communication with the outer air ought to be used as a sleeping-room.

The size of rooms will depend upon questions of cost, convenience, and the purpose for which they are intended. The height of rooms should not be less than 9 feet and rarely need exceed 12 feet. Every room should have at least one window in it which opens to the outer air direct; if possible, it should open half its size, extending nearly to the top of the room and equal in area to at least one-tenth of the floor space. In addition, every habitable room must have a fire-place and ought also to have some ventilating aperture, the sectional area depending on the size of the room and the number of occupants.

In the construction of dwellings, one of the most important points is to select a proper position for water-closets. They should be placed in a separate or outstanding part of the house; and where there are several water-closets, these ought to be built one over the other, and quite confined to one part of the building. The closets themselves should be of the best construction and efficiently disconnected from the drains.

Each closet ought to have at least one window of a minimum superficial area of 2 square feet opening direct into the outer air, and also have some means of special ventilation, so as to secure a circulation of air independently of that of the house. The floor and walls to a height of 5 or 6 feet should be of glazed tiles, and the remainder of the wall and ceiling ought to be varnished or painted.

The more detailed account of the ultimate disposal of the contents of water-closets, &c., as well as their form and construction, is given in Chapter X.

Artisans' Dwellings.—In selecting a site, it is of great importance to secure sufficient area, a well-drained subsoil and a suitable aspect. The buildings should occupy about one-third of the entire site, leaving two-thirds for air, light, approaches, &c. The height of the buildings should not exceed five stories above the ground, on account of fatigue in ascent and obstruction of light and air. The yards are best spread with a 9-inch layer of cement concrete laid to falls for drainage; it may be finished with a coating of tar-paving.

Staircases in blocks of artisans' dwellings should be built against an outside wall, so that windows may light them: the staircase should be made of stone or concrete, so as to resist the action of fire. The minimum width should be 6 feet 9 inches.

Internal corridors are specially to be avoided, as they are difficult to light and consequently are usually dirty.

The internal arrangement of a tenement should, as far as possible, assimilate to that of a well-planned country cottage, the size and number of the rooms depending upon local circumstances. A convenient size for the living-room or kitchen is 11 feet wide by 13 feet from front to back, the fireplace being so placed as to afford ample room in case of emergency for a bedstead. The windows should not be less than 3 feet 6 inches in width, and should extend to within 6 inches of the ceiling, in order to obtain the utmost light and ventilation. The room should be fitted with a cooking range 3 feet in width and provided with an oven. A food store, ventilated from the external air, should also be available. In the Peabody Buildings the sinks as well as the water-closets are on the staircase landings, and used jointly by the occupants of two or more tenements; they should be open to the constant inspection of the superintendents.

The bed-rooms vary in size; usually they are about 13 feet by 9 feet. Fanlights over the doors are useful as ventilators. Every bed-room should have a fireplace, which will act as a ventilator.

The Model Bye-laws of the Local Government Board suggest 300 cubic feet of air space for each adult and 150 for each child as a minimum in a sleeping-room; it is necessary, therefore, to provide floor space equivalent to at least 6 feet 6 inches by 5 feet for each adult, and 5 feet by 5 feet 3 inches for each child.

In the country more space is available, and a labourer's cottage comprises generally a living-room with a small scullery attached, and sufficient bed-room accommodation. The most economical arrangement is found in a two-storied building, the height of the lower story of which should be 9 feet, and that of the upper not less than 8 feet. The living-room should have a minimum floor area of 150 square feet and be fitted with a cupboard for storing food, also lighted and ventilated by a separate window. The scullery adjoining the living-room should be 10 feet by 7½ feet; and there should be, if possible, a well-lighted, cool and dry pantry with an entrance from the scullery. The bed-rooms for adults should have at least 80 feet of floor area, and those for children 50 feet: all the rooms should have fire-places in them. The privy accommodation and places for deposit of refuse are in these houses best placed out of doors. They should be conveniently placed and afford as much privacy as is possible.

Schools.—The Education Department of the Privy Council requires all schoolrooms to have a width from 18 feet to 22 feet, and states, that if the width does not exceed 20 feet, groups of three long desks must be used, but if the width is 22 feet, then dual desks, five rows deep, must be used. Each child or scholar must be allotted 18 inches on the long desks with gangways 18 inches wide between the groups. When the dual desks are used, and which are 40 inches long, then the gangways between them need be only 16 inches. The height of the rooms must be from 12 to 14 feet; these dimensions give an average floor space of 10 square feet and a cubic space of about 125 feet to each child. In infant schools, the floor space demanded is only 8 square feet per child, which, with rooms of the foregoing measurements, gives scarcely 100 cubic feet per head. These standards are decidedly low, and are only permissible if the warming and ventilation arrangements are so complete that the air of the room will be constantly changed without draught or unduly affecting the room temperature. The theoretical requirements for a child in an elementary schoolroom are 400 cubic feet, and for a boy in a large public school, 800 cubic feet as minima; such amounts will, however, seldom if ever be obtained.

The best means for heating large schoolrooms is by steam or hot-water pipes connected with some central apparatus in the basement.

The lighting of schoolrooms is of great importance. The window area should not be less than one-tenth of the floor area, and may with advantage be made quite one-sixth. Every window should be carried up to the ceiling and be made to open from the top. They should be so placed as to permit of light being received direct from the sky into the room. Roof lighting where practicable is the very best, but failing this, opposite windows facing east and west are to be recommended, since in rooms so arranged there is during school hours no direct sunlight for the greater part of the year. Should circumstances permit, windows may be made in the north wall also, as, excluding sunshine, there can never be too much light. If this is not possible, the windows should be so arranged as to admit the light on the left side of the pupils. For artificial lighting, electric lights or the incandescent gas light is preferable to oil or gas, not only on account of the greater purity and intensity of the light, but even more from the absence of heat and of the products of combustion which add so much to the deterioration of the air.

The size and position of school desks and seats are closely connected with lighting and its influence on the eyesight. The height of the desk above the bench should be such that, when the child is sitting down, he can place both his forearms comfortably on the desk, without raising or depressing his shoulders; the height of the desk above the floor or surface on which the foot rests should correspond with the length of the child's leg from knee to heel. When the child is sitting down, his legs should not dangle in the air, nor should his knees be elevated above the bench. The desk should slope gently; the slope should not exceed an angle of 20°, or a difference between the upper and lower edge of the desk of about 3 inches vertically. The seat should be from 10 to 12 inches wide and hollowed out towards the back to the depth of an inch. Every seat should have a back to support the sitter, hollowed in such a way that the upper part of it may fit the concavity of the back.

The following table gives the measurements of the "Hygienic" desk devised by Priestley Smith and which completely fulfils all the above conditions.

Height of Scholars.	No. 1. 3 ft. 6 in.–4 ft.	No. 2. 4 ft.–4 ft. 6 in.	No. 3. 4 ft. 6 in.–5 ft.	No. 4. 5 ft.–5 ft. 6 in.
Height of seat from floor,	13 ins.	14½ ins.	16 ins.	18 ins.
Breadth of seat,	10 ,,	11 ,,	12 ,,	13 ,,
Height of seat to edge of desk,	8 ,,	8¾ ,,	9½ ,,	10½ ,,
Height of seat to top of back,	20 ,,	22 ,,	24 ,,	26½ ,,
"Overhang" of desk,	1 ,,	1 ,,	1½ ,,	1½ ,,
Play of desk, . .	4½ ,,	4½ ,,	6 ,,	6 ,,
Breadth of desk (front to back), .	15 ,,	15 ,,	17 ,,	17 ,,

As regards school dormitories, the usual width of the room in the Poor-Law schools is 18 feet, each bed having a minimum of 3 feet 9 inches of wall space, 36 feet of floor area; and 360 cubic feet of space. If the room is only 15 feet wide, the wall space is increased to 4 feet. There is reason to believe that very few private schools, even those of the better class, afford more than 300 cubic feet of space per head in their dormitories, an allowance which is quite inadequate. Dukes advocates for this climate 800 cubic feet of space with some 70 square feet of floor area for each child in all school dormitories, and certainly the amount of ventilation necessary to keep a smaller space wholesome would be found almost intolerable in cold weather.

The system of closed cubicles adopted in some of the large public schools is to be condemned on sanitary grounds; neither should dormitories be used as places to study in during the day. The ventilation of dormitories should be carefully seen to; where gas is used for lighting, means should be adopted to carry off the products of combustion, so as not to deteriorate the air: on no account should it be used for heating purposes.

In school lavatories, supervision needs to be exercised to see that all children wash daily, and that no two of them use the same water. Each child should have a separate towel, and the use of roller towels forbidden. The regulations of the Local Government Board lay down that bathing arrangements in the Poor-Law schools must admit of every child being bathed at least once a week in winter and twice a week in summer, and certainly in other schools the bathing facilities ought not to be less.

The amount of closet accommodation for schools is of importance; it should be at least 15 per cent. for girls, and 10 per cent. for boys with in addition 5 per cent. of urinals. The closets should be placed out of doors at a convenient distance and well lighted. The kind best adapted for schools is the trough or flush closet. Several schools have tried the dry earth system, but with only partial success: it is quite unsuitable for closets for girls for obvious reasons.

In all schools a proper cloak-room should be provided. The result of heaping together a mass of foul garments may be easily imagined; zymotic disease or vermin may be disseminated, and clothes acquire a disagreeable odour.

Examination of Dwellings, &c.—In examining a house to discover the sources of unhealthiness, it is best to begin at the foundation, and to consider first the site and basements, then the living and sleeping rooms (as to size, cubic contents, and number of persons, and condition of walls and floors), ventilation, water-supply, and plans of waste-water and sewage removal, in regular order.

The following memorandum, written by Eassie, shows the general principles on which engineers usually examine a house.

"Sanitary engineers consider that an unusual smell is generally the first evidence of something wrong, and that, traced to its source, the evil is half cured. They inspect first the drainage arrangements. If the basement generally smells offensive, they search for a leaking drain-pipe, *i.e.*, a pipe badly jointed or broken by settlement, and these will often show themselves by a dampness of the paving around. If, upon inquiry, it turns out that rats are often seen, they come to the conclusion that the house drain is in direct communication with the sewer, or some old brick barrel-drain, and therefore examine the traps and lead bends which join the drain-pipes to see if they are gnawed or faulty. If the smell arises from any particular sink or trap, it is plain that there is no ventilation of the drain, and more especially no disconnection between the house and the sewer, or, at least, no trap at the house-drain delivery into the sewer. If a country house be under examination, a smell at the sink will, in nearly every case, be traced to an unventilated cesspool; and, in opening up the drain under the sink, in such a state of things, they will take care that a candle is not brought near, so as to cause an explosion. If the trap is full of foul black water, impregnated with sewer air, they partly account for the smell by the neglect of flushing. If the sink, and kitchen, and scullery wastes are in good order, and the smell is still observable, they search the other cellar rooms, and frequently find an old floor-trap without water, broken and open to the drain. If the smell be ammoniacal in character, they trace the stable-drains and see if they lead into the same pit, and if so, argue a weak pipe on the route, especially if, as in some London mansions, the stable-drains run from the mews at the back, through the house, to the front street sewer."

"Should a bad persistent smell be complained of mostly in the bedroom floor, they seek for an untrapped or defective closet, a burst soil-pipe, a bad junction between the lead and the cast-iron portion of the soil-pipe behind the casings, &c., or an improper connection with the drain below. They will examine how the soil-pipe is jointed there, and, if the joint be inside the house, will carefully attend to it. They will also remove the closet framing, and ascertain if any filth has overflowed and saturated the flooring, or if the safe underneath the apparatus be full of any liquid. If the smell be only occasional, they conclude that it has arisen when the closet handle has been lifted in ordinary use or to empty slops, and satisfy themselves that the soil-pipe is unventilated. They, moreover, examine the bath and lavatory waste-pipes, if they are untrapped, and, if trapped by a sigmoidal bend, whether the trapping water is not always withdrawn owing to the siphon action in the full-running pipe. They will trace all these water-pipes down to the sewer, ascertain if they wrongly enter the soil-pipe, the closet-trap, or a rain-water pipe in connection with the sewer."

"If the smell be perceived for the most part in the attics, and, as they consider, scarcely attributable to any of the foregoing evils, they will see whether or not the rain-water pipes, which terminate in the gutters, are solely acting as drain ventilators, and blowing into the dormer windows. They will also examine the cisterns of rain-water, if there be any in the other portions of the attics, as very often they are full of putridity."

"A slight escape of impure air from the drains may be difficult to detect, and the smell may be attributed to want of ventilation, or a complication of matters may arise from a slight escape of gas. Neither are all dangerous smells of a foul nature, as there is a close sweet smell which is even worse. Should the drains and doubtful places have been previously treated by the inmates to strongly smelling disinfectants, or the vermin killed by poison, the inspectors of nuisances will find it difficult to separate the smells. In such a case, however, they will examine the state of the ground under the basement flooring, and feel certain that there are no disused cesspools, or any sewage saturation *of any sort.* They will also ascertain if there be any stoppage in the drain-pipes, by taking up a yard trap in the line of the drain course, and noting the reappearance of the lime-water which they had thrown down the sinks. And invariably, after effecting a cure for any evil which has been discovered, they will leave the traps cleaned out and the drains well flushed."

"A thoroughly drained house has always a disconnection chamber placed between the house drain and the sewer or other outfall. This chamber is formed of a raking siphon, and about two feet of open channel pipe, built around by brickwork and covered by an iron man-hole. Fresh air is taken into this chamber by an open grating in the man-hole, or by an underground pipe, and the air thus constantly taken into the chamber courses along inside the drain, and is as continuously discharged at the ventilated continuations of the soil-pipes, which are left untrapped at the foot, or at special ventilating pipes at each end of the drain. This air-current in the drain prevents all stagnation and smell."

"When a house is undergoing examination, it is wise to test for lighting-gas leakages, and there is only one scientific method of doing so, which is as follows:—Every burner is plugged up save one, and to that is attached a tube in connection with an air force-pump and gauge—the meter having been previously disconnected. Air is then pumped into the whole system of pipes, and the stop-cock turned, and if, after working the pump for some time, and stopping it, the gauge shows no signs of sinking, the pipes may be taken as in safe condition; but if the mercury in the gauge falls, owing to the escape of air from the gas-tubes, there is a leak in them, which is discoverable by pouring a little ether into the pipe close by the gauge, and recommencing pumping. Very minute holes can be detected by lathering the pipes with soap and water, and making use of the pump to create soap bubbles."

"Besides the drainage, they will, especially if they detect a bad and dank smell, see if it arises from the want of a damp-proof course or of a dry area, see if there be a wet soil under the basement floor, a faulty pipe inside the wall, an unsound leaden gutter on the top of the wall, or an overflowing box-gutter in the roof, a leaky slatage, a porous wall, a wall too thin, and so on."

"They will also keep an eye upon the condition of the ventilating arrangements, and whether the evils complained of are not mainly due to defects there. The immediate surroundings of the house will also be noted, and any nuisances estimated."

"Sanitary inspectors, whilst examining into the condition of the drains, always examine the water cisterns at the same time, and discover whether the cistern which yields the drinking water supplies as well the flushing water of the closets. They will also ascertain if the overflow pipe of the cistern, or of a separate drinking-water cistern, passes directly into the drain."

"If the overflow pipe be siphon-trapped and the water rarely changed in the trap, or only when the ball-cock is out of order, they will point out the fallacy of such trapping, and, speaking of traps generally, they will look suspiciously on every one of them, endeavour to render them supererogatory by a thorough ventilation and disconnection of the drains."

Hospitals.—The term "hospital" includes a great variety of institutions having for their object the treatment and care of the sick. These institutions may be divided into two main sections: (1) general hospitals, and (2) special hospitals.

General hospitals will include all the hospitals which receive all kinds of medical and surgical diseases except infectious fevers and chronic incurable and mental diseases. They include county infirmaries and the large and increasing class of buildings called cottage hospitals and the infirmaries built and administered under the Poor-Law system.

Special hospitals include fever and small-pox, lying-in, consumption, children, incurable and chronic, convalescent, sea-bathing, eye, ear, throat, skin and cancer hospitals. This group of hospitals can be further and conveniently divided into (*a*) those not for infectious diseases, and (*b*) those for infectious diseases.

All that has been said in respect of site, surroundings, and construction of houses and schools applies with still greater force to hospitals. As charitable institutions, existing for the purpose of affording medical and surgical aid to the sick poor, hospitals, on economical grounds, have largely to be so constructed that the patients may be grouped together in general wards. It is this aggregation of large numbers of sick or diseased persons under one building that constitutes the most important factor in hospital hygiene. It has long been known that overcrowding in the wards of hospitals is productive of the worst results, particularly in surgical wards, where the neglect of proper sanitary measures produces the class of diseases known as "septic," of which well-known forms are erysipelas and blood-poisoning. Bearing this fact in mind, we are able to understand that the chief conditions to be avoided in all hospitals are: (1) insufficiency of cubic space; (2) inefficient ventilation; (3) improper arrangements for the removal of excreta, refuse, soiled linen, dressings, poultices, &c.; (4) faulty arrangements of the buildings.

General hospitals should always be placed within a reasonable distance of the population whose needs they serve. This essential feature naturally raises a difficulty as to site, especially in the large towns. The importance of a free air space round about a hospital cannot be overestimated, and, as illustrating the value attached abroad to this condition, the following table by Gordon Smith is both suggestive and interesting:—

Name of Hospital.	Approximate area of site per bed, in square feet.
Friedrichshain (Berlin),	1713
Tempelhof ,,	1308
Moabit ,,	1144
University (Halle), .	1575
University (Heidelberg),	1070
Bourges (France),	1600
St Eloi (Montpelier),	1615
St Denis (France),	1685
Antwerp (Belgium),	1126
John Hopkins (Baltimore),	1679
St Thomas's (London),	660
St George's ,,	166
Middlesex ,, .	273
Great Northern Central (London),	293

The remarkable disparity of the approximate area of the site per bed between some of the Continental and English hospitals is at once obvious, but in several of the institutions in the foregoing list the very large proportion of site area to bed is due to the fact that the ward pavilions are all limited to one story. Owing to the great value of land, this mode of construction can rarely be adopted in this country, more especially in London or the larger provincial towns.

In every hospital of whatever size there must always be :—(*a*) Administration offices; (*b*) wards and their offices; (*c*) operation room, with subsidiary rooms; (*d*) out-patient department; (*e*) mortuary and *post-mortem* room; to these will be added in the case of very large hospitals, (*f*) laundry; (*g*) nurses' home; (*h*) medical school.

The precise disposition of these several parts of the hospital, in relation to each other, of necessity greatly depends on the size of the hospital, and on the shape and area of the site. In Heidelberg, Berne, Baltimore and several other continental hospitals each of these departments has been placed in an absolutely separate building, and in some cases (Baltimore) unconnected by even covered ways. The drawbacks to this mode of arrangement are: (1) the great extent of land necessarily occupied; (2) the greater proportional cost of both land and buildings as well as of administration. The value of a sufficiency of open space about a hospital is undoubtedly very great, but in cases where the cost of land is so great as it is in London and some provincial towns the absolute necessity for so large an area of site per bed may reasonably be questioned. The chief defect usually met with in the older and in some of the newer hospitals is the absence of effective separation of the wards from the other parts, with due regard to economy of construction. Consequently, it may be stated that the really essential principles which should guide us in constructing a hospital are, briefly: (1) an avoidance of all intimate connection between the wards and the administration buildings; (2) separation of medical from surgical wards; (3) complete atmospheric disconnection between the wards on the one hand, and the mortuary, laundry, and out-patient department on the other.

To secure these results, the most common plan now is to build hospitals upon what is called the pavilion system. This system is merely the arranging, on a plot of ground, of a series of one, two or more story buildings, called pavilions, and connecting them together by corridors or covered ways. The individual pavilions or blocks of buildings may be of any shape or size, as, for instance, in the new Great Northern Central Hospital, London, where, although there are both circular and oblong wards, they are all practically isolated from each other and from the rest of the hospital. Care should be taken to see that the various buildings are not so close to each other as to seriously interfere with the free circulation of air, or shut out light. A good rule to adopt is, if of two buildings one is higher than the other, the distance between them must be equal to the height of the higher; if two buildings are of the same height, then the distance must be one and a half times their height.

While no particular hospital can be quoted as an ideal or perfect type of what a hospital should be both in planning and construction, still, as illustrating how the essential principles of the separation of parts can be complied with upon a comparatively small area of site per patient, few existing hospitals afford this object lesson so well as the Great Northern Central of London. The general arrangement of the *administration block* will necessarily vary with the size of the hospital. For a large building the offices will be numerous and the residential part extensive; but the modern custom of housing the nursing staff in a separate building very much reduces the amount of accommodation to be provided in the main administration block. In some modern hospitals, the kitchen offices, with the dormitories for servants, are placed in a separate block, thus still further reducing the main block. Practically, the administration block of most hospitals comprises the secretary's office, board-room, residences for medical staff, matron and secretary, steward's office, storerooms, kitchen offices, and servants' dormitories. To these may be added a consultation room for the professional staff and an office for the matron. The kitchen offices may be advantageously placed on the top floor, and the stores in the basement, with communication between the two by means of a lift and speaking-tube. Separate dining-rooms should be provided for male and female servants.

Wards.—The ward of a hospital may be regarded as the central unit of hospital construction. The buildings in which they are placed should be detached, on the pavilion system, and so disposed as to obtain the greatest amount of air and light. With detached buildings the size of a hospital is dependent merely on the facility of administration.

There can be no doubt that the necessity for an unlimited supply of air is the cardinal consideration in the erection of hospitals, and, in fact, must govern the construction of the buildings. For many diseases, especially the acute, the merest hovels with plenty of air are better than the most costly hospitals without it. It is ill-judged humanity to overcrowd febrile patients into a building, merely because it is called a hospital, when the very fact of the overcrowding lessens or even destroys its usefulness.

In order to keep the air in a hospital pure, it is necessary to fix some standard for the minimum cubic space required by each sick person, and to provide for a change of atmosphere sufficient to maintain health, but not so frequent as to cause draughts. It may be laid down as a good rule that the number of patients under one roof or in any one pavilion should not exceed 100 to 120; for surgical cases, 80 to 100 would be better.

As a general rule, it may be said that large wards are more readily ventilated, warmed and managed than small ones. The most general form of hospital wards is rectangular; but in a few hospitals they are circular; and in the John Hopkins Hospital, Baltimore, there are octagonal wards. The dimensions of wards are dependent upon the number of patients to be accommodated and the amount of cubic space to be allotted to each. Rectangular wards vary from 24 to 30 feet in width, 13 to 14 feet in height, and from 30 to over 100 feet in length. Each patient should have from 100 to 120 square feet of floor area, and from 1500 to 2000 cubic feet of air space. For fever, severe surgical or lying-in cases, the requirements are greater, being about 3000 cubic feet of air space and 140 square feet of floor area. Experience shows that nursing is best carried out when the number of beds in a ward do not exceed thirty or thirty-two. These beds are best arranged with their heads to the wall and facing into the ward. Each bed should be placed between two windows, or, at most, two beds in between two windows.

Where possible, the ventilation should be natural, *i.e.*, dependent on the movement of the outer air, and on inequalities of weight of the external and internal air. The reason of this is, that a much more efficient ventilation can be obtained at a cheaper cost than by any artificial means. Also, by means of open doors and windows, we can obtain at any moment any amount of ventilation in a special ward, whereas local alterations of this kind are not possible in any artificial system. The amount of air, also, which any artificial system can give cheaply is comparatively limited. The amount of air should be restricted only by the necessity of not allowing its movement to be too perceptible.

Ventilation by windows and fireplaces, assisted by additional inlets and outlets, is the usual system employed in this country. Inlets are made independent of the windows; usually a Sherringham valve is placed near the ceiling, or a Tobin's tube with openings at about 6 feet from the floor level. If the incoming air is too cold this may be warmed by passing it over a steam coil or hot-water pipes. It may further be filtered and washed by passing it through moist canvas screens as carried out at the New General Hospital in Birmingham.

Windows are best placed opposite one another, and should extend from 3 feet above the floor to within 6 inches of the ceiling; the upper part may be so made as to fall inwards and form a hopper ventilator. They should all be capable of being opened at their upper parts. One square foot of window area may be provided for every 80 cubic feet of space in the ward.

With an open fireplace in a ward, the chimney acts as an extracting shaft if a fire is kept burning, and for this reason it should be placed in the centre of a ward; it also distributes thence its heat more equably. As additional outlets, vertical shafts should be carried from the room to above the roof; these are best made of galvanised iron, and may be fitted at the top with a Boyle's ventilating cowl or some similar contrivance: they should be perfectly straight and vertical, any bends only cause friction. They should be of such a size as will ensure a moderate current of air through them. The movement of air in the shaft will depend on the movement of the external air, but will rarely be less than 3 or 4 feet per second. These shafts should never exceed 12 square inches in area. With proper inlets for air, these shafts will afford continuous and adequate ventilation, and may be supplemented as occasion requires by opening the windows. With a proper system of ventilation in which large masses of cold air are continually replacing a large volume of heated air, a proper system of warming the wards is essential. The open fire is not sufficient for this purpose, and this has to be supplemented by some other method. High-pressure hot-water pipes or low-pressure steam pipes carried round the outer walls of the ward is the most convenient arrangement. Sometimes pipes of different dimensions are used, so that each pipe may be turned on separately, or used in combination with another: this plan allows of the temperature of the wards being regulated to any degree of heat; it may be so arranged that the incoming air may be warmed by passing over some branch of these steam pipes, and this would prevent the feeling of draught from the cold air entering through the open inlets.

In some hospitals, as the Eppendorf Hospital at Hamburg, steam pipes are placed beneath the floor: in such an arrangement, which is generally applied to a building of one story, the floor is laid with "terazzo" (pieces of marble laid in cement); this plan is inadmissible with wooden floors; under the flooring are a series of channels 2 feet 6 inches wide, in each of which runs a steam pipe, supported on iron rails. The steam is supplied by a boiler, each pavilion being provided with its own boiler. In addition in each ward are two steam radiators which are connected by tubes with the outer air.

This system of heating the floors of wards is generally adopted on the Continent now; it is claimed for it that it has the following advantages: (1) it renders possible the use of an impervious material for floor surfaces; (2) that the greatest warmth is at the part needed, that is, nearest the feet; and (3) the air being constantly circulating, the system materially assists ventilation. In one-story buildings, in place of outlet shafts as described above, ridge ventilation is usually resorted to: the best form is a "roof lantern" running about two-thirds the length of the ward.

The position of water-closets and sinks is a matter for careful consideration. The most complete severance of all atmospheric connection between the ward and the closets should be aimed at, and this is best attained when the closets are entered from an intervening lobby or from the open air. In some of the most recently built hospitals the form of the intervening lobby is a sort of covered bridge, the object being to give as free play as possible to the air, so as to prevent stagnation in the vicinity of the ward. The removal of excreta must be by water, except in the tropics, where this plan is not always available. In hospitals, nothing else can be depended upon, as regards certainty and rapidity. The best arrangement for closets is not the handle and plug, which very feeble patients will not lift; but a bell-pull wire or chain connected with a water-waste preventer that has a siphon action; a very short pull of the chain is sufficient to set the siphon acting and ensure proper flushing by the most careless persons. This plan is better than the self-acting spring seat, which is not always easily depressed by a thin patient. The number of water-closets required may usually be reckoned as one for every twelve beds. In close proximity to the closets should be a separate space, enclosed for a slop sink, and also for keeping bed pans, &c. It should be provided with water for washing these vessels. The place should have ample light and preferably be provided with a glass panel in the door, so as always to be under inspection. It should be ventilated direct into the outer air.

The floors of hospital wards should, if possible, be fire-proof. Such a floor may be constructed of iron beams embedded in cement, on which is laid a solid and impervious floor surface. Solid oak or teak parquet laid on the surface of the cement is the best arrangement, but is expensive. Tongued floors of the same wood, with the intervening spaces filled in with white lead or marine glue, forms an excellent floor and is cheaper. Such floors, if properly laid and of well-seasoned wood, when paraffined, form a practically impervious solid surface. The paraffin treatment of floor surfaces is as follows:—The paraffin is melted and then poured on the floor, and ironed into it with a box-iron, heated from the interior by burning charcoal; it penetrates about a quarter of an inch into the wood. The excess of paraffin is scraped off, and the floor brushed with a hard brush; a little paraffin in turpentine is then put on and the flooring is good for years.

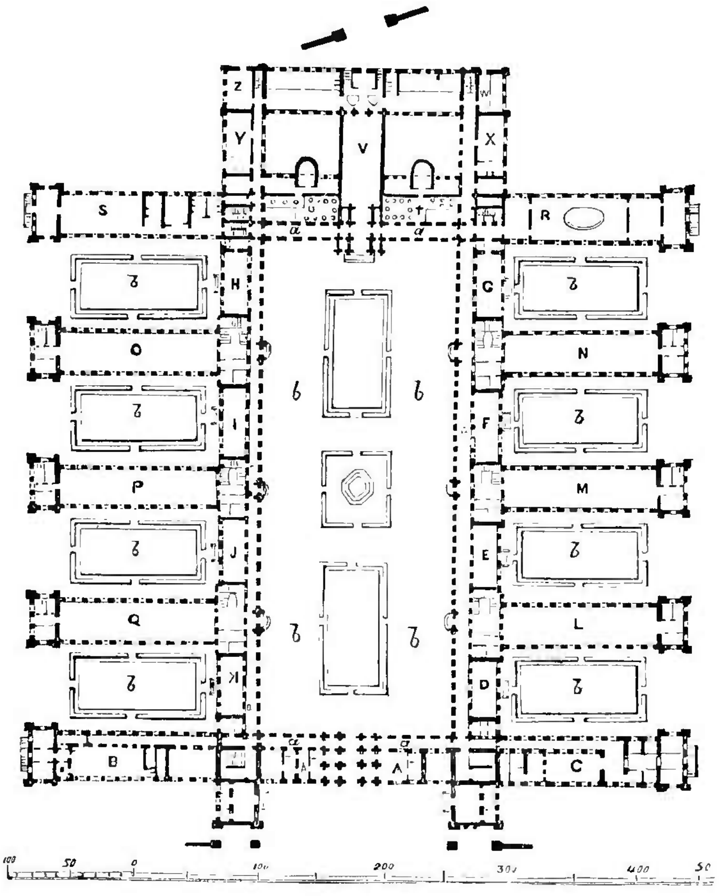


Fig. 66.

The material best adapted for the wall surfaces of a ward is perhaps one of the most difficult problems in hospital construction. Various means have been taken to secure a truly impervious surface, and Parian cement was supposed to fulfil the necessary requirements. In practice, however, it was found to be anything but impervious, and experiments made show it to be almost as absorbent as ordinary plaster. The best material is, perhaps, fine plaster, which can be washed as often as desired, and colour-washed with caustic lime. To facilitate cleaning, and to prevent stagnation of air, it is advisable to round the angles formed at the junction of the wall with the ceiling and wall with floor and the vertical angles of the walls.

The various forms of wards which have been adopted in hospitals are connected with the period in which the hospital was built. Since the pavilion system has become that now almost universally adopted, cross ventilated single wards is the form generally used. In it the windows face each other at equal distances on each side of the ward, while the beds are arranged in two rows. The Lariboisière Hospital at Paris (fig. 66), the Herbert Hospital at Woolwich (fig. 67), and the Cambridge Hospital at Aldershot are examples of this class on a large scale.

Circular wards for hospitals were first advocated in this country by the late Professor Marshall, F.R.S., the advantages claimed for them being: (1) freedom of frontage to all points of the compass, and consequently greater accessibility to both light and air; (2) greater area within a given length of wall; (3) greater facilities for administration and cleanliness. Circular wards now exist both in this country and on the Continent, notably at Antwerp, Gravesend, Burnley, Liverpool, and Greenwich. The differences between one circular ward and another lie mainly in the mode of attachment to the central or main building and in the treatment of the central part. In some the rooms on either side of the corridor of approach abut on the circle, while in others the attachment is by a corridor only. At Burnley a staircase to the roof occupies the central part, while at Liverpool and Greenwich the central portion is occupied by stoves with smoke and ventilating shafts. At the John Hopkins Hospital at Baltimore two octagonal wards are conveniently arranged so as to allow free access of air and light to the adjoining pavilions; it was also found that if the ordinary rectangular ward was selected for the site, it would have come too close to the nurses' home.

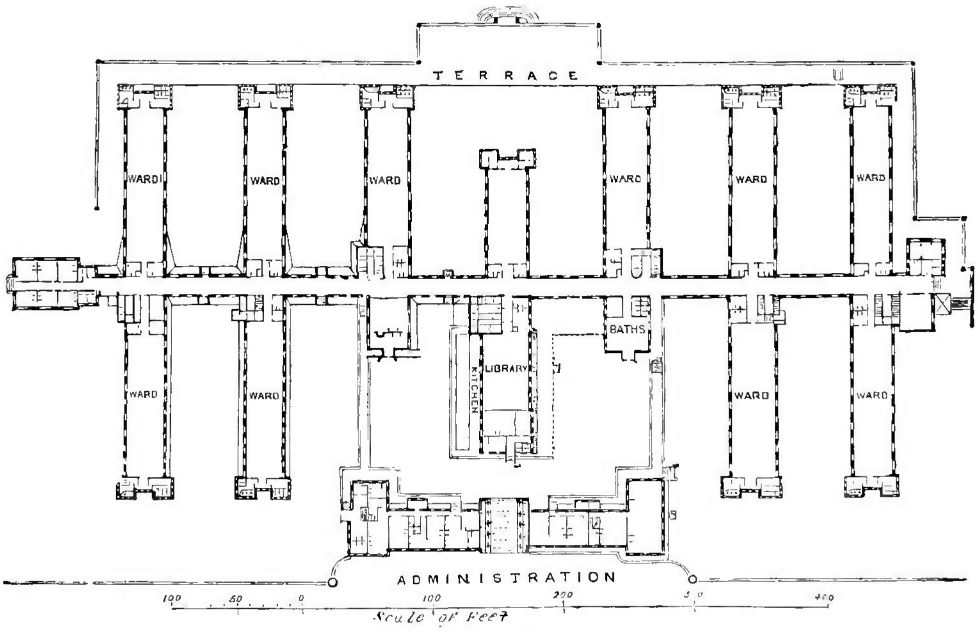


Fig. 67.

Bath-rooms and lavatories are generally placed for the purposes of convenience and economy with the water-closets in the projecting wings. The same necessity does not, however, exist for cutting them off from the ward by an intervening lobby. The floor of the bath-room should be of impervious material, preferably that called "mischiati." This is formed of cubes of marble laid close together, but without any attempt at regularity of pattern; a lattice wooden standing-board should be placed over it. The bath-room and lavatory should be heated by hot-water pipes. Lavatory basins should be provided in the proportion of about one to every six patients.

Ward sculleries are usually attached to each ward, where the plates, &c., used by the patients are washed, and where simple articles of food are cooked. It should be provided with a small cooking range. A sink with hot and cold water laid on is also necessary.

The nurses' room is generally placed at the end of the ward, but not communicating directly into it; it has, however, usually a small window looking into the ward. It was formerly used as a combined sitting-room and bed-room. Under the modern system of nursing, where the duties are assigned for regular hours and where nurses are relieved in turn, there is no necessity for their sleeping near the wards, nor is it advisable that they should do so. This room can hardly be considered absolutely necessary in a modern well ordered hospital.

Operating Room.—In all hospitals where surgical cases are received, a special room must be set apart where operations are performed. It must be within easy access of the wards, yet completely severed from aërial contact with them: neither must there be any connection with the kitchen, laundry, or mortuary. Its best position is in a separate wing connected to the main corridor by an intercepting lobby and so situated with relation to adjoining buildings that it is not overshadowed or overlooked by them. It should be so placed as to have free access of light, preferably from the north. In its construction everything of an absorbent nature should as far as possible be eliminated.

The floor is best made of "mischiati" mosaic laid on concrete, and may be finished with a slight fall to the external wall where an iron pipe will carry away the water used for washing purposes: the walls up to a height of seven feet are best lined with marble, above this they may be finished with fine plaster and cement, which, with the ceiling, should be painted and varnished. The tops of sinks, and basins, and the shelves should be made of glass, which is not only impervious but enables dust or dirt to be easily seen. The windows should be made flush with the wall and made to open for the purposes of ventilation: they should be glazed with plate glass and be very large. The room should be heated with hot-water coils. Both hot and cold water should be supplied for the basins and cold water for the sink. Fresh-air inlets should be provided, and in some cases it may be advisable to filter the incoming air through cotton wool. Outlet shafts with an opening into them near the floor of the room should also be provided. In large hospitals it is desirable to provide also a room for the administration of anæsthetics.

The *Out-patient department* should be on one floor only, and entirely detached from the main buildings of a hospital. It should consist of a spacious and well-ventilated waiting hall; a sufficient number of consulting rooms readily accessible from the waiting room; a dispensary with small waiting room attached, so placed that patients do not have to re-enter the main waiting hall after they leave the consulting room; water-closets and lavatories for both males and females.

The *Mortuary* should be a detached building and single story where possible. In the case of a crowded site, it may be conveniently placed at the top of a building, communication thereto being made by an outside staircase and lift. The mortuary should include, besides the room where several dead bodies may be placed at one time, a small room where one body can be separately viewed by friends.

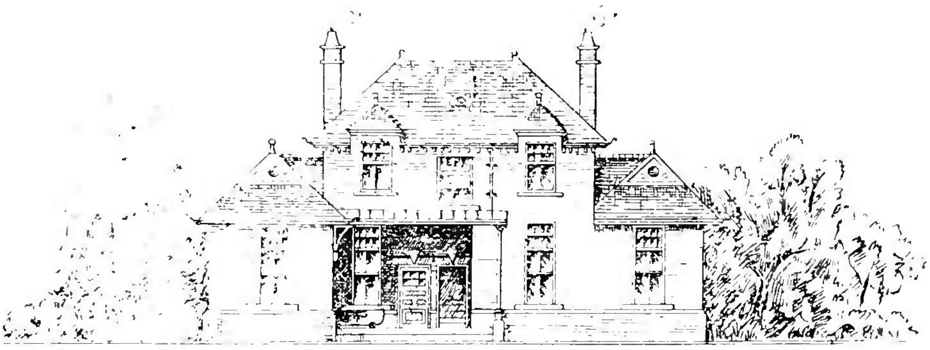
Attached to the dead-house, but having no communication with the inspection room, should be a *post-mortem* room. This must be top-lighted, with a floor of some impervious material, made to fall to a channel under the table. The walls should be lined with glazed bricks or tiles, the table should be of marble on an iron frame, and the shelves should be of the same material. A large and deep sink must be provided, and the waste pipe therefrom treated in the same way as a soil-pipe. An efficient trap must be placed immediately under the sink, and the pipe taken out through the wall into a vertical pipe, which must be carried up in full diameter as a ventilator.

Non-infectious Special Hospitals.—Although in all matters of structural hygiene these hospitals require the same care as the ordinary hospitals, still, in addition, they present some special needs. Thus, ophthalmic hospitals need the removal of sharp angles in wards against which blind or partially blind persons may accidentally injure themselves, and the provision of handrails on both sides of staircases. Open fireplaces are a mistake in these hospitals, as often the flickering flame of a fire is both trying and injurious to diseased eyes. Consumption hospitals require special warming and ventilation arrangements for their inmates, as well as liberal provision for those able to get up and move about. The most prominent need in all children's hospitals is an isolation ward, as young children are extremely susceptible to infectious diseases. Convalescent hospitals are more properly homes for those recovering from acute illness, rather than mere hospitals for the sick. In the same way, cancer and incurable hospitals need to conform more to the freedom and independence of home life than to the more rigid arrangements of the institutions for treating acute cases. Lying-in hospitals, from the peculiar nature of the cases they receive, should be constructed with small rooms and not with large wards. Every such hospital should be provided with an isolation ward, absolutely distinct from the rest of the building.

Infectious Disease Hospitals.—These are quite a class by themselves; they may be either permanent or temporary buildings. It is, as a rule, undesirable to select any site for an isolation or infectious hospital which is less than some two acres in extent, and even then regard should be had to the need for extension of hospital buildings, whether for temporary purposes, or owing to increase of population. Moreover, in determining the locality where such a hospital should be placed, the wholesomeness of the site, the character of the approaches, together with the facilities for water-supply and for slop and refuse removal, are matters of primary importance.

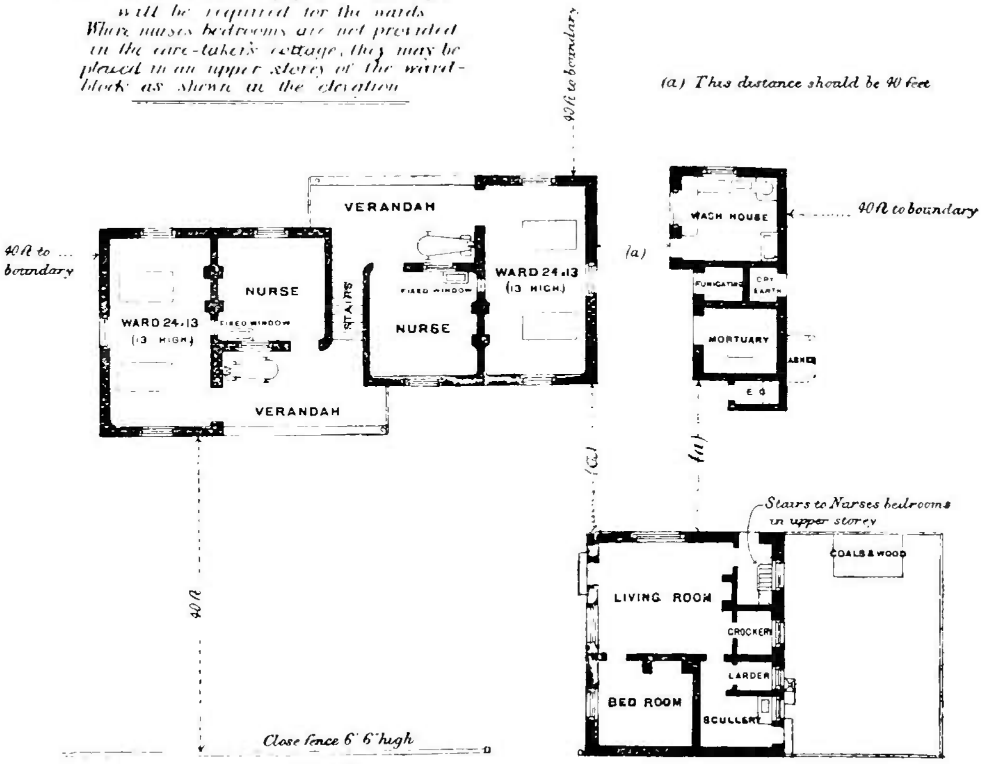
Sites for hospitals designed to receive small-pox require a very much larger space about them than sites for other infectious diseases hospitals. Small-pox hospitals are apt to disseminate small-pox, and their sites should therefore be placed outside towns, and should indeed be sought at places as far distant from any populated neighbourhood as considerations of accessibility permit. The Local Government Board have suggested that, with a view of lessening the risk of infection, a local authority should not contemplate the erection of a small-pox hospital—

PLATE III.



ELEVATION.

N B Moveable baths and Earth Commodes will be required for the wards. Where nurses bedrooms are not provided in the care-taker's cottage, they may be placed in an upper storey of the ward-block as shewn in the elevation



PLAN.

Scale 16 ft to one inch.

1st. On any site where it would have within a quarter of a mile of it as a centre either a hospital, whether for infectious diseases or not, or a workhouse, or any similar establishment, or a population of 150–200 persons.

2ndly. On any site where it would have within half a mile of it as a centre a population of 500–600 persons whether in one or more institutions or in dwelling-houses.

It must also be understood that, even where the above conditions are strictly fulfilled, there may be circumstances under which the erection of a small-pox hospital should not be contemplated. Cases in which there is any considerable collection of inhabitants just beyond the half-mile zone should always call for especial consideration.

It has been suggested that small-pox hospitals may be so constructed as not to be dangerous to neighbouring habitations; and that this can be done by a system of passing through a furnace all outgoing air from infected wards and places. But, thus far, the efforts made in this direction cannot be regarded as having successfully attained the end in view. More promising, however, is the system suggested by Key and Henman, whereby the outgoing air is made to pass through canvas screens, and in so passing is exposed to the action of a disinfectant.

Reference has already been made to the need, in isolation hospitals, of greater cubic space and ventilation. Owing to the remarkable tendency to aërial spread of infection in the diseases taken to infectious hospitals, the communication with the outside world has in them to be kept under the strictest control and each disease isolated separately, and kept, if possible, in separate blocks or buildings, the communication between which should be absolutely forbidden. Each block, besides wards, closets, bath-rooms, and sinks, should have linen, store, and fuel rooms, as well as a nurse's room. The disinfecting chamber, mortuary, and stables for ambulances and horses should also be clearly disconnected from all other parts of the building.

Considerable controversy has taken place as to whether infectious hospitals should be permanent buildings or merely temporary ones. The truth probably lies in the view that all administrative arrangements, and a certain limited accommodation for the infectious sick, should be in permanent buildings, which, existing thus ready to hand in non-epidemic times, can be quickly supplemented by additional wards in either huts or tents within a few days, in case of widespread epidemics. Some means of isolation are needed in every community at all times, and it is a sounder policy to be able to delay and prevent epidemic outbreaks by isolating the first few sporadic cases as they occur, in a small but permanent infectious hospital, than have to grapple with epidemics already in full existence by means of hastily constructed, and often expensive, temporary structures. Many materials have been suggested for the construction of these temporary buildings, more particularly wood, galvanised iron, canvas, and water-proof paper. Although they are comparatively cheap and rapidly erected, temporary hospitals should never be regarded as able to supersede permanent buildings of brick or stone; their true use is to supplement not to supersede. Moreover, they are extremely difficult to ventilate, and to warm in winter or to cool in summer. Their durability is small, and their proper disinfection is almost impossible. Of course they can be burnt when done with; but if epidemics of infectious disease rapidly succeed each other, the renewals of temporary hospital buildings will soon exceed the cost of structures of a more permanent nature. As infectious hospitals, unlike the great bulk of general and special hospitals, are in no sense charitable institutions, but really public buildings provided and supported by rates, the true bearing and merits of the question whether these hospitals should be temporary or permanent buildings is one which intimately concerns the interests of every citizen.

The extent of hospital accommodation which it is necessary or desirable to provide must depend upon the population and other conditions peculiar to the district it has to serve. Whatever may be the amount of accommodation to be provided, the general principles of arrangement will remain the same. In a memorandum on the provision of Isolation Hospital Accommodation by local authorities, the Local Government Board have pointed out that large villages and groups of adjacent villages will commonly require the same sort of provision as towns. "Where good roads and proper arrangements for the conveyance of the sick have been provided, the best arrangement for village populations is by a small building accessible from several villages; otherwise the requisite accommodation for (say) four cases of infectious disease in a village may at times be got in a fairly isolated and otherwise suitable four-room or six-room cottage which has been acquired by the Authority; or by arrangement made beforehand with some trustworthy cottage-holders, not having children, that they should receive and nurse, on occasion, patients requiring such accommodation."

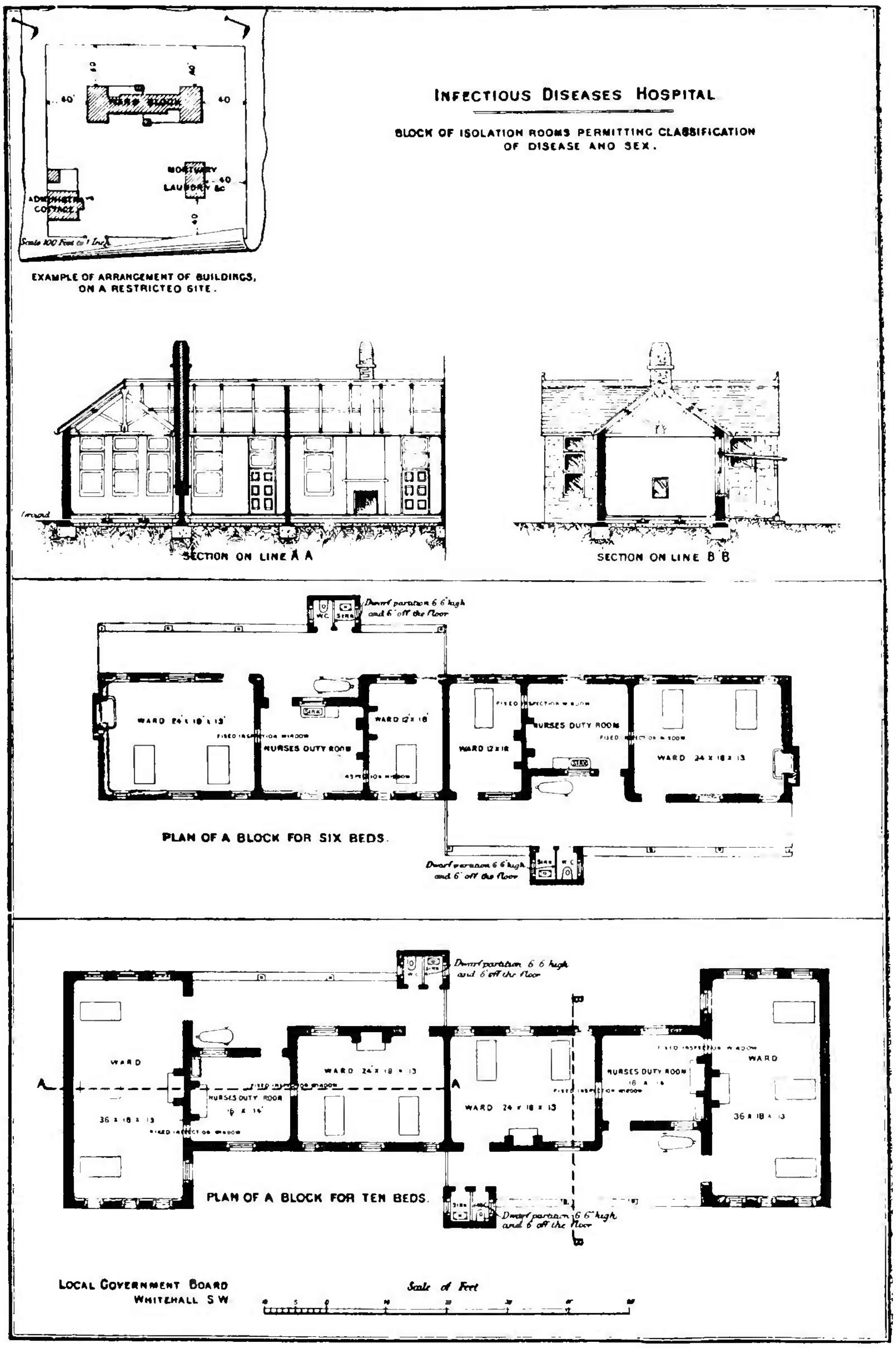
"In towns, hospital accommodation for infectious diseases is wanted more constantly, as well as in larger amount than in villages; and in towns there is greater probability that room will be wanted at the same time for two or more infectious diseases which have to be treated separately. The permanent provision to be made in a town should consist of not less than four rooms in two separate pairs; each pair to receive the sufferers from one infectious disease, men and women of course separately. The number of cases for which permanent provision should be made must depend upon various considerations, among which the size and the growth of the town, the housing and habits of its population, and he traffic of the town with other places, are the most important. There is no fixed standard, therefore, by which the standing hospital requirements proper for a town can be measured. Furthermore, it is to be remembered that occasions will arise (as where infection is brought into several parts of a town at one time) when isolation provision, in excess of that commonly sufficient for the town, will become needful."

"For a town the hospital provision ought to consist of wards in one or more permanent buildings, with space enough for the erection of other wards, temporary or permanent. Considerations of ultimate economy make it wise to have permanent buildings sufficient for somewhat more than the average necessities of the place, so that recourse to temporary extensions may less often be necessary. In any case it is well to make the administrative offices somewhat in excess of the wants of the permanent wards; because thus, at little additional first cost, they will be ready to serve, when occasion comes, for the wants of temporary extensions."

An isolation or infectious disease hospital, of whatever size, should consist of (1) a detached administrative block; (2) wards, with their offices in separate pavilions, or blocks, or cottages, at safe distances, providing for the separation of the sexes, and for patients suffering from different diseases; (3) outhouses, such as laundry, stores, disinfecting apparatus, mortuary, &c.

The administrative block should minister to the whole hospital, except perhaps when small-pox is isolated. In these cases, nurses attending small-pox should be accommodated in rooms apart from the general administrative building. If obliged to sleep in the administrative building, they should

PLATE IV


INFECTIOUS DISEASES HOSPITAL
BLOCK OF ISOLATION ROOMS PERMITTING CLASSIFICATION OF DISEASE AND SEX.
WARD BLOCK
40'
40
MORTUARY
LAUNDRY &c
ADMINISTRATIVE COTTAGE
Scale 100 Feet to 1 Inch
EXAMPLE OF ARRANGEMENT OF BUILDINGS, ON A RESTRICTED SITE.
Ground
SECTION ON LINE A A
SECTION ON LINE B B
Dwarf partition 6 6" high and 6" off the floor
W.C.
SINK
WARD 24' x 18' x 13'
FIXED INSPECTION WINDOW
NURSES DUTY ROOM
WARD 12 x 18
WARD 12 x 18
WARD 24 x 18 x 13
PLAN OF A BLOCK FOR SIX BEDS.
WARD
36 x 18 x 13
NURSES DUTY ROOM
16 x 14
WARD 24 x 18 x 13
A
PLAN OF A BLOCK FOR TEN BEDS.
LOCAL GOVERNMENT BOARD
WHITEHALL S.W.
Scale of Feet
10
5
0
10
20
30
40
50

change their clothes and take a bath on going off duty. No food, clothing, earthenware, furniture, &c., should get mixed in the work of administration. The block or ward used for one disease should be at least 40 feet from the ward occupied by patients suffering from any other disease. When a patient is admitted, he should be sent into the receiving room of the block set apart for his disease. If there is doubt as to the nature of the disease, he should be sent to an isolation ward until a diagnosis can be definitely made. If there is no doubt about the case, it should be sent to the ward intended for it. The patient, if able to bear it, should be undressed in the bath-room, bathed, provided with a clean night-dress, and put to bed. His own clothes should be put immediately into the disinfecting chamber. If necessary, they should be destroyed. All bed-clothes, linen, towels, &c., in an infectious hospital should be marked separately for each disease, stored in its special department, and on no account used in any other part of the building. Care should be taken to prevent clothes becoming infected in the laundry. The clothes from each department should be thoroughly disinfected before being taken to the laundry. When dry, the clothes should at once be brought back and stored in their special department.

All spoons, knives, forks, feeding-cups, glass and earthenware should be of different patterns for each disease, or differently marked for each department, and washed and stored there. The main articles of food should be conveyed to each block in utensils belonging to the administrative block by a person not engaged in any of the wards, and then transferred into utensils belonging to that block. Nurses should keep to one disease exclusively when on duty.

The simplest type of isolation or infectious disease hospital is that shown in Plate III., suggested by the Local Government Board. It must comprise three separate buildings: (1) the administrative block, comprising accommodation for a caretaker, kitchen offices, and two or three rooms for nurses; or it may be simply a cottage containing a living-room and two or three bedrooms for the caretaker, with the kitchen offices; (2) a block for patients; and (3) the wash-house, mortuary, and disinfection chamber block.

The ward block shown on the same plan provides accommodation for two patients of each sex, with two nurses' ante-rooms on the ground floor, and their bed-rooms above. The third block contains a mortuary, wash-house, and small disinfecting chamber. It will be obvious that such a hospital provides the smallest possible amount of accommodation, and contemplates the reception of patients suffering from one disease only.

In Plate IV., a rather larger hospital building is shown, the plans and sections providing for six and ten patients. These may be regarded as typical isolation blocks in which patients of each sex, and suffering from two distinct diseases, can be treated. This block is the most important one, and whatever else is omitted this must always be provided. A convenient disposition of buildings upon the site is also indicated on the same sheet.

In Plate V. is shown the plan and section of a small pavilion adapted to receive six male and six female patients suffering from one kind of infectious disease.

"It will be found that in all the plans proper standards of space are observed, namely, not less than 2000 cubic feet of air space, than 144 square feet of floor space, and 12 linear feet of wall space to each bed; and that means are provided for the adequate ventilation and warming of wards, and for securing them from closet emanations and the like. In plan A, earth-closets, in other plans water-closets, are indicated as the means of excrement disposal. The latter are to be regarded as preferable where efficient sewers are available. Places for washing and disinfection, and for a mortuary are indicated. It will be observed that an interval of 40 feet is everywhere interposed between every building used for the reception of infected persons or things and the boundary of the hospital site. This boundary should have a close fence of not less than 6 feet 6 inches in height, and the 40 feet of interval should not afterwards be encroached on by any temporary building or extension of the hospital. In the construction and arrangement of such temporary buildings as may at times be wanted in extension of the permanent hospital, the same principles should be held in view."

In all hospitals for infectious diseases provision must be made to prevent, if possible, the conveyance of infection to the outside world, either by patients on their discharge or by nurses or servants going outside the gates. For patients on their discharge a suite of three rooms communicating with each other should be arranged. The first room should be just sufficiently large for one person to undress in; in this room the patient leaves his or her infected clothing. The second or intermediate room is a bath-room. After bathing, the patient enters the third room, where he puts on a complete suit of clean, or preferably new clothing. Having dressed, he should leave the building by a door leading directly into the open air, and should not again enter any part of the hospital buildings. For the staff, ample bathing accommodation should be provided; and, as far as possible, it should be made a rule that no one employed in the hospital wards should leave the grounds without having previously bathed. It is obvious that such a rule as this cannot be rigidly enforced, but, all the same, the means of complying with it should be provided, and its observance should be encouraged as far as possible.

BIBLIOGRAPHY AND REFERENCES.

BAILEY-DENTON, *A Handbook of House Sanitation*, Lond., 1882. BILLINGS, *Hospital Construction and Management*, New York, 1876; also *Description of the John Hopkins Hospital*, New York, 1890. BURDETT, *Hospitals and Asylums of the World*, Lond., 1891.

DEGEN, *Die Kasernen und Krankenhaüser der Zukunft*, Berlin, 1883.

GALTON, *Healthy Dwellings*, Oxford, 1880; also "Notes on Hospital Construction," *Brit. Med. Journ.*, 1883, ii. p. 422; also *Healthy Hospitals*, Oxford, 1893.

HAGEMEYER, VON, *Das allgemeine Krankenhaus der stadt Berlin im Friedrichshain*, Berlin, 1879. HOOPER, "On Artisans' Dwellings," *Trans. San. Instit.*, vol. xi. p. 201.

LE FORT, *Note sur quelques points de l'hygiene hospitalière en France et en Angleterre*, Paris, 1862.

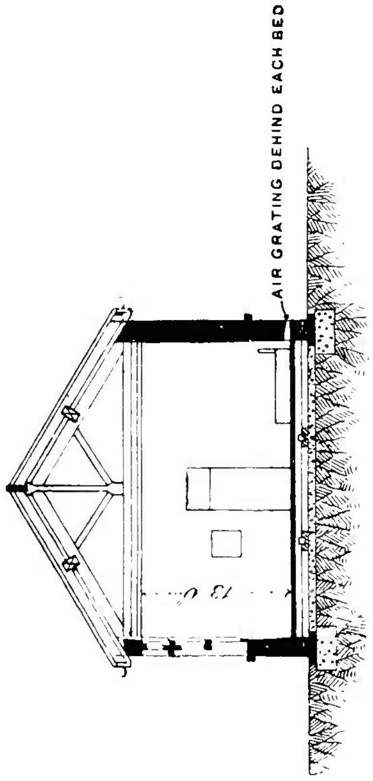
MARSHALL, "Note on the New Hospital at Antwerp, with Remarks on the Advantages of the Circular Ward System," *Brit. Med. Journ.*, 1882, ii. p. 349; also *On the Circular System of Hospital Wards*, Lond., 1878. M'NEIL, *The Prevention of Epidemics and the Construction and Management of Isolation Hospitals*, Lond., 1894. *Memorandum on the Provision of Isolation Hospital Accommodation by Local Authorities*, issued by the Local Government Board, 1892. MOUATT, "On Hospital Construction and Management," *Lancet*, 1883, ii. p. 615.

NIGHTINGALE, MISS, *Notes on Hospitals*, Lond., 1863. POWER, *On the Use and Influence of Hospitals for Infectious Diseases*, Supplement to 10th Report of Med. Off. to Local Government Board, 1882.

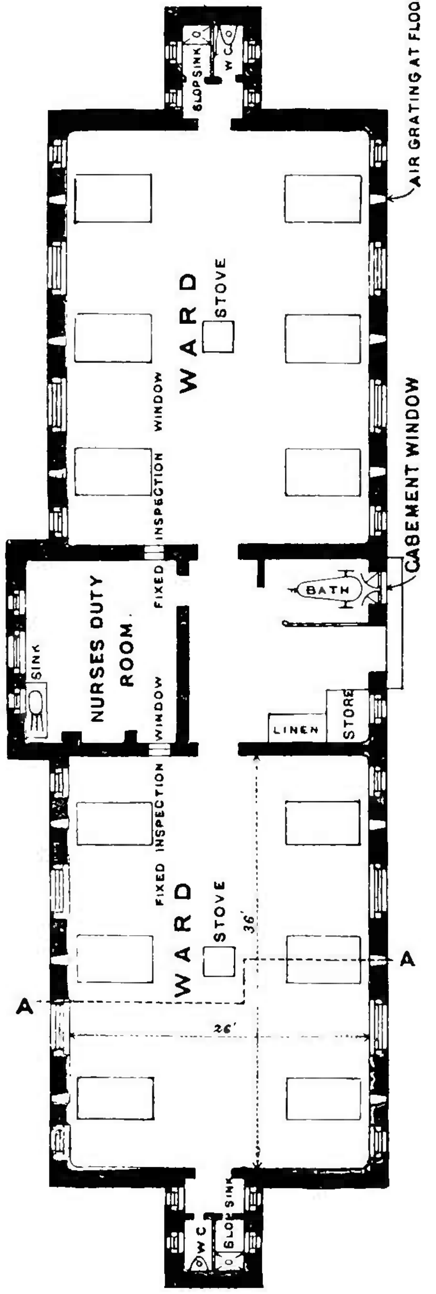
Report of the Small-pox and Fever Hospitals Commission, Lond., 1882; also *Report on Infectious Diseases Hospitals*, issued by Local Government Board, C. 3290, issued 1882, re-issued in 1884.

SMITH (GORDON), "On the Planning and Construction of Hospitals," *Trans. Epid. Soc.*, 1882, ii. p. 142; also "Notes on Modern Hospital Construction," *Practitioner*, June 1888.

PLATE V.



SECTION ON LINE A.A.



Dwarf partition 6'6" high and 6' off the floor

PLAN OF A WARD PAVILION FOR 12 BEDS.

CHAPTER X.

DISPOSAL OF SEWAGE AND REFUSE.

The term "Sewage" is here used in its widest sense, and is meant to include the solid and liquid excreta of men and animals; the refuse from houses (dust, ashes, &c.) and the waste waters from sinks and lavatories; the liquid and solid refuse from stables, cowsheds, and slaughter-houses; the waste waters used for trade purposes, and the sweepings of streets and alleys.

When men live in thinly-populated countries, following, as they will then do, an agricultural or nomad life, they will not experience the consequences of insufficient removal of excreta. The sewage matter returns at once to that great deodoriser, the soil, and, fertilising it, becomes a benefit to man, and not a danger. It is only when men collect in communities that the disposal of sewage becomes a matter literally of life and death, and before it can be settled the utmost skill and energy of a people may be taxed.

The question of the proper mode of disposal of sewage has been somewhat perplexed by not keeping apart two separate considerations. The object of the physician is to remove as quickly as possible all excreta from dwellings, so that neither air, water, nor soil shall be made impure. The agriculturist wishes to obtain from the sewage its fertilising powers. It is not easy to satisfy both parties, but it will probably be conceded that safety is the first thing to be sought, and that profit must come afterwards.

Composition of Sewage.—Sewer water varies very much in its composition, being sometimes very turbid and highly impure; in other cases hardly more impure than water from surface wells. The Rivers Pollution Commissioners gave (1868) the following as the average composition of sewage from towns sewered on the water-closet system and from towns using middens:—

Average Composition of Sewage, in Parts per 100,000.

	Total Solids in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
							Mineral.	Organic.	Total.
Midden towns,	82·4	4·181	1·975	5·435	6·451	11·54	17·81	21·30	39·11
Water-closet towns,	72·2	4·696	2·205	6·703	7·728	10·66	24·18	20·51	44·69

Amount of Solid and Liquid Excreta.—The amount of the bowel and kidney excreta varies in different persons and with different modes of life. On an average, in Europe, the daily solid excreta are about 4 ounces by weight, and the daily liquid excreta 50 ounces by measure for each male adult. Women and children pass rather less. Vegetarians pass more solid excreta than those living on a mixed diet, but this is chiefly owing to the large proportion of water in their food. Taking all ages and both sexes into consideration, we may estimate the daily amount per head of population in Europe at 2$\frac{1}{2}$ ounces of fæcal and 40 ounces of urinary discharge.

The following table gives the average amounts in ounces of fæces and urine passed daily by an adult male (15 to 50 years of age) (Lawes).

	Fresh Excrements.	Dry Substances.	Mineral Matter.	Carbon.	Nitrogen.	Phosphates.
Fæces,	4·17	1·041	0·116	0·443	0·053	0·068
Urine,	46·01	1·735	0·527	0·539	0·478	0·189
Total,	50·18	2·776	0·643	0·982	0·531	0·257

Fresh healthy fæcal matter from persons on mixed diet, unmixed with urine, has an acid reaction, and this it retains for a considerable time; it then becomes alkaline from ammonia. If free from urine it usually decomposes slowly, and in hot weather often dries on the surface and subsequently changes but little for some time. The urine, when unmixed with fæcal matter, also retains its natural acidity for a variable number of days,—sometimes three or four, sometimes eight or ten, or even longer, and then becomes alkaline from ureal decomposition. When the fæces and urine are mixed, the formation of ammonium carbonate from ureal decomposition is much more rapid; the solid excreta seem to have the same sort of action as the bladder mucus, and the mixed excreta become alkaline in twenty-four hours, while the separate excreta are still acid. And in its turn the presence of the urine seems to aid the decomposition of the solid matter, or this may be perhaps from the effect of the liquid, as pure water seems to act almost as rapidly as urine in this respect. Pappenheim states that the absorption of oxygen by the fæces is greatly increased when urine is added.

When the solid excreta and urine are left for two or three weeks, the mixture becomes usually extremely viscid, and this occurs, though to a less extent, when an equal quantity of pure water takes the place of urine. The viscidity is prevented by carbolic acid.

When the solid excreta (unmixed with urine) begin to decompose, they give out very fœtid substances, which are no doubt organic; hydrogen sulphide is seldom detected, at any rate by the common plan of suspending paper soaked in lead solution above the decomposing mass. When heated, a large quantity of gas is disengaged, which is inflammable, and consists in great measure of carburetted hydrogen. When (instead of being dry) urine is present, ammonia and fœtid organic matters are disengaged in large quantity. When water is also present, and if the temperature of the air is not too low, not only organic matters but gases are given out, consisting of light carburetted hydrogen, nitrogen, and carbon dioxide. Hydrogen sulphide can be also disengaged by heat, and is almost always found in the liquid, usually in combination with ammonia, from which it is sometimes liberated and then passes into the air.

The Waste Waters from Houses.—This is a very complex liquid. The kitchen sink waters contain vegetable, animal, and other refuse, and that from baths and wash-houses soap and dirt from the surface of the body and from clothes. These waste waters, when mixed with the drainage from stables and cowsheds and from slaughter-houses, with the urine from public urinals, form the sewage of non-water-closet towns where privies and cesspools are used. The sewage from these waste waters is so impure that there is no object in providing a separate system to deal with human excreta; there is a remarkable similarity between the sewage of midden towns and those in which water-closets are used.

Trade and Manufacturing Refuse.—In manufacturing towns a large proportion of waste is passed into the sewers. These waste waters are of very variable composition, many of them being mixed with the special matters made use of in the different manufacturing processes, as in dye-works, chemical works, papermaking, woollen works, &c.

METHODS OF REMOVAL OF EXCRETA.

While all will agree in the necessity of the immediate removal of excreta from dwellings, the best modes of doing so can hardly be said to be yet settled. The fact is, that several methods of removing sewage are applicable in different circumstances and their relative amounts of utility depend entirely on the condition of the particular place.

The different plans may be conveniently divided into:—

1. The dry method.
2. The water method.

Removal of Excreta by Dry Methods.

The use of sewers and methods of removing excreta by water are in many cases impracticable. Either a fall cannot be obtained; or there is insufficient water; or the severity of the climate freezes the water for months in the year, that removal by its means cannot be attempted. Then either the excreta will accumulate about houses, or must be removed in substance daily or periodically. Even when water is abundant, and sewers can be made, many agriculturists are in favour of the dry system, as giving a more valuable fertilising product; and various plans are in use.

Middens.—In places where no facilities exist for the use of water-closets, recourse has to be had to some dry method of removing excreta from the house. This, in many cases, necessitates such arrangements as middens or privies and pail closets, in which are used ashes, earth, &c. Until recent times, open middens or pits were the almost universal receptacle for the excretal and other waste matters of the habitation, over which was erected some primitive form of privy. The institution of middens or the setting aside of some spot for depositing filth and refuse was no doubt a great advance on depositing everything anywhere.

Unfortunately, middens, objectionable as they are, still exist, in some form or other, in rural districts and in certain towns. In these places it is attempted to minimise the pestilential odours which arise from them by an admixture of ashes, which to a certain extent keeps them dry and delays putrefaction.

The original midden pit was a hole dug in the ground full of rotting and offensive matter and giving rise to offensive gases and liquids, which only too readily polluted both the soil around houses and the wells near them.

Various improvements have from time to time been attempted upon the old midden pit, and where these remain, their existence is subject to certain definite rules and conditions. The general rule now is that for the old midden pit, dug in the ground, should be substituted a small receptacle intervening between the seat of the closet and the floor. The model Bye-laws of the Local Government Board for the construction of privies and middens in new buildings are to the following effect. The midden or privy must be at least 6 feet away from any dwelling and 50 feet away from any well; ready means of access must be provided for the scavenger, so that the contents need not be carried through a dwelling; the privy must be roofed to keep out the rain and provided with ventilating apertures as near the top as possible; that part of the floor which is not under the seat must not be less than 6 inches above the level of the adjoining ground and moreover be flagged or paved with hard tiles having an inclination towards the door of the privy of one half inch to the foot, so that liquids spilt upon it may run down outside and not find their way to the receptacle under the seat; the size and capacity of this receptacle may not exceed 8 cubic feet, by which limitation a weekly removal of its contents is necessitated; the sides and floor of this receptacle must be of some impermeable material, the floor being at least 3 inches above the adjoining ground level; the seat of the privy should be hinged, so as to allow of the ashes being thrown in and the receptacle unconnected with any drain or sewer. Middens constructed and maintained under these conditions, lessens the danger of percolation of filth into the soil or of fouling the wells; while the pollution of air is safeguarded to a great extent by keeping the contents in a dry and inodorous condition. No matter how well conducted and supervised, middens are objectionable. Their success depends on proper scavenging arrangements and efficient sanitary supervision.

Tub and Pail Closets.—These are really nothing but middens having a limited capacity, in which the ash-pit is represented by a movable receptacle, such as a tub or pail, placed under the seat for the removal of the excreta. In this system the filth removal is easier and the air pollution less than when midden contents are removed. The pails, whether of wood or of galvanised iron, should have close fitting lids and be both air and water tight. Tarred oak is the best material for making pails, as they last longer and are easily repaired. The structure of the closet in which the pails are used should be similar to that proposed for middens. The pail or tub should be removed at least once a week and a clean one substituted for it. In order to delay decomposition and to avoid smells, the contents of the pail (fæces and urine) must be kept as dry as possible, and this is effected by the addition of some absorbent substance, such as dry earth, ashes, or charcoal, or the pail may be lined with some absorbent material, such as peat. If the urine and fæces remain without admixture with any such substances, they rapidly undergo decomposition, but in this state they have a higher commercial value as manure than if mixed with ashes, charcoal, or earth.

Various modifications of this system are adopted in various towns. In Nottingham not only ashes but all the other household refuse is added to the pail, while in Leicester and Birmingham the pails only receive excreta. In Manchester the ashes are sifted and only the finer portion is allowed to fall into the pails. In Halifax the Goux system is in use; the pail or tub is lined with some absorbent material, such as peat, or a mixture of tan, saw-dust, and soot, the object being to render the contents drier and less offensive. The material used is pressed firmly to the sides of the pail, by means of a mould, which is afterwards withdrawn, leaving a cavity in the centre for the reception of the excreta. Nothing but fæces and urine should find a place in these pails, as the absorbent capacity of the material is limited: the contents should be removed every two or three days and a fresh pail provided. A separate receptacle is used for ashes, house refuse, &c. The use of sifted coal ashes form very efficient desiccators, but the deodorising effect is very slight. The mixture of coal ashes and excreta usually finds a sale, but the profit is much greater if no ashes are mixed with it. Wood ashes are far more powerful as deodorisers, but it is not easy in this country to have a proper supply.

Charcoal Closets.—There is no better deodoriser than charcoal. Animal charcoal is too expensive, but peat charcoal is cheaper; according to Danchell, 3 ounces of peat charcoal are equal to 1½ ℔ of earth; and this author states that the cost of charcoal for a family of six persons would only be 1s. 6d. per month. A plan has been proposed by Stanford which may obviate the difficulty of price. Stanford proposes to obtain charcoal from sea-weed; the charcoal is cheap, and remarkably useful as a deodoriser. The charcoal itself contains 63 per cent. of carbon, 34 per cent. of ash, and only 2·6 per cent. of water. It has no oxidising effect, and merely acts as a dryer (Corfield). After it has become thoroughly impregnated with fæces and urine, the mixture is recarbonised in a retort, and the carbon can be again used; the distilled products (ammoniacal liquor, containing acetate of lime, tar, gas) are sufficient to pay the cost, and it is said even to give a profit.

The closet used with this carbon is, in principle, similar to Moule's earth closet, with various improvements for more thoroughly mixing the charcoal and sewage.

The advantages claimed by Stanford's process are a complete deodorising effect; the small amount of charcoal required as compared with dry earth (three-fourths less required); the value of the dry manure, or of the distilled products, if the mixture is reburnt; and, in the last case (burning), the complete destruction of all noxious agencies. In using it the mixed charcoal and sewage may be stored for some months without odour in some convenient receptacle outside, but not under the house. The reburning of the mixture can be done in a gas retort, or a special retort is built for the purpose; the charcoal left in the retort is returned to the house.

Earth Closets.—Neither ashes or charcoal have the same beneficent and disintegrating action on the excreta as dry earth.

Since the late Rev. Henry Moule pointed out the powerful deodorising properties of dried earth, many different closets have been proposed.

Moule's earth closet consists of a wooden box, with a receptacle below, and a hopper above, from which dried earth falls on the sewage when the plug is pulled up. The earth is previously dried, half a pound of the dried earth per head daily being the usual allowance. For a single house the earth can be dried over the kitchen fire; but if a village is to be supplied a small shed, fitted with tiles, below which smoke pipes from a small furnace pass, is required. The earth used in the closet is sufficient to deodorise the solid excreta and the portion of the urine passed with them, but the rest of the urine and house water has to be carried off in pipes, and disposed of in some other way. The receptacle is emptied from time to time, and the mixture is stored until it can be applied to land. Its value, however, is not great, as most of the nitrogen disappears in a gaseous form. Indeed, so complete is the disintegration of organic matter that even paper disappears, and the earth after redrying has been used again and again.

The best kinds of earth for the purpose are loamy surface soil, vegetable mould, dry clay or brick earth. Chalk, gravel, or sand are not suitable. Care must be taken that the earth is sifted and dry. If dried in a stove or over a hot floor, the temperature must not be raised sufficiently high to sterilise it. Earth dried in the sun acts most efficiently. Care has to be taken that each particular stool is covered at once with the earth and no slop water added to the pail contents.

The advantages of this plan are obvious; its disadvantages are the necessity of collecting, and drying, and storing the earth, which, for cottagers who have little space, and possibly no means of getting earth, is a serious matter. The supply of dried earth to large towns is almost a matter of impossibility, so large is the amount required. Again, the attention necessary to prevent the house water being thrown in, and to remove the soil at sufficiently short periods, sometimes militates against its success.

If a pail closet has to be used, from a sanitary point of view the earth closet is the very best form, as, if properly managed, the closet is free from smell, and the process of removing the contents not offensive.

The system of adding weak disinfectants in order to control the smell is based entirely on a misconception of the process. These inhibit, if they do not destroy, the action of the nitrifying ferment in the earth and render it sterile: there is, therefore, no disintegration and oxidation of organic matter, and the whole process by which the organic substances are destroyed is arrested. It is because of the absence of the nitrifying organisms in such soils as chalk and sand that these soils, being relatively sterile, are not suitable for the purpose. The use of all disinfecting and deodorising powders in earth closets should therefore be prohibited.

The contents of earth closets require no further treatment, and may be applied at once to the land. In agricultural districts, after admixture with fine ashes, the manure from middens and pails may be used on land, but there is always a difficulty of disposing of it to farmers; it is best suited for heavy clay soils.

In some towns where the midden and pail system is still in use, the crude contents are converted into a dry manure, which can be transported in bags or casks: it is, however, very offensive.

In Manchester Fryer's patent method is in operation, and it is also being applied, in whole or in part, at Birmingham and at Leeds. It consists of a *destructor*, which reduces to slag all the more bulky town refuse, such as cinders and ashes, broken earthenware and glass, which cannot be dealt with except by being accumulated in a rubbish heap. This slag is ground, mixed with lime, and sold as mortar. The apparatus is so arranged that none of the heat is lost, while the heated products of combustion pass over fresh portions of material and prepare it for combustion. The mass is reduced in bulk to one-third. Other refuse, such as condemned food, vegetable garbage, street sweepings, and the like, are reduced to charcoal in another apparatus called the *carboniser*. The carbon thus produced is used for disinfecting purposes, for decolourising the waste water from factories, &c. The excreta proper are collected in pails and reduced to small bulk by drying in a closed apparatus, called the *concretor*, the ammonia being fixed by the sulphuric acid fumes produced by the other processes. By this means the contents of the pails are reduced to one-twelfth, and a valuable manure obtained, which may be either in the form of poudrette or mixed with a little charcoal. Similar plans of disposing of town refuse are in operation in Glasgow, Leeds, Bradford, Stafford, Birmingham, Blackburn, and elsewhere. This system has been favourably reported on as the best available means for disposing of town refuse. "Not only are poisonous and disgusting elements dealt with and satisfactorily disposed of, without nuisance of any kind, but products having a marketable value can be and are produced without any infraction of true hygienic principles, whilst at the same time they may have the effect of materially reducing the expenses" (Saunders).

Movable tubs or pails are also in use in many continental towns. They are usually placed in the basement of houses and are capable of holding from fifty to sixty gallons of liquid; they are connected with the closets by means of an iron or stoneware pipe. As a rule there are no traps, and the sewer gases readily enter and diffuse themselves through the dwelling. In Paris the contents of these cesspools are collected in tanks outside the city, where the liquid part is allowed to evaporate or run to waste into the nearest water channel; the solid part is dried by being spread out on the surface of the ground, where it is allowed to accumulate for many months. It is then sold under the name of *poudrette*.

There have been great discussions as to the salubrity of the French poudrette manufactories, and the evidence is that they are not injurious to the workmen or to the neighbourhood, although often disagreeable. Apparently the poudrette may undergo a kind of fermentation which renders it dangerous, as Parent-Duchâtelet has recorded two cases of outbreaks of a fatal fever (enteric?) on board ships loaded with it.

Removal of Excreta by Water.

This is the cleanest, the readiest, the quickest, and in many cases the least expensive method. The water supplied for domestic purposes, which has possibly been raised to some height by steam or horse power, gives at once a motive force at the cheapest rate; while, as channels must necessarily be made for the conveyance away of the waste and dirty water which has been used for domestic purposes, they can be used with a little alteration for excreta also. It would be a waste of economy to allow this water to pass off without applying the force which has been accumulated in it for another purpose.

Slop-Closets.—In some towns, particularly in the north of England, where a sufficient water-supply is not available or where it is not utilised for flushing and washing out water-closets, advantage is taken of the household waste water to do the necessary cleansing.

There are two kinds of slop-closets, viz., those in which the waste water is allowed to run directly into the basin, and those in which, with a view to give a better flush, the waste liquid is collected in a suitable contrivance, called a tipper, and then discharged from time to time in a sudden forcible stream: these latter are called "automatic slop-closets."

The advantages claimed for this class of closets are that (1) on sanitary grounds they appear to be satisfactory appliances; that (2) the trouble arising from frozen pipes and cisterns in the case of ordinary water-closets placed in outbuildings practically need not be considered in the case of slop-closets; that (3) by utilising the slop water of a household for flushing closets considerable economy is effected in the consumption of water, and the volume of sewage to be dealt with at the outfall is lessened.

The best type of closet of the non-automatic form is perhaps that known as Fowler's closet, largely in use in Newcastle, Salford, and Hanley.

The general arrangement of these closets will be readily seen from fig. 68. The objections to these closets are (1) that the stream of water is not sufficient to keep them clean, and (2) that the back and sides get fouled by the excrement falling against them. These closets to work properly should have a fall of 5 feet to the sewer for the soil pipe.

Another form of slop-closet is that of Hill, in use at Birmingham, and in which either a siphon-cistern or tipper is used to collect the slop water and then discharge it in a sudden flush. The tipper is preferable to the siphon tank as the latter fails sometimes to act owing to clogging with greasy water. A number of these closets can be placed on one drain, a single trap serving for the whole; a ventilation shaft is provided at the upper end. Fig. 69 shows this arrangement.

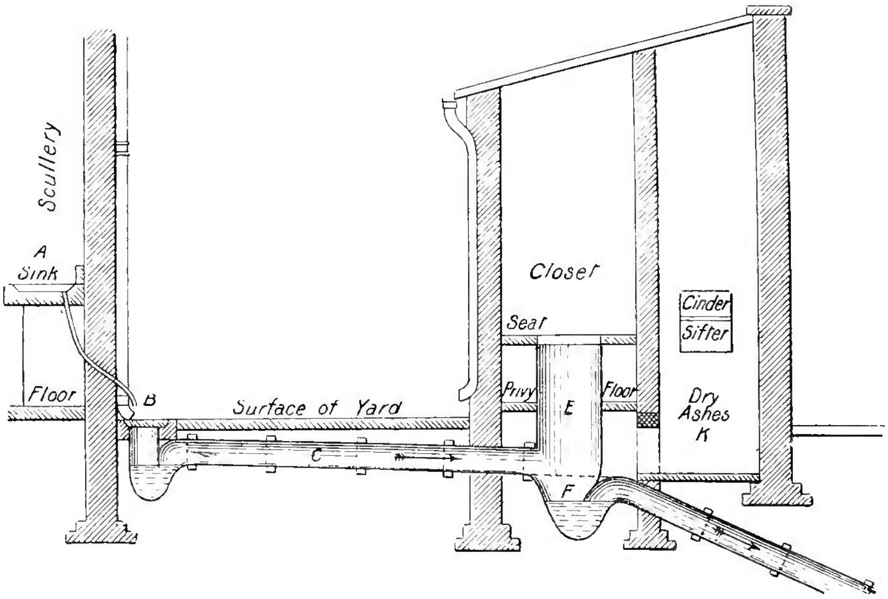


Fig. 68.

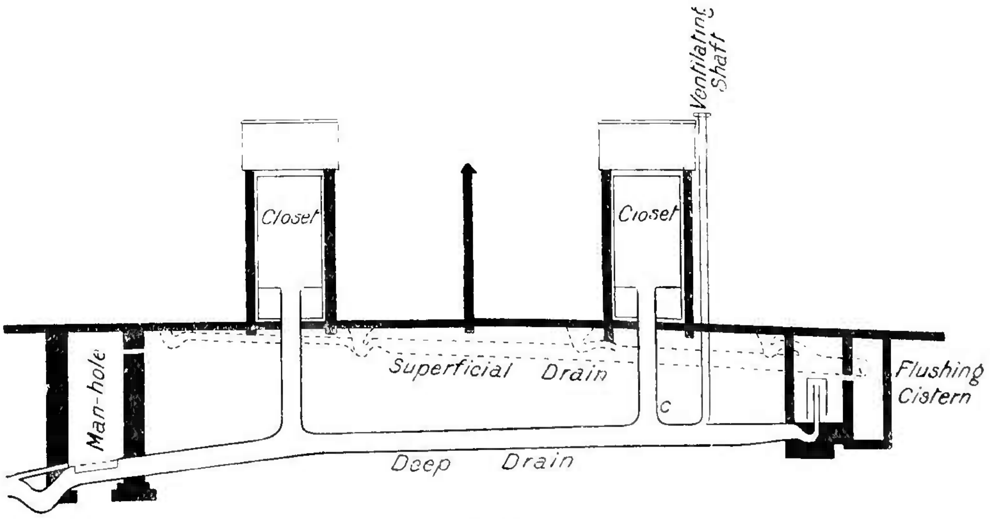


Fig. 69.

An improvement of these closets are the various kinds of automatic slop-closet, in which the slow and uncertain trickle of the slop water from the sinks is replaced by a sudden gush of the slop water after storage in either siphon-cistern or tipper. The tipper is merely an iron or earthenware vessel, so shaped and balanced on pivots that when full the weight of the contained liquid overbalances it and causes its contents to be suddenly poured down the pipe. There are several kinds of these automatic slop-closets; in some the tipper is placed close to the sink discharge pipe (top flushing), in others the tipper is placed well away from the slop stone and more or less in a piece with the lowest section of the closet-shaft (bottom flushing). The best form of these closets appears to be Duckett's of Burnley (fig. 70). The tippers to be effectual must contain at least three gallons of water for single closets and five gallons if flushing two or more closets in a row. Some kinds, such as Whalley's, do not have a self-acting tipper, but are discharged by pulling up a handle. Others have the tipper situated at the side or back of the closet basin (fig. 71).

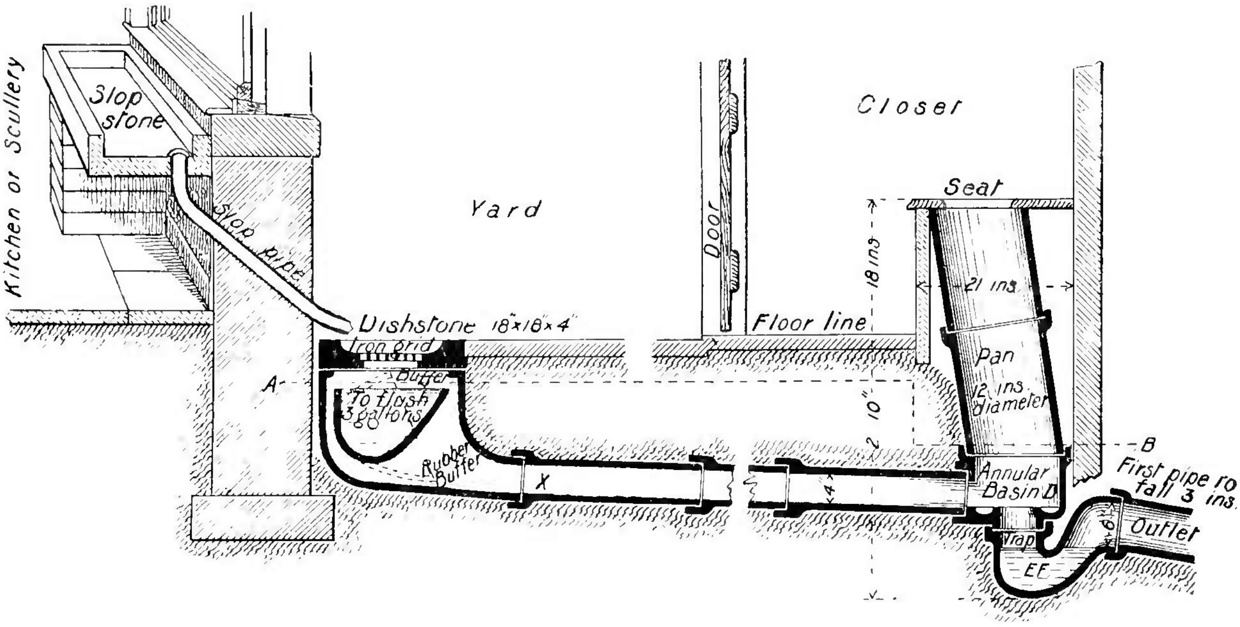


Fig. 70.

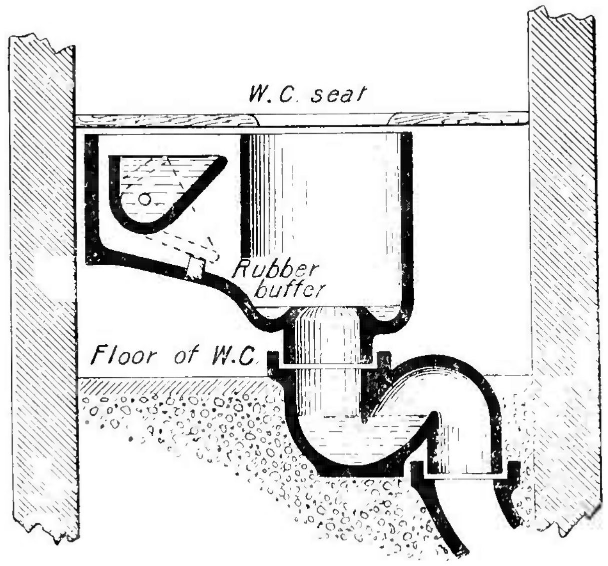


Fig. 71.

The various automatic slop-closets appear to be advantageous in that their original cost is small, they consume less water and produce less sewage, and, too, are less apt to freeze or get out of order than the ordinary water-closets; against them are the facts that they are unsightly, less cleanly than water-closets owing to the fouling and lodgment of excreta on the sides; the sewage is exceeding foul, much fouler than is the case where the closets in use are ordinary water-closets with a clean water flush. This is accounted for by the fact that it is composed solely of the slop water of cottages and the excreta and urine of the inhabitants. The concentrated quality of the sewage, and its tendency to rapid putrefaction, increase the difficulties connected with its ultimate disposal.

The use of slop-closets can only be recommended out of doors, and where the sewers have a good fall, and where a public service of water is laid on to each house. It is also important that each house should have a separate closet. Subject to these conditions these slop-closets may be of use and value in places where it is desirable to economise the water.

Trough closets are those in which a long metal or earthenware trough partially filled with water passes beneath the seats of the closets, placed side by side, and receives the excreta from them. These troughs are regularly flushed by the discharge of a volume of water, either by an attendant or automatically by a siphon-cistern or tilting receiver and the contents carried away to the sewer through a trap at the end of the trough. These closets are adapted for schools, factories, and groups of artisans' houses, being little liable to damage by rough usage, or get out of order; the only desideratum being a good large drain well jointed with cement and plenty of water.

Their drawbacks are, original cost, the large quantity of water used and the alarming noise and splashing which results if the flushing happens to take place when the seat is in use. Trough closets, whether automatic or otherwise, can only be used where good drains exist and a supply of water is laid on.

Water-Closets.—The essential features of a good water-closet are, a basin or other suitable receptacle of some non-absorbent material and of such shape and capacity as to allow the excreta to fall free of the sides and directly into the water in the basin. There may be said to be five distinct types of water-closets now in general use; they are, the *pan* or *container closet*, the *long hopper*, the *valve* or *plug closet*, the *wash-out* and the *wash-down closet.*

The pan or container closet is now being abandoned, although still to be found in many dwellings and public buildings. It consists of a conical pan surrounded by a container, and having at the bottom a small movable pan, usually of tinned copper, to receive the excreta; this holds a certain amount of water, and is intended to act as a water seal or trap. Frequently, from failure of water, defective apparatus, or from the copper being eaten through by oxidation (not uncommon when there are nitrates in the water-supply), the pan is empty, so that free passage is given to noxious gases. Add to this that the container is always more or less filthy, and that the soil pipe from it usually terminates in a D trap, and we have one of the worst combinations from a sanitary point of view. All such closets ought to be definitely abolished.

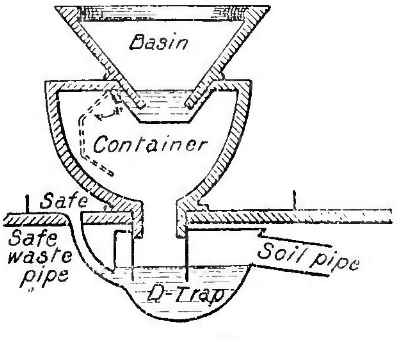


Fig. 72.

The Model Bye-laws of the Local Government Board prohibit the fixing in any new water-closet of what is known as a "container" or D trap. A diagram of a closet constructed with these arrangements is shown in fig. 72. The long hopper closet is a deep conical basin ending in a bent tube or siphon trap and which, from its shape and construction, is extremely liable to become filthy by the fouling of its sides; the flow of water is sluggish and in its spiral course round the basin fails to cleanse it.

The valve or plug closet (fig. 73) is an improvement on the two preceding forms; but in recent years has been superseded by other and better kinds. Its chief faults were that it was complicated, its plug or valve often leaked and failed to keep a supply of water always in the basin, while at the same time it was difficult to keep clean; another defect was that, if by chance the siphon trap became unsealed, foul air could escape up into the house from the soil pipe through the overflow pipe.

Of the modern forms of water-closet the best kinds are the wash-out and the short hopper or wash-down closet. Both of them are made out of a single piece of earthenware. In the wash-out closet (fig. 74) a certain amount of water is kept in the basin by means of a dam or ridge over which the excreta are carried by a flush of water. The objections to this closet are, that the water in the basin is not sufficient to cover the excreta, and that part beyond the ridge and near the outlet is liable to get foul from insufficient flushing; in some varieties of this closet the ridge is made too high, with the result that, unless the flush be good, the contents are not at once carried away. Of the short hopper or wash-down class (fig. 75) one of the best is the "Deluge," which is provided with a flushing rim from which the water flows in such a manner and direction that the basin is kept constantly clean. In these forms of water-closets the back of the cone should be made as vertical as possible, so that the excrement drops into the water of the trap and not upon the sides of the basin.

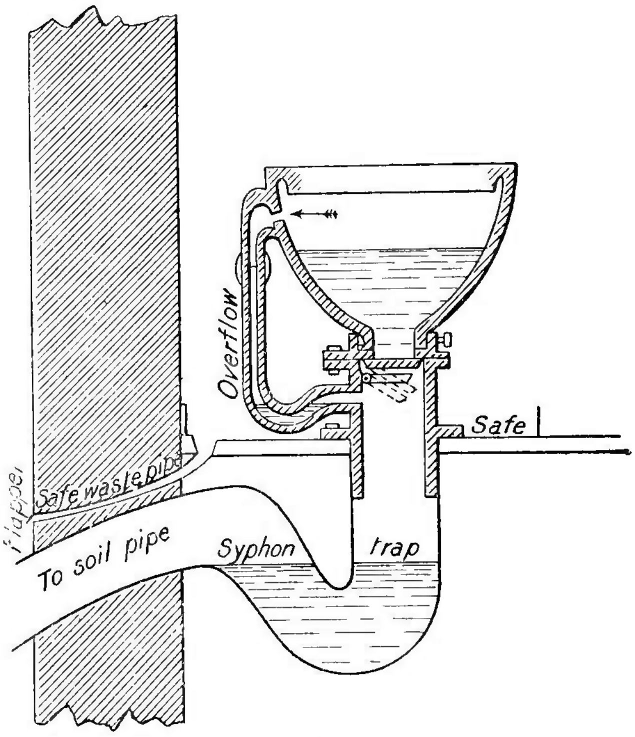


Fig. 73.

A recently introduced and good type of water-closet is that known as the "Century closet" (fig. 76). By reference to the illustration it will be seen that the service pipe from the cistern has two connections to the closet—one leading into the basin in the usual manner, the other leading into the top of the long leg of a siphon pipe. The flush from the cistern is thereby divided into two streams—one flushes the basin, the other rushes down the siphon leg, expels the air through the puff pipe, starts the siphonic action and empties the basin, which is refilled with clean water by a simple after-flush arrangement in the cistern.

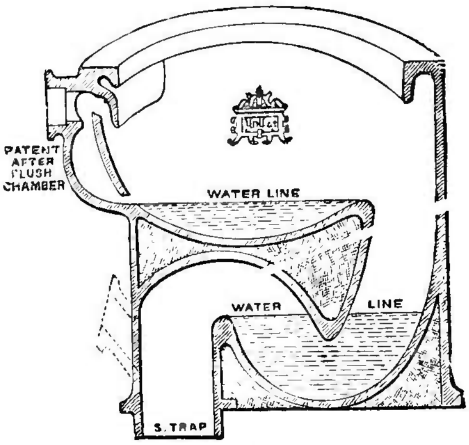


Fig. 74.

The quantity of water required for flushing closets is three gallons, and to avoid waste should not exceed three and a half gallons. The closet should be flushed from a waste-preventing cistern placed not less than 4 feet above the seat, the service or supply pipe being $1\frac{1}{4}$ to $1\frac{1}{2}$ inch in diameter. The flushing water should on no account be supplied from a cistern or service pipe which supplies water for household purposes; but each closet should have its own separate cistern. They are usually made of iron and those with a siphon action are best. A very short pull of the chain will put the siphon in action, when the whole contents of the cistern are discharged. The overflow pipe from the cistern should discharge direct through the wall into the outer air, a few inches from the brickwork; it should under no circumstances be allowed to discharge into any pipe connected with closets.

Water-closets should always be placed against an outside wall of a building, in which is a window which should open quite to the ceiling. If possible, it should be in an outbuilding or a projection with thorough ventilation between it and the house; the air from the closet should find easy exit to the external air and not pass into the house.

The points to be looked to in examining closets are—1*st*, that the amount and force of water is sufficient to sweep everything out of the siphon; 2*nd*, that the soil pipe is ventilated beyond the siphon by being carried up full-bore to the top of the house; 3*rd*, that the junctions of siphon and soil pipe and of the lengths of the soil pipe are perfect.

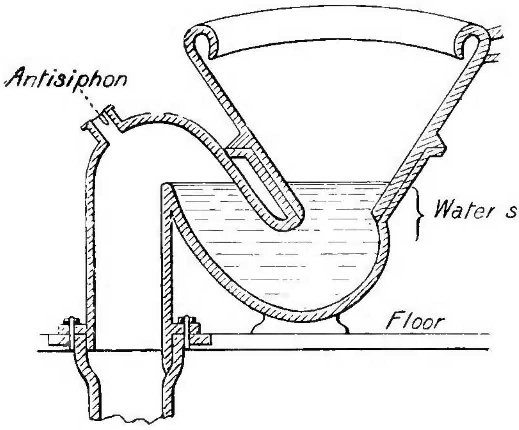


Fig. 75.

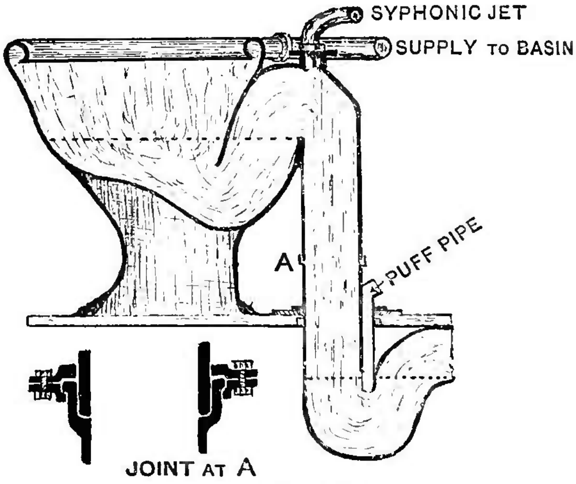


Fig. 76.

Many methods have been proposed to secure a perfect joint between the outlet and ventilation connections of a stoneware closet with the house drain; lead traps have usually been adopted, the joint to the stoneware being on the house side of the trap and the connections rendered tight by red lead, putty, or other bedding. While this overcomes the difficulty of the joint, it necessitates the use of a material (lead) which readily becomes coated and is liable to corrode. By the use of such a connection as Doulton's metallo-keramic joint an absolutely perfect connection may be made by the incorporation of the stoneware and metal at the point of junction. It is generally desirable to have slop-sinks separate from water-closets; their connections with the drain demand the same care and attention as those of water-closets. The waste pipe from the sink should be made of stout lead, not less than 10 lb to the square foot, in order to resist the action of hot and cold water; they are usually 3 inches in diameter, with a 3-inch siphon water seal and are carried separate from the soil pipe, to terminate in the open air 18 inches above a gully trap.

Waste pipes discharging water from kitchen sinks, scullerys, &c., and bath waste pipes carrying away water from baths, should not connect directly with any drain, but must discharge into the open air, about 18 inches above a grating covering a good water trap ; they should not be made to open under the grating, as sewer gas may be sucked up through the pipes by the higher temperature in the house. Waste pipes should also have a siphon trap (fig. 78) with a 3-inch water seal. They should *not* be connected with any soil pipe.

Soil pipes for carrying away sewage must be placed outside the building and protected as far as possible from the direct rays of the sun, so as to avoid its becoming bent from expansion or the joints opening. They should be 4 inches in diameter and carried up full-bore to above the eaves of the house and terminate away from all chimneys and windows; an upcast cowl is sometimes placed over the top, but this is not necessary ; thin wires may be strung across to exclude birds, &c.

Drawn lead is the best material; seamed lead pipes should never be used. Soil pipes, whether inside or outside buildings, should be made of such material that its weight shall be in the following proportions to length and internal diameter :—

Diameter.	Lead.	Iron.
	Weight per 10 feet length not less than	Weight per 6 feet length not less than
3 inches	63 lb.	37 lb. $\frac{3}{16}$ in. metal
$3\frac{1}{2}$,,	73 ,,	42 ,, ,,
4 ,,	83 ,,	62 ,, ,,
5 ,,	104 ,,	103 ,, ,,
6 ,,	125 ,,	138 ,, ,,

Cast-iron pipes are cheaper, but they must be strong and the inner surface as smooth as possible ; when cast-iron pipes are used it is advisable to coat them with Angus Smith's composition, which renders the inner surface perfectly smooth ; all joints should be caulked with molten lead. As it is difficult to make a perfect joint with iron pipes, they should never be placed inside the house.

The connection between the soil pipe and drain should always be outside the house, and an air and siphon disconnecting trap should be placed at this point where this is possible. With an air disconnecting trap at the bottom of the soil pipe, and where the pipe is taken, without bends, to a level above the roof, there should be a constant current of pure air through the soil pipe. When the closet is used the flush of water through the pipe will draw air in from the open top and thus keep the soil pipe clean and sweet. If the trap of the closet should fail from any cause, by this arrangement air and not sewer gas would escape into the house. With the air disconnecting trap at the bottom of the soil pipe, it is advisable to place an ordinary siphon trap before it joins the drain, so that the inlet for air may be as free from sewer gas as possible ; this is particularly necessary in those cases in which it is not possible to have an air disconnecting trap at the bottom of the soil pipe.

Traps.—These are used as barriers to keep the sewer air in the drains from entering the house or from polluting the surrounding air. The method by which the sewer air is kept back is by the interposition of water between the inlet and the outlet of the trap. This "water seal" should have at least a depth of three-quarters of an inch, so as to provide a sufficient and constant barrier against the passage of sewer air. There must be no angles or projections in the trap itself, which will prevent the passage of solid matter or favour its deposit, as this would undergo putrefaction; the trap should be self-cleansing as far as possible, and every portion should be washed at every flush. Surface traps should never be placed on the ground floor in houses or cellars, but outside the building, and so situated that if from any cause sewer air escaped through them, it would do so into the open air and not into the house.

There is almost an infinite variety of traps; those most usually met with in practice may be conveniently divided into the *siphon*, the *midfeather*, the *flap-trap* and the *ball-trap*.

The simplest form of siphon trap is an ordinary pipe with a bend in it, so that there is always a water seal between the inlet and outlet. It is a useful trap, and efficient if the curve is deep enough, so that there is a certain depth of water (not less than $\frac{3}{4}$ inch) standing above the highest level of the water in the curve; the water, however, is liable to be sucked out of it, if the pipe be too small, owing to the water being carried away, when it runs full, by the siphon action of the pipe beyond. If two siphons succeed each other in the same pipe, without an air opening between, the one will suck the other empty.

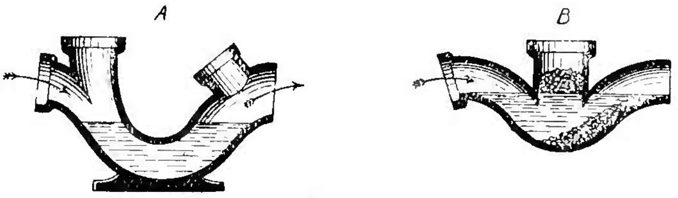


Fig. 77.

The siphon trap shown in fig. 77A is a good form of intercepting trap for disconnecting the house drain from sewer or cesspool. It has a flat external bottom which ensures its being laid level; there are two openings in addition to the inlet and outlet, one of which may be made to act as an air inlet by being carried up by means of pipes to the surface of the ground where it should be covered by an open grating, and the other beyond the seal, which may be used for cleaning the drain.

Another form of siphon trap is shown in fig. 77B. This is a bad form of trap. The bottom of the trap being rounded is difficult to keep in its proper position; there is no provision for ventilating the drain in the shape of an inlet opening on the house-side of the water seal, and no means of cleansing the drain beyond the seal; floating matters, such as paper, &c., often accumulate in the central shaft and the dip is not sufficient to wash out the trap. The siphon bends in the waste pipes from baths and sinks should be furnished with a screw at the lowest point, to allow of unstopping (fig. 78).

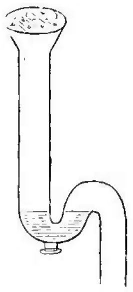


Fig. 78.

The *midfeather* is in principle a siphon; it is merely a round or square box, with the entry at one side at the top, and the discharge pipe at a corresponding height on the opposite side, and between them a partition reaching below the lower margin of both pipes. Water, of course, stands in the box or receptacle to the height of the discharge, and therefore the partition is always to some extent under water (fig. 79). The extent should not be less than ¾ of an inch. Heavy substances may subside and collect in the box, from which they can be removed from time to time; but as ordinarily made it is not a good kind of trap, as it favours the collection of deposit, and is not self-cleaning.

Another bad form of trap is the D trap (fig. 80). It is usually found in connection with soil pipes; there is a large surface which becomes coated with filth, and foul air is generated. This trap is generally rectangular in section and has too many sharp angles and projections which prevent its being self-cleansing: it should therefore never be used. Bell-traps, though constantly used for sinks and sometimes for gullies, are very defective traps. They should be condemned wherever they are met with. This trap (fig. 81) is unsealed whenever the perforated bell cover is removed, and the small quantity of water which forms the water seal soon evaporates. In order to hasten the flow of water through the discharge pipe the cover is frequently taken off, leaving the waste pipe untrapped; the bell is easily broken off from the perforated plate, in which case it no longer constitutes a trap, and sewer gas escapes.

The *flap* is used only for some drains, and is merely a hinged valve which allows water to pass in one direction, but which is so hung as to close afterwards by its own weight. It is intended to prevent the reflux of water into the secondary drains, and is supposed to prevent the passage of sewer gas; it is, however, a very imperfect safeguard.

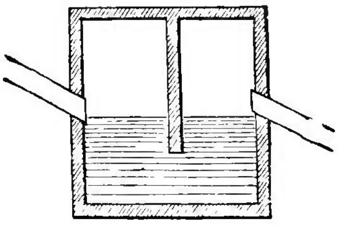


Fig. 79.

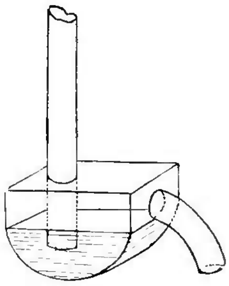


Fig. 80.

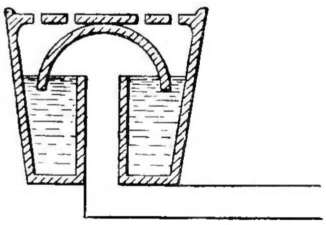


Fig. 81.

The *ball-trap* is used in some special cases only; a ball is lifted up as the water rises, until it impinges on and closes an orifice. It is not a very desirable kind.

However various may be the form and details of the water trap, they can be referred to one or other of these patterns.

A grease-intercepting chamber is sometimes necessary to prevent the deposit of grease or sand in the drain. This chamber is generally made of hollow stoneware, with a tight iron cover, and ventilated. The hot water from the sink is cooled on entering the chamber, the grease solidifies and rises to the top, the sand sinking to the bottom; the grease and sand must be removed periodically. The outlet of the trap is at the bottom, and as the grease floats on the top of the water and becomes solid on cooling, it can be readily removed from time to time. The size of the chamber should be proportional to the amount of sink water to be passed through it, so as to prevent the displacement of the body of water in the trap too rapidly, in order that the grease, being chilled, may be deposited in it. The trap should be easily accessible for periodical cleaning.

Buchan's disconnecting and ventilating drain trap is much used (fig. 82): the soil pipe and drain are both 4 inches in diameter; there is a fresh air inlet and an opening beyond the water seal for cleaning, &c.; the sewage enters the trap with a considerable fall and the trap is flushed clean.

The ordinary form of gully trap (fig. 83) is a very simple and efficient form of trap, so far as the drainage of the yard and rain-water pipes is concerned; but it is essential that it should be periodically cleaned out and deposits removed. The openings should never be below the grating, but all pipes be made to discharge above it.

A good form of disconnecting trap for sink and slop waters is Deans' (fig. 84), which is fitted with a bucket; this can be lifted out by means of a handle, so that any grease or deposit can be easily removed.

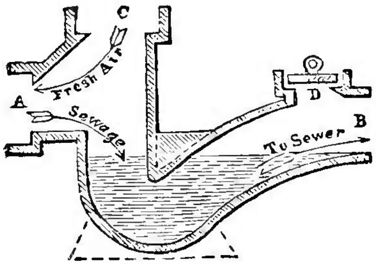


Fig. 82.

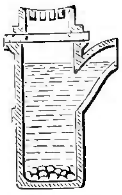


Fig. 83.

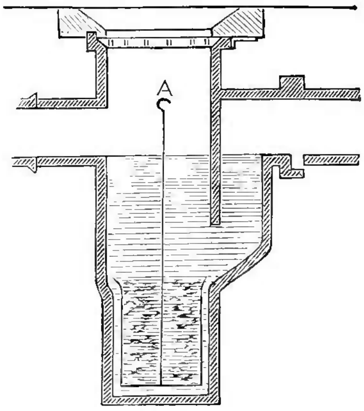


Fig. 84.

The Bye-laws of the Local Government Board require that "the waste pipe from any bath, sink (not being a slop-sink constructed or adapted to be used for receiving any solid or liquid filth), or lavatory, the overflow pipe from any cistern and from every safe under any bath or water-closet, and every pipe in such building for carrying off waste water, to be taken through an external wall of such building, and to discharge in the open air over a channel leading to a trapped gully at least 18 inches distant."

The trap as shown in fig. 85 is in compliance with this bye-law; the gully is fitted with a bucket which can be lifted out by the handle, so that its contents can be easily removed. The bucket is provided with a flange round the top, and fits the sides of the trap accurately, so that dirt is unable to pass into it when it is being removed.

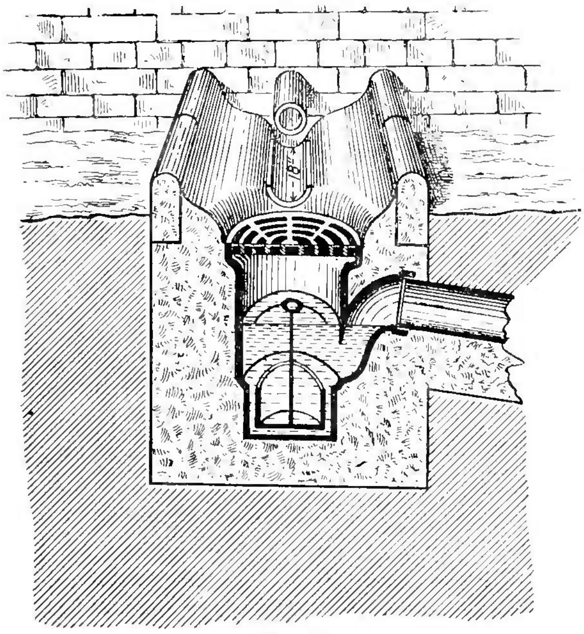


Fig. 85.

Efficiency of Traps.—Water should stand in a trap at least ¾ of an inch above openings, and it should pass through sufficiently often and with sufficient force to clear it. An essential condition of the efficiency of all traps is that they should be self-cleansing. Many traps are so constructed that no amount or velocity of water can clear them. Such traps are the common mason's or dip-trap (fig. 79), and the old D trap, both of which are simply cesspools, and could never be cleaned without being opened up. Such traps ought to be unhesitatingly condemned. Traps are often ineffective:—1. From bad laying, which is a very common fault. 2. From the water getting thoroughly impregnated with sewer effluvia, so that there is escape of effluvia from the water on the house side. 3. From the water passing too seldom along the pipe, so that the trap is either dry or clogged. 4. From the pipe being too small (2 or 3 inches only), and "running full," which will sometimes suck the water out of the trap; it usually occurs in this way, as frequently seen in sink traps; the pipe beyond the trap has perhaps a very great and sudden fall, and when it is full of water it acts like a siphon, and sucks all the water out of the trap; to avoid this, the pipe should be large enough to prevent its running full, or the trap should be of larger calibre than the rest of the pipe. This, however, will not always prevent it, as even 6-inch pipes have sometimes sucked a siphon dry. The question has been very carefully investigated, in America, by Philbrick and Bowditch, whose report has shown the danger of unsiphoning to which small pipes are exposed. The remedy appears to be to introduce an air-vent at the crown of the trap and not to have too small a pipe, especially when several pipes unite in one general waste. Their experiments also showed how unsiphoning might take place from the pressure of descending water from upper floors, so that air might be forcibly driven into the house when upper closets or sinks were used; but with proper ventilation these dangers may be completely obviated. 5. Traps may perhaps be inefficient from the pressure of the sewer air, combined with the aspirating force of the house displacing the water, and allowing the air uninterrupted communication between the sewer and the house. The extent of the last danger cannot be precisely stated. From a long series of observations on the pressure of the air in the London sewers, Burdon-Sanderson ascertained that in the main sewers, at any rate, the pressure of the sewer air, though greater than that of the atmosphere, could never displace the water in a good trap. In a long house drain which got clogged, and in which much development of gaseous effluvia occurred, there might possibly be for a time a much greater pressure, but whether it would be enough to force the water back, with or without the house suction, has not yet been experimentally determined; water siphon traps act efficiently so long as they are not emptied by any siphon action beyond. But the

Disconnecting Man-hole.

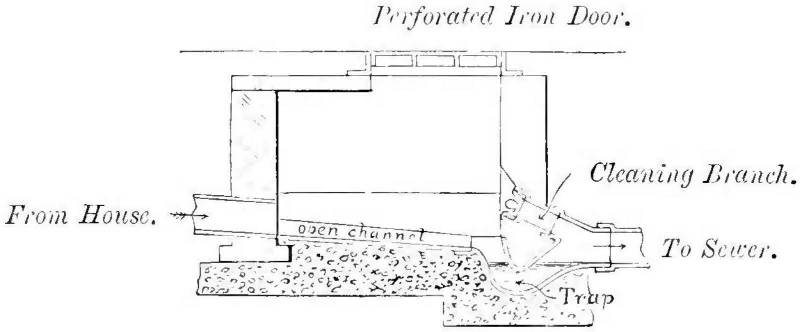


Fig. 86.

reasons already given show that we ought not to place dependence solely on traps, they should be treated merely as auxiliaries to a good drainage system. In arranging the house pipes the sink and water-waste pipes must not be carried into the closet soil pipes, but must empty in the open air over a grating. (See fig. 85.) In the case of soil or water-closet pipes, there must be also a complete air disconnection between the pipe and drain by means of one of the contrivances now used by engineers. At the point where this disconnection is made there ought to be some easy means of getting at it for inspection.

Man-holes.—In the event of a drain terminating in a man-hole or disconnecting chamber, a special form of disconnecting trap is used. The Kenon air chamber and trap is one now generally recommended. It serves to cut off aërial communication with the sewer and at the same time to facilitate inspection and cleansing. A long straight pipe unites the longer arm of the siphon to the chamber, and by its means the drain beyond the siphon can be cleansed; the orifice of this pipe is covered by a movable lid.

Man-holes should be introduced where tributary sewers join; they should mark off sections where the sewer has to alter its straight course. A man-hole chamber (figs. 86, 87, 88) is built of brickwork, set in cement, and the drain or sewer is continued along the floor of the chamber by means of open half-channel pipes set in a bed of cement. The surface of the concrete should be raised some inches above the edges of the half-channel pipes to prevent the sewage from overflowing on to the floor of the chamber, and it should be lined with cement all over so as to present a smooth and impervious surface. All street man-holes should be fitted with a perforated iron grid; a tray placed beneath the grating will catch any dirt that may enter, and still allow of the free circulation of air in the sewers.

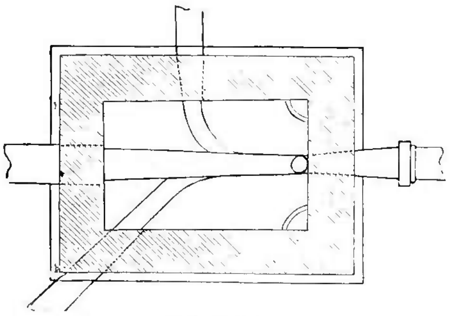


Fig. 87.

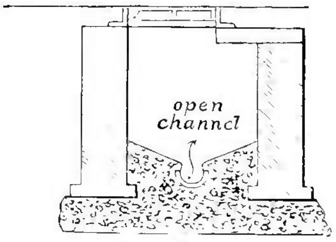


Fig. 88.

In the case of private drains the man-hole lids are made air-tight, with the exception of the terminal one, which should be open so as to provide for a current of air along the sewer.

Drains and Sewers.—*Drain* means any drain of, and used for the drainage of, *one* building only, or premises within the same curtilage, and made merely for communicating therefrom with a cesspool or like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed.

Sewers include sewers and drains of every description, except drains to which the word "drain," as above defined, applies. In other words, a sewer is a drain receiving the drainage of two or more buildings, and may be an open channel, such as a polluted water-course, as well as an underground culvert. Under the Metropolitan Local Management Act, 1862, this distinction between drain and sewer is not accepted, but a combined drain is deemed to remain a drain. So, again, in urban districts which have adopted the Public Health (Amend.) Act, 1890, the interpretation of "drain" is different. Whereas, under Public Health Act, 1875, if one or more houses drain into a common pipe, such common pipe or combined drain is a sewer; but under section 19 of the Amended Act this common pipe is deemed to be a sewer only if all the houses belong to one owner; if they belong to more than one owner, then the combined drain is a drain repairable at the owners' expense, and not a sewer repairable at the expense of the sanitary authority.

The function of a drain is to carry away as rapidly as possible to the sewer or cesspit the waste products that are capable of being removed by the agency of water. In order to do this, it must be made of such a form as will cause the least resistance to the free passage of its contents, and be constructed of materials that will permit of no leakage of surface waters into the drain, or of sewage into the ground; the joints between the different sections must be also made impervious, so that the whole drain is both air and water-tight throughout its entire length, except at those exits which are provided for the purposes of ventilation.

The usual form of drain is a circular pipe, made in lengths of about two feet, in glazed stoneware, semi-vitrified ware, or of cast-iron or other suitable material. They must be of adequate size: for small houses 4 or 5 inches in diameter; for larger houses 6-inch pipes may be necessary, and for hospitals or other large institutions 9-inch pipes. They should be well glazed internally. If the drain is made of cast-iron, the weight and thickness of the pipes in proportion to the diameter should be as follows:—

Internal diameter. Inches.	Per 6 ft. length. Not less than
$3\frac{1}{2}$	42 lb $\frac{3}{16}$ in. metal.
4	62 ,, $\frac{1}{4}$,, ,,
5	103 ,, $\frac{5}{16}$,, ,,
6	138 ,, $\frac{3}{8}$,, ,,

Laying of Drains.—They should be laid very carefully on concrete on all sides. If the ground on which the pipe has to be laid is not solid, or if there is any likelihood of subsidence taking place, the pipes must be laid in a bed of concrete of sufficient thickness. Sometimes in very loose soils even piling for the depth of a foot must be used besides the concrete; the foundation of concrete should support the pipes in their length and not at the sockets only; it should never be less than 3 inches under the centre of the pipe.

Each length of stoneware pipe is provided at one end with a socket into which the spigot of the next pipe fits. The space between the spigot and the socket is generally filled in with cement to make the joint water-tight, but care must be taken that this does not penetrate to the inside of the pipe and afterwards obstruct the flow of sewage. Another joint is made by casting on to the spigot and socket a specially prepared patent material, the two rings being fixed with a composition of Russian tallow and resin, finally adding a ring of cement outside the joint. Stanford's joint is composed of boiled tar (1 part), clean sharp sand (1 part), and sulphur ($1\frac{1}{2}$ part). Clay luting should never be permitted, as it is washed out of the joints in a short time.

In wet soils it may be necessary to drain the subsoil, and this may require pervious drains or drain-sewers. If pipe-sewers only are used, the subsoil water remains unaffected, except so far as a small portion may find its way along the channels formed by the pipe. Sometimes pervious drains of earthenware are laid down to carry off the subsoil water. Brooks of Huddersfield has combined in one system a drain and sewer, in which there is an arrangement for subsoil drainage under the sewer pipe (fig. 89). In this arrangement the subsoil drain and pipe-rest is first laid and clay-jointed; the cement-jointed pipe-sewer is laid afterwards on this, with the result of getting a better laid sewer, and at the same time effectually carrying off the subsoil water.

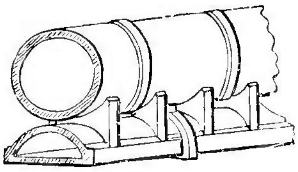


Fig. 89.

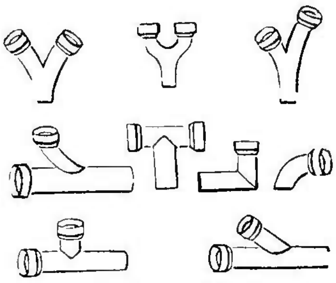


Fig. 90.

The "junction" of pipes is accomplished by special pipes, known by the names of single and double squares, curved or oblique junctions, according to the angle at which one pipe runs into the other (fig. 90). The square junctions are undesirable, as blockage will always occur, and the oblique junctions should be insisted upon. When a smaller pipe opens into a larger,

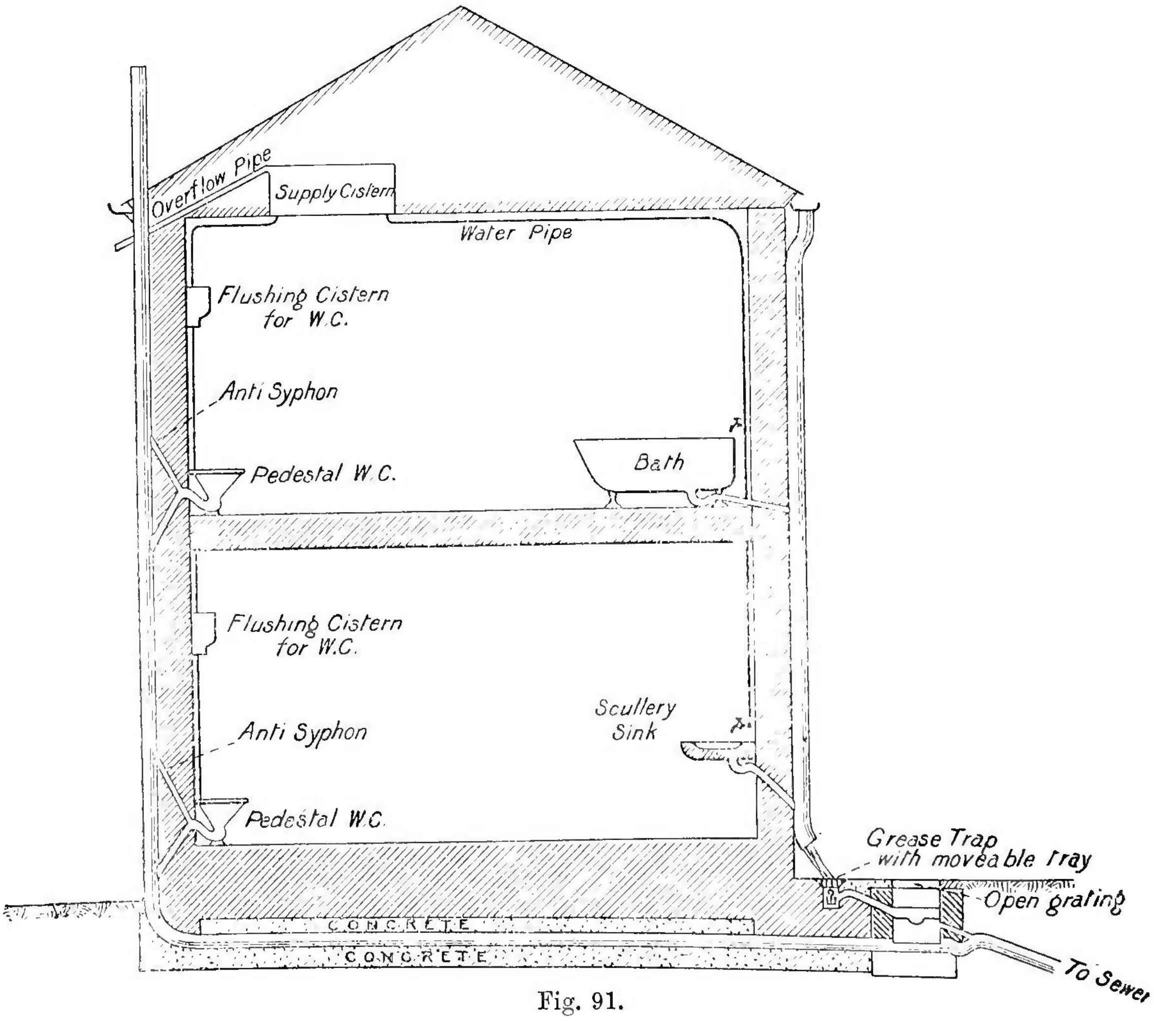


Fig. 91.

a taper pipe should always be used, the calibre being contracted before it enters the receiving pipe. All jointing must be in good cement, unless special patent joints (such as Stanford's) are used. Clay jointing is wholly inadmissible.

Drains should never, if possible, be carried under the house: but when this is unavoidable, there should be a distance equal to the diameter of the drain between its highest point and the surface of the ground under the building; the pipe should be taken in a straight line from one point to the other, with a man-hole or access pipe at each end, and it should be completely embedded in cement with solid concrete 6 inches thick all round; or the pipe may be taken above the basement floor and exposed throughout its course. In such case it should be made of cast-iron with lead jointings. In the United States, where this alternative system is adopted, this is made compulsory.

The drains should end outside the house, and as far as possible every house pipe should pass outside and not inside or between walls to meet the drain. The object of this is that any imperfection in the pipe should not allow the pipe air to pass into the house. At the junction of the house pipe and drain there should not only be a good water trap, but also complete ventilation and connection with the outside air at the point of junction. The rule, in fact, should be, that the union of any house pipe whatever with the outside drain should be broken both by water and by ventilation. It is hardly possible to insist too much on the importance of this rule of disconnection between house pipes and outside drains.

A general scheme for the arrangement of house drains, and showing the chief points here mentioned, is given in fig. 91.

The "Durham" system of house drainage has recently been introduced into this country from America. The pipes are of wrought-iron lined with asphalte, and are joined together by wrought-iron collars and cast-iron bends and junctions. It is said that by this system faulty joining is an impossibility; but the effect of changes of temperature on their stability is not stated. Events have shown what a risk the richer classes in this country often run, who not only bring the drains into their houses, but multiply water-closets, and often put them close to bed-rooms. The simple plan of disconnection with ventilation, if properly done, would guard against the otherwise certain danger of sewer gas entering the house. Houses which have for years been a nuisance from persistent smells have been purified and become healthy by this means. Every house drain should be trapped as near as practicable to its junction with the public sewer.

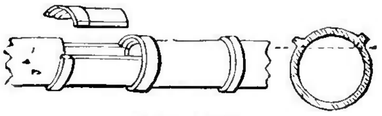


Fig. 92.

Cleansing of Pipes and Drains.—Pipes are cleaned by flexible bamboo or jointed rods with screws and rollers to loosen sediment. The safest plan of cleaning drains is from man-holes, the drains being laid in straight lines from man-hole to man-hole. By this means obstructions are easily detected and removed. Most engineers now lay down a half round pipe where required, raise up the sides in cement, and cover the space over with an air-tight iron cover. The use of movable caps runs the risk of leakage, it being difficult to make the

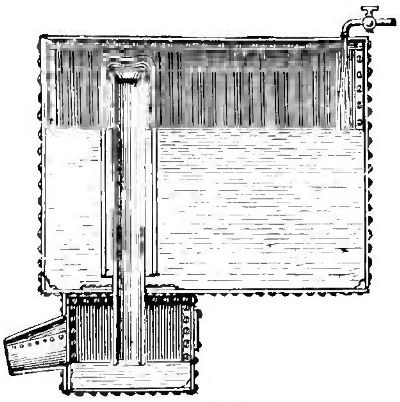


Fig. 93.

drain water-tight again after removing the cap, but with care such caps (see fig. 92) are useful with small pipes, where man-holes cannot be employed. Drain pipes should also be cleared out by regular flushing when necessary. This may be done by means of an automatic apparatus such as Field's flush tank (fig. 93). By regulating the flow of water it may be made to empty itself as often as necessary.

Tanks of this description which are connected with large sewers are usually built in brickwork, but those for drains and smaller sewers are made of galvanised wrought-iron. In the case of ordinary drains, these tanks usually hold from 80 to 100 gallons of water, the diameter of the discharge pipe being 4 inches.

Fall of Drains.—The fall or inclination given to a drain must depend on the circumstances of the case, but it may be taken as a general rule that a house drain should have a fall of about 1 in 50. Maguire gives the following rule for determining the fall necessary:—Multiply the diameter of the drain in inches by 10: thus a 4-inch drain should have a fall of 1 in 40; a 6-inch drain 1 in 60. The fall should be such that the scouring of the drains can be effectually accomplished without the use of special flushing; on the other hand, the inclination must not be too great, or the liquid portion flows away too rapidly, leaving the solid matters behind. To prevent as far as possible the occurrence of deposits, pipes of greater diameter than 6 inches should not be used. When the current of water is feeble, automatic flushing tanks may be placed at the upper end of the drain.

The inclination at which house drains are laid depends on the velocity of the current that is desired to be attained. For house drains it is recommended that this should be 4½ feet per second in circular pipes running two-thirds full, and 3 feet per second running a quarter full.

All house pipes (except the soil pipe), including rain-water pipes, should end below in the open air, not less than 18 inches distant from the gully trap, so as to completely disconnect them from the drain. Rain-water pipes should not be made to act as ventilators to any drain, as, independent of their small size, which often leads to blockage, they are often full of rain, and cannot act at the time when ventilation is most required. They are also apt to deliver sewer gas into garret windows. The plan is objectionable, and ought to be abandoned.

To Test Drains and Pipes.—Pipes and traps are generally so covered in that they cannot be inspected; but this is a bad arrangement. If possible, all cover and skirting boards concealing them should be removed, and the pipe and trap underground laid bare, and every joint and bend looked to. But supposing this cannot be done, and that we must examine as well as we can in the dark, so to speak, the following is the best course:—Let water run down the pipe, and see if there is any smell; if so, the pipe is full of foul air and wants ventilation, or the trap is bad. If a lighted candle, or a bit of smouldering brown paper, is held over the entrance of the pipe or the grating over a trap, a reflux of air may be found with or without water being poured down. It should be noticed, also, whether the water runs away at once, or if there is any check. This is all that can be done inside the house; but though the pipe cannot be disturbed inside, it may be possible to open the earth outside, and to get down to and open a drain; in that case, pour water mixed with lime down the house pipe; if the whitened water is long in appearing, and then runs in a dribble merely, the drains want flushing; if it is much coloured and mixed with dirt, it shows the pipes and trap are foul, or there is a sinking or depression in some part of the drain where the water is lodging. The pipe should then be flushed by pouring down a pailful of lime and water till the lime-water flows off nearly clear.

If any doubt exists as to the integrity of the pipes or drains, the *water test* may be used. This is done by carefully plugging the outlet into the sewer or cesspool, and filling the drain full of water until it reaches the level of one of the traps. The main drain should be so constructed as to be capable of resisting a pressure of at least 2-feet head of water. If after one or two hours there is no change in the level of the water, it may be considered sound; on the other hand, should it subside, leakage must be taking place either from broken pipes or imperfect joints. Soil pipes may be tested in the same way by plugging the drain at the junction, as well as the various closet connections. This test is a very severe one. Or, the drain may be filled with smoke by a forcing apparatus, when the situation of a leak will be detected by the presence of the smoke—smoke rockets have been recently introduced for this purpose; also glass grenades charged with pungent chemicals (Banner's patent). The simplest method, perhaps, is to pour down the pipe, at the highest part, an ounce of oil of peppermint with a few gallons of hot water; as this is a very volatile oil, there is no difficulty in tracing whence the odour is emitted, and so detecting any leak.

Yard traps are often very foul, and if the trap-water be stirred, gas bubbles out, which is a sign of great foulness or that the traps are seldom used.

Sewers are conduits employed to remove waste water and waste products suspended in water from houses, or to carry away rain. Among the waste products may be the solid and liquid excreta of men and animals, or the refuse of trade and factory operations. Or sewers may be used merely for the conveyance of dirty house water, without the admixture of excreta or trade refuse.

It is quite impossible that any town or even any large number of houses can be properly freed of its waste water without sewers, and in more or less perfect condition they are to be found not only in all modern but in most ancient cities. Originally, no doubt, they were mere surface channels, as they are still in many towns; but for the sake of appearance and inoffensiveness, the custom must have soon arisen of placing them underground, nor in modern towns could they now be arranged otherwise. In some large towns there are many miles of sewers constructed often with great skill and science; these serve in some instances as the channels not only for rain, but for natural streams which have been enclosed.

The sewers form thus in the subsoil of towns a vast network of tubes, connecting every house, and converging to a common outlet where their contents may be discharged.

In some towns the sewers carry away none of the solid excreta, though probably urine enters in all cases. In most towns, however, solid excreta in greater or less quantity enter, owing especially to the prevalent use of water-closets, or to the drainage of middens and manure heaps.

Whether the solid excreta pass in or not, the liquid in the sewers must always contain either suspended or dissolved animal or vegetable matters derived from the refuse of houses. It is generally warmer than the water of streams, and is of no constant composition: sometimes it is very turbid and highly impure; in other cases it is hardly more impure than the water of surface wells. The suspended matters are, however, generally in larger proportion than the dissolved.

In some cases the sewer water is in greater amount than the water supplied to the town and the rainfall together. This arises from the subsoil water finding its way into the sewers.

One ton of London or Rugby sewage contains only from 2 ℔ to 3 ℔ of solid matter (Lawes). One ton of Southampton sewage contains about 2 ℔ dissolved and 1¼ ℔ to 1½ ℔ suspended matter.

The average composition of sewer water in towns with water-closets is: organic matter, 39·6; nitrogen, 8·87; phosphoric acid, 2·24; potash, 2·9 parts per 100,000.

The Rivers Pollution Commissioners give 7·728 parts per 100,000 of total combined nitrogen, 6·703 of ammonia, and 10·66 of chlorine.

Under the microscope, sewage contains various dead decaying matters, and, in addition, large numbers of *Bacteria* and amœbiform bodies, as well as ciliated infusoria. *Fungi*, especially *Paramecia* (spores and mycelium), are seen, but there are few *Diatoms* or *Desmids*, and seldom any of the forms of higher animal life.

The sewers of a town are for the most part used also to carry off the rainfall, and, indeed, before the introduction of water-closets they were used only for this purpose and for taking away the slop and sink water of houses. In countries with heavy rainfall, and in this country in certain cases, the rainfall channels are distinct from the sewers, and often having their outfalls in an entirely different direction. This arrangement is sometimes called the "separate system."

The separate system consists in providing two separate channels; one to carry off the rain and storm waters, the washing of streets and open spaces; the other to carry off the sewage. The former discharge their contents into the nearest river or water-course; the latter will convey the sewage to be treated in some one of the methods described subsequently. The advantages claimed for this are that smaller sewers are required, and that the amount of sewer-water is less, richer in quality and more regular in flow; no storm-waters enter the sewers to flood the lower districts of a town, and no road detritus is washed into the sewers. The disadvantages are that separate channels have to be provided, and rain-water washes away much that would pollute a stream; the scouring effect of rain on sewers is also lost, but this is a doubtful objection. Adoption of either plan must depend on local circumstances. This method will be considered further subsequently.

Whether the solid excreta are allowed to pass in or not, it is clear that the dirty water of the sewers must in some way be disposed of. It is in every case more or less impure, containing animal and vegetable substances in a state of commencing decay, which pass readily into putrefaction. The readiest mode of getting rid of it is to pass it into streams, where it is at once subjected to the influence of a large body of water, and where the solid matters become either slowly oxidised, or form food for fishes or water plants, or subside. Although from an early period streams were thus contaminated and their water, originally pure, was thus rendered unfit for use, it is only lately that a strong opposition has arisen to the discharge into streams. This is owing partly to the greater pollution and nuisance caused by the more common use of water-closets and the largely increasing trade of the country, which causes more refuse to be sent in, and partly to the evidence which has been brought forward of the diseases which are caused by drinking water made impure in this way. To prevent the nuisance and danger caused by the pollution of streams, many actions at law have been brought, and in some cases special Acts of Parliament have forbidden the discharge of sewer-water into certain rivers until after efficient purification. The Rivers Pollution Act of 1876 now deals with the question, its provisions having come into operation on the 15th August 1877. This Act has been further amended (1893) so as in future to prevent the pollution of any river. If sewage is now conveyed into any stream, after passing through a sewer vested in a sanitary authority, no matter when the sewer was constructed, it is an offence for the sanitary authority to continue to allow its passage into the stream.

There is now probably a general agreement as to the principle on which this difficult question should be dealt with. Animal substances in a state of decay can be best prevented from contaminating the air, the soil, or the water of streams by imitating the operations of nature. In the endless cycle of physical change, decaying animal matters are the natural food of plants, and plants again form the food of animals.

It so happens that, with the exception of some mineral trades, the waste products of which are hurtful to agriculture, many of the substances contained in the sewage of our towns are adapted for the food of plants, and we seem to be on sure ground when we decide that it must be correct to submit these matters to the action of plant life, and thus to convert them from dangerous impurities into wholesome food.

The difficulty is, however, with the application of the principle, and at the present moment there is the utmost diversity of opinion on this point. It seems, however, that we may divide the opinions into two classes. According to one opinion, the proper mode is to bring the waste water of towns, when it contains fertilising matters, at once to the ground, and, after the arrest of substances which may block the pipes, to pour it over the land in such a way as may be best adapted to free it from its impurities and to bring it most rapidly and efficiently under the influence of growing plants.

The other opinion objects to this course on two grounds,—first, that the substances are not brought to the ground in the most convenient form for agriculture, and also that the plan entails evils of its own, arising from the immense quantity of water brought upon the land, and from the difficulty of efficient management. The advocates of this second view would, therefore, use some plan of separating the impurities of the water, and would then apply them in a solid form to the land, or use them for some other purpose, as in General Scott's plan of adding the materials for cement and then making this substance. The purified water would then be filtered through land, or passed into streams, without further treatment.

In the case of the sewage containing materials not adapted for agriculture, both parties would deal with it in the same way, viz., purify it by chemical agencies or filtration, and then allow the water to flow off into streams, while the solid products would be disposed of in the most convenient way.

These general views apply to any sewer water, whether it contains solid excreta or not, although if these excreta can be perfectly excluded the sewer water is less offensive, though not much so, when the volume of water is large. It has hitherto been often poured into streams without previous purification, but now this practice is prohibited by law, with certain reservations.

In any system for the removal of excreta by water, it is obvious that certain conditions of success must be present, without which this plan, so good in principle, may utterly fail. These conditions are, that there shall be a good supply of water, good sewers, ventilation, a proper outfall, and means of disposing of the sewage. If these conditions cannot be united, we ought not to disguise the fact that sewers, improperly arranged, may give rise to no inconsiderable dangers. They are underground tubes, connecting houses, and allowing possibly, not merely accumulation of excreta but a ready transference of gases and organic molecules from house to house, and occasionally also causing, by bursting, contamination of the ground, and pollution of the water-supply. And all these dangers are the greater from being concealed. It is probably correct, as has been pointed out, that in deep-laid sewers the pressure inwards of the water of the surrounding soil is so great as frequently to cause an overflow *into* the sewer, and so prevent the exit of the contents; but, in other cases, the damage to the sewer may be too great to be neutralised in this way, and, in the instance of superficially laid and choked-up pipes, the pressure outwards of the contents must be considerable. These defects of sewers are now obviated, by using good material, having better construction, good ventilation, sufficient water-supply, and adequate means of sewage disposal.

Engineers are by no means agreed as to the quantity of water required for preventing deposits in sewers intended for the removal of excreta. Twenty-five gallons per head per diem, on the authority of Brunel, is the amount required to keep common sewers clear, and even with this amount there should be some additional quantity for flushing. But in some cases a good fall and well-laid sewers may require less, and in other cases bad gradients or curves or workmanship may require more. It is a question whether rain-water should be allowed to pass into sewers; it washes the sewers thoroughly sometimes, but it also carries débris and gravel from the roads, which may clog; while in other cases storm waters may burst the sewers, or force back the sewage. To obviate this, storm overflows have to be provided; of these there are about fifty within the metropolitan area, to relieve the low-level sewers on both sides of the Thames.

Main Sewers.—House drains end in a channel or sewer which is common to several drains and is of larger size. These sewers, up to 18 inches in diameter, are generally made of well glazed earthenware pipes; for larger sewers well-burnt impervious brick is used, moulded in proper shape, and set in Portland cement or concrete.

The surface should be rendered in pure Portland cement to a perfectly smooth face, and in case of brick culverts the rendering should be carried up to at least one-half their depth. Engineers take the greatest care with these brick sewers; they are most solidly put together in all parts, and are bedded on a firm unyielding bed. Much discussion has taken place as to their size, but the question is so complicated by the admission of rain-water, that it is difficult to lay down any fixed rule, at least as regards the main channels. All other sewers, however, should be small, and with such a fall as to be self-cleansing.

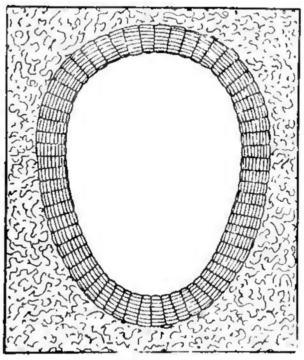


Fig. 94.

The shape now almost universally given, except in the largest outfall part, is that of an egg with the small end downwards, so that the invert is the narrowest part (fig. 94). The object of this is to secure the maximum scouring effect with a small quantity of water. When the quantity of sewage is small the lesser diameter of the invert of the egg-shaped sewer affords a better scouring power than the larger diameter of an equivalent circular sewer, while the increased size of the former conduit affords the requisite space for an increasing outflow. The best form of egg-shaped sewer is where the horizontal diameter is two-thirds of the vertical height, the radius describing the invert being one-fourth the horizontal diameter.

The semi-circle drawn upon the horizontal diameter becomes the upper part of the sewer, while the segment drawn on the radius forms the invert.

Pipes for conveying sewage should have their joints set in cement to prevent leakage. With an ordinary socket joint tarred gasket should be used to prevent the cement entering the joint; each joint should be carefully examined on the inside, and any cement that may have been pushed into the interior removed before the next length of pipe is laid, so as not to obstruct the proper flow of sewage. The joints of pipes set in cement cannot be opened for examination in case of stoppage without breaking one of the pipes; to obviate this, Doulton has introduced a self-adjusting joint in which no cement is required, and which is not supposed to be injured by settlement.

Another joint is Archer's patent air and water-tight joint; a luting of clay is first introduced and the spigot of one pipe is pressed into the socket of the other; liquid cement is then poured in at an opening in the top of the socket after the pipes have been adjusted. The clay merely prevents the cement from entering the interior of the pipes.

Sewers should be laid in as straight lines as possible, with a regular fall; tributary sewers should not enter at right angles, but obliquely; and if the sewer curves, the radius of the curve should not be less than ten times the cross-sectional diameter of the sewer.

Sewers of unequal sectional diameter should not join with level inverts, but the lesser, or tributary sewer, should have a fall into the main sewer at least equal to the difference in the sectional diameter. If a man-hole is used for a junction, the bottom can always be constructed so as to give the required curve in the direction of the flow of the current.

Calculation of the Velocity of Flow in Sewers and of their Discharge.—In order to prevent deposit in sewers from 6 to 9 inches in diameter a velocity of not less than 3 feet per second should exist; for sewers of 12 to 24 inches the velocity should not be less than $2\frac{1}{2}$ feet per second, and for larger sewers 2 feet per second. These velocities would require a fall of from 1 in 140 to 1 in 200 for pipes from 6 to 9 inches in diameter, and of 1 in 400 to 1 in 800 for pipes from 12 to 24 in diameter, and for larger sewers 1 in 244 to 1 in 784 according to size. The fall should be equable without sudden changes in level.

In some cases a fall is almost impossible to obtain, as, for instance, at Southport, in Lancashire, where the ground is nearly a dead level. The fall there is about 1 in 5000, and never exceeds 1 in 3000. In such a case the drain would have to be cleaned either by locks or valves (flushing-gates) to retain a portion of the contents for a time, and then set them free suddenly in order to flush the next section, or by special arrangements, such as Field's flush-tank, or Shone's ejector.

To calculate the discharge from sewers, several formulæ have been given, of which the following is the most simple:—

$$V = 55 \times (\sqrt{D \times 2F}).$$

V = velocity in feet per minute.
D = hydraulic mean depth in feet.
F = fall in feet per mile.

Then, if A = section area of current of fluid, VA = discharge in cubic feet per minute.

To use this formula, the hydraulic mean depth when the sewage is flowing, and the amount of fall in feet per mile, must be first ascertained. The "hydraulic mean depth" is the section area of current of fluid divided by the wetted perimeter. In circular pipes it is always $\frac{1}{4}$th the diameter, whether running full, half full, or otherwise.

This may be shown thus: Let r = the radius of section: then the perimeter $= \pi 2r$, and the section of fluid (or area of circle) $= \pi r^2$, then $\frac{\pi r^2}{\pi 2r} = \frac{r}{2}$, *i.e.*, $\frac{1}{2}$ the radius or $\frac{1}{4}$ the diameter.

Example.—Let the sewer be 12 inches in diameter and circular in shape; then the hydraulic mean depth is 3 inches or 0·25 of a foot; let the fall in feet per mile be 73; then we have $55 \times \sqrt{\cdot 25 \times 146} = 333$ feet per minute velocity; then the sectional area of the pipe running full = 0·7854 of a square foot, and 0·7854 × 333 = 261 cubic feet discharged per minute.

In egg-shaped sewers, the hydraulic mean depth varies with the volume of water flowing through them, but in sewers constructed on the usual plan, where the transverse diameter is $\frac{2}{3}$ of the vertical, the hydraulic mean depth is as follows:—

Running full,	transverse	diameter	× 0·2897
$\frac{2}{3}$ full,	,,	,,	× 0·3157
$\frac{1}{3}$ full,	,,	,,	× 0·2066

The "wetted perimeter" is that part of the circumference of the pipe wetted by the fluid. In an egg-shaped sewer under these three conditions it equals the transverse diameter multiplied by 3·9649, 2·3941, and 1·3747 respectively. The fall in feet per mile is easily obtained, as the fall in 50 or 100 or 200 feet can be measured, and the fall per mile calculated (5280 feet = 1 mile).

This may be done by dividing 5280 by the denominator of the fraction; thus a fall of 1 foot per mile is 1 in 5280, a fall of 1 in 100 = 52·80 feet per mile; 1 in 30 $= \frac{5280}{30} = 176$ feet per mile, and so on.

The following table taken from Wicksteed shows the velocity in feet per mile and the gradient required for pipes of various diameters:—

Sewers.

Diameter.	Velocity in feet per minute.	Gradient required.		
4 inches	240	1	in	36
6 ,,	220	1	,,	65
8 ,,	220	1	,,	87
9 ,,	220	1	,,	98
10 ,,	210	1	,,	119
15 ,,	180	1	,,	244
18 ,,	180	1	,,	294
21 ,,	180	1	,,	343
24 ,,	180	1	,,	392
30 ,,	180	1	,,	490
36 ,,	180	1	,,	588
48 ,,	180	1	,,	784

To show the inclination required to produce different velocities in pipes, Baldwin Latham gives the following table:—

Diameter in inches.	Rate of Inclination for Velocity per second.				
	2 feet.	3 feet.	4 feet.	5 feet.	6 feet.
4	1 in 194	1 in 92	1 in 53	1 in 34	1 in 24
6	292	137	80	51	36
8	389	183	106	69	48
9	437	206	119	77	54
10	486	229	133	86	60
12	583	275	159	103	72

In this table the velocity in feet multiplied by the inclination equals the length of the sewer to which the calculation applies.

Example.—If the velocity is 6 feet per second in a pipe whose diameter is 4 inches, then 6 × 24 = 144 feet is the length of the sewer.

Bailey-Denton has calculated the discharge from different sized pipes running full at different velocities and the fall required to produce these velocities; these are given in the following table:—

Diameter of Pipe.	180 ft. per minute, 3 ft. per second.		270 ft. per minute, 4½ ft. per second.		360 ft. per minute, 6 ft. per second.		540 ft. per minute, 9 ft. per second.	
Inches.	Fall.	Gallons per minute.	Fall.	Gallons per minute.	Fall.	Gallons per minute.	Fall.	Gallons per minute.
3	1 in 60	54	1 in 30·4	81	1 in 17·2	108	1 in 7·6	162
4	1 in 92	96	1 in 40·8	144	1 in 23·0	192	1 in 10·2	288
6	1 in 138	216	1 in 61·2	324	1 in 34·5	432	1 in 15·3	648
9	1 in 207	495	1 in 92	742·5	1 in 51·7	990	1 in 23·0	1485

Beardmore states that the following bottom velocities have the effect stated on the different materials particularised:—

30 feet per minute will not disturb clay with sand and stones.
40 ,, ,, move along coarse sand.
60 ,, ,, ,, fine gravel, size of peas.
120 ,, ,, ,, rounded pebbles 1 inch diameter.
180 ,, ,, ,, angular stones 1¾ inch diameter.

Movement of Air in Sewers, and Ventilation.—It seems certain that no brick sewer can be made air-tight; for on account of the numerous openings into houses, or from leakage through brickwork, or exit through gratings, man-holes, and ventilating shafts, the air of the tubes is in constant connection with the external air. There is generally, it is believed, a current of air with the stream of water, if it be rapid. The tension of air in main sewers is seldom very different from that of the atmosphere, or if there be much difference equilibrium is quickly restored. In twenty-three observations on the air of a Liverpool sewer, it was found by Parkes and Burdon-Sanderson that in fifteen cases the tension was less in the sewer than in the atmosphere outside (*i.e.*, the outside air had a tendency to pass in), and in eight cases the reverse; but on the average of the whole there was a slight indraught into the sewer. In the London sewers, on the other hand, Sanderson noticed an excess of pressure in the sewers.

Reeves believes that temperature is an important factor in influencing the movement of air in sewers; when the temperature of the sewer, and that of the outside air, is the same or nearly so, stagnation follows.

If at any time there is a very rapid flow of water into a sewer, as in heavy rains, the air in the sewer must be displaced with great force, and possibly may force weak traps; but the pressure of air in the sewers is not appreciably affected by the rise of the tide in the case of seaboard towns. The tide rises slowly, and the air is displaced so equably and gradually through the numerous apertures, that no movement can be detected. It is not possible, therefore, that it can force water traps in good order, when there are sufficient ventilating apertures.

On the contrary, the blowing off of steam, or the discharge of air from an air-pump (as in some trade operations), greatly heightens the pressure, and might drive air into houses. So also the wind blowing on the mouth of an open sewer must force the air back with great force.

It is, therefore, important to protect the outfall mouth of the sewer against wind by means of a flap, and to prohibit as far as possible steam or air being forced into sewers.

To how great an extent the openings into houses thus reduce the tension of the air in main sewers it is difficult to say, but there can be little doubt that a large effect is produced by houses which thus act as ventilating shafts.

When a sewer ends in a *cul-de-sac* at a high level, sewer gas will rise and press with some force; at least in one or two cases the opening of such a *cul-de-sac* has been followed by so strong a rush of air as to show that there had been considerable tension. It is also highly probable from the way in which houses, standing at the more elevated parts of sewers and communicating with them, are annoyed by the constant entrance of sewer air, while houses lower down escape, that some of the gases may rise to the higher levels.

That no sewer is air-tight is certain, but the openings through which the air escapes are often those we should least desire. It is, therefore, absolutely necessary to provide means of exit of foul and entrance of fresh air, and not to rely on accidental openings. The air of the sewer should be placed in the most constant connection with the external air, by making openings at every point where they can be put with safety. In London there are numerous gratings which open directly into the streets, and this plan, simple and apparently rude as it is, can be adopted with advantage wherever the streets are broad; the openings should be in the middle of the roadway, and not near the pavement. But in narrow streets, or when too near the pavement, the sewer gratings often become so offensive that the inhabitants stop them up. In such cases there must be ventilating shafts of as large a diameter as can be afforded, running up sufficiently high to safely discharge the sewer air. In some of these cases it may be possible to connect the sewers with factory chimneys. The sewer should never be connected with the chimneys of dwelling-houses. It has been suggested that pipes should be carried up through the street gas lamps, for the purpose of ventilating the sewers, so that the sewer air would be subjected to the gas flame, and rendered innocuous, and a constant current kept up.

In making openings in sewers it seems useless to follow any regular plan. The movement of the sewer air is too irregular to allow us to suppose it can ever be got to move in a single direction, though probably the most usual course of the air current is with the stream of water, if this be rapid. The openings should be placed wherever it can conveniently be done without creating a nuisance. Some of these openings will be inlets, others outlets, but in any case dilution of the sewage effluvia is sure to be obtained.

Rawlinson considers that every main sewer should have one ventilator every 100 yards, or 18 to a mile, and this should be a large effective opening.

But there may be cases when special appliances must be used. For example, in what are called "sewers of deposit," as when the outflow of the sewer water is checked for several hours daily by the tide or other causes, it may be necessary to provide special shafts, and the indication for this will be the evidence of constant escape of sewer air at particular points.

The use of *charcoal trays* has not answered the expectations that were formed of them. Their use is now discontinued.

It is of importance that, to all sewers capable of being entered by a man, there should be an easy mode of access. Man-holes opening above, or, what is better, at the side, should be provided at such frequent intervals that the sewers can be entered easily and inspected at all points. The man-holes are sometimes provided with an iron shutter to prevent the sewer air passing into the street, or by the side of the man-hole there may be a ventilating chamber.

Objections to Sewers.—The main objections are as follows:—

1. *That, as underground channels connecting houses, they allow transference of effluvia from place to place.*—The objection is based on good evidence, but it must be said in reply that, if proper traps are put down, and if air disconnection, in addition, is made between the outside drains and the house pipe, such transference is impossible. The objection is really against an error of construction, and not against the plan as properly carried out. Besides, the objection is equally good against any kind of sewer, and yet such underground conduits are indispensable.

2. *That the pipes break and contaminate the ground.*—This is a great evil, and it requires care to avoid it. But such strong pipes are now made that, if builders would be more careful to make a good bed and to connect the joints firmly, there would be little danger of leakage, as far as the pipe drains are concerned, and not much damage of the main brick sewers. All pipes, however, ought to be actually and carefully tested after being laid and before being covered in, otherwise it is impossible to insure their being water-tight, even when everything is sound to all appearance.

3. *That the water-supply is constantly in danger of contamination.*—This also is true, and as long as overflow pipes from cisterns are carried into sewers, and builders will not take care to make a complete separation between water pipes and refuse pipes, there is a source of danger. But this is again clearly an error in constructive detail, and is no argument against a proper arrangement.

Inspection of Sewers.—The inspection of sewers is in many towns a matter of great difficulty, on account of the means of access being insufficient, and also because the length of the sewers is so great. Still inspection is a necessity, especially in the old flat sewers, and should be systematically carried out, and a record kept of the depth of water, the amount of deposit, and of sewer-slime on the side or roof.

Choking of and deposits in sewers are due to original bad construction, too little fall, sharp curves, sinking of floor, want of water, check of flow by tides; all these conditions favour the subsidence of suspended matters.

Well-made sewers with a good supply of water are generally self-cleansing, and quite free from deposit, but this is, unfortunately, not always the case.

Even in so-called self-cleansing sewers, it has been noticed by Rawlinson that the changing level of the water in the sewers leaves a deposit on the sides, which, being alternately wet and dry, soon putrefies. In foul sewers a quantity of slimy matter collects on the crown of the sewers; it is sometimes from 2 to 4 inches in thickness, and is highly offensive. When obtained from a Liverpool sewer by Parkes and Burdon-Sanderson, it was found alkaline from ammonia and containing nitrates. On microscopic examination, this Liverpool sewer-slime contained a large amount of fungoid growth and *Bacteria*. There were also *Acari* and remains of other animals and ova.

When deposits occur, they are either removed by the sewer-men or they are carried away by flushing of water.

Flushing of Sewers.—This is sometimes done by simply carrying a hose from the nearest hydrant into the sewer, or by reservoirs, provided at certain points, which are suddenly emptied. The sewage itself is also used for flushing, being dammed up at one point by a flushing gate, and when a sufficient quantity has collected the gate is opened. An automatic system is, however, preferable, such as is carried out by Field's annular siphon, before mentioned, or by Shone's ejector.

Almost all engineers attach great importance to regular flushing, and practically the only advantage of allowing the rain to enter the sewers is the scouring effect of a heavy rainfall which is thus obtained. This, however, is so irregular that it is but a doubtful benefit. Where there is no deposit, foul gases are not generated. This is shown in the case of Bristol, where the main sewer is neither ventilated nor flushed, and is stated to require neither the one nor the other, there being no deposit nor accumulation of foul gas.

DISPOSAL OF SEWAGE.

The difficulty of the plan of removing excreta by water really commences at the outfall.

This difficulty is felt in the case of the foul water flowing from houses and factories without an admixture of excreta almost as much as in sewer water with excreta. The exclusion of excreta from sewers, as far as it can be done, would not solve the problem—would, indeed, hardly lessen its difficulty. In seaboard towns the water may flow into the sea, but in inland towns it cannot be discharged into rivers, being now prohibited by law. Independent of the contamination of the drinking water, sewage often kills fish, creates a nuisance which is actionable, and in some cases silts up the bed of the stream. It requires in some way to be purified before discharge. At the present moment the disposal of sewage is the sanitary problem of the day, and it is impossible to be certain which of the many plans may be finally adopted. It will be convenient to briefly describe these plans.

Storage in Tanks—Cesspits.—The sewage runs into a cemented tank with an overflow pipe, which sometimes leads into a second tank similarly arranged. The solids subside, and are removed from time to time; the liquid is allowed to run away. Instead of letting the liquid run into a ditch or stream, it has been suggested to take it in drain pipes, ½ to 1 foot under ground, and so let it escape in this way into the subsoil, where it will be readily absorbed by the roots of grasses. The fat, grease, and coarser solids should be intercepted in a proper trap, and removed as found necessary. The liquid portions may be discharged periodically by means of an automatic flush-tank. In a light soil this could no doubt be readily done; and if the drain pipes are well laid, a considerable extent of grass land could be supplied by this subterranean irrigation. The tank plan is, however, only adapted for a small scale, such as a single house or small village, and there should be ventilation between the tank and the house in all cases. This plan is applicable to the disposal of slop waters in villages, even when the excreta are dealt with by dry methods.

This is really a modification of the old *cesspit* plan, which is still in use in most rural districts; but unless the cesspit is at a considerable distance from any habitation, and far removed from all sources of water-supply, it should be replaced by a cemented tank. In any case, ventilation and complete disconnection are absolutely necessary.

Discharge into the Sea.—This method consists of the direct discharge of the sewage at ebb tide, so as to carry out the sewage to a distance from the shore, and diffuse it into the sea before the tide begins to flow. Where tidal currents exist, the point of discharge should be situated below the place in the direction of the falling tide and not above it.

The greatest difficulty with such outfalls is at low water. As the flow of sewage in sewers towards the outfall is continuous, the best method is to conduct the sewage into a tank or reservoir, where it can be stored, and discharged into the sea at suitable states of the tide. This plan has recently been adopted at Margate.

Sewage should not be discharged into tidal estuaries, as it is never carried any great distance away from the shore, owing to currents and the rise of the tide; the sewage is very frequently taken back and deposited near the outfall or on the foreshore. This system is only available for a limited number of places situated near the sea coast, and cannot be employed for the disposal of sewage of inland towns.

Precipitation.—This process consists in collecting the sewage in tanks, thus allowing a large volume to remain comparatively quiescent, so that the solid particles subside. In order to produce greater purification, the sewage in the subsiding tanks is mixed with some chemical agent or precipitant. The solids formed, in settling, take down with them the suspended matters in the sewage together with some of the dissolved organic impurities; the proportion, of course, varies with the amount of solid matters precipitated. The effluent from the tanks then flows at once into a river or stream, or may be passed over land, or be filtered through it. A large number of methods have been suggested in order to secure adequate precipitation.

The Lime Process.—The purest lime only should be used. Before being added to the sewage, it must be reduced to the "milky" condition and thoroughly incorporated with the sewage. The quantity of lime required is 1 ton to each million gallons of sewage (15·68 grains per gallon), but the tendency is to reduce the quantity of lime to the smallest effective amount, since an alkaline effluent is liable to undergo putrefaction. Lime and chloride of lime are said to be good precipitants; one-third of a grain of chloride of lime per gallon prevents the growth of sewage fungus; it is especially useful in hot weather.

Lime and Sulphate of Alumina.—The quantity of lime added first to the sewage should be just sufficient to make it slightly alkaline—probably from 5 to 7 grains per gallon will be required; it should be added in the form of milk of lime, and thoroughly mixed with the sewage. A solution of crude sulphate of alumina is then added and the sewage again stirred. In the alkaline sewage the alumina will be precipitated, and, combining with the organic matter, will form a bulky insoluble precipitate which deposits in the tanks.

Lime and Proto-Sulphate of Iron.—This process is used by the London County Council in connection with the metropolitan sewage. The quantities recommended are 3·7 grains of lime in solution, and 1 grain of proto-sulphate of iron per gallon of sewage. This method of precipitation is said to be a good one, and produces a fairly clean effluent, but the smell often is so disagreeable that it cannot be discharged into the river during warm weather at all states of the tide. Dibden proposes to use manganate of soda and sulphuric acid in order to destroy any offensive odour after chemical precipitation.

Lime and Black-ash Waste.—This is the residue from the manufactures carried on at alkali works, and is used in conjunction with lime. At Wimbledon, where this process was tried, it was found that, while the sludge was greatly increased in quantity, the effluent was not appreciably affected.

The A B C process (Sellar's patent) consists in the addition of a mixture of alum, charcoal or refuse from prussiate works, and clay. Blood was at one time employed, but is not found to be necessary and is sometimes omitted. The alumina precipitated by the lime forms a very bulky precipitate, well suited to the entanglement of suspended matters. The clearance of the sewage is more perfect than with lime alone, but otherwise the process and the objections are the same, while the cost is greater. The whole of the phosphoric acid is precipitated as aluminum phosphate. To a gallon of sewage water there should be added 73½ grains of aluminum sulphate, 3½ grains of sulphate of zinc, 73½ grains of charcoal, and 16¾ grains of quicklime. The manure from this process is perceptibly superior to that resulting from the lime process. The sludge is pressed in filter presses, and subsequently dried in steam cylinders and sold as a granular manure containing about 20 per cent. of moisture. The process is in operation at Aylesbury and Kingston-on-Thames, being carried on by the Native Guano Company.

Ferrozone and Polarite Process.—In this process, the introduction of the precipitating material "Ferrozone" is followed by the filtration of the effluent through polarite: this latter material consists of about 50 per cent. of magnetic oxide and carbide of iron combined with silica, lime, and alumina in an insoluble form. Ferrozone consists largely of proto-sulphate of iron. The process is now in use at Acton and Hendon.

Spencer's magnetic carbide of iron has also been used as a filtering medium for sewage effluents and yields very similar results.

The Amines Process.—This process consists in the employment of from 30 to 50 grains of lime per gallon of sewage and about 3 grains of herring brine; the volatile matters produced, composed of amines and ammonia, are passed into the crude sewage, which, it is said, is completely sterilised by this means. It is in use at Wimbledon Sewage Works and Farm.

Sulphate of iron was advocated by Conder as a precipitant; it is applied in direct proportion to the quantity of putrescible matter to be dealt with. It is said to destroy all smell and to render the effluent and precipitant inoffensive.

Character of the Effluent Water.—The effluent water from all these processes is merely clarified sewage; it contains ammonia, together with some soluble organic matter, as well as phosphoric acid, and it would thus appear that nearly the whole of the substances which give fertilising power to sewage remain in the effluent water.

When sewage is clarified by any of these plans and freed from suspended matters, it is not likely to cause a nuisance if discharged into a fairly rapid river, if the ordinary volume of water is considerably greater than the effluent. It is now universally recognised that it is unsafe to use any river or stream as a source of water-supply which has at any time received sewage or sewage effluents higher up in its course. It is even doubtful whether sewage can be sufficiently purified by filtration through land or other filtering media to render the water into which it is discharged a safe source for drinking water.

Many analyses are given in the *First* and *Second Reports of the Rivers Pollution Commissioners*, from which it appears that on an average the chemical processes remove 89·8 per cent. of the suspended matters, but only 36·6 per cent. of the organic nitrogen dissolved in the liquid. Crookes' analyses show that the A B C process, when well carried out, removes all the phosphoric acid. Voelcker's analysis of the effluent water treated by the acid phosphate of aluminum shows that it contains more ammonia than the original sewer water, less organic nitrogen by one-half, and less phosphoric acid. The clear fluid is well adapted for market gardens; the plants grown as vegetables for the table are sometimes injured by irrigation with unpurified effluent water.

Disposal of Sludge.—This is always a great difficulty. Efforts have been made, in connection with the chemical processes, to utilise the sludge as manure. The best method of utilising the sludge is by separating the liquid from the solid matter, so as to reduce the bulk as much as possible, and this should be done speedily, so as to allow of no putrefaction.

The deposit obtained from these processes is sometimes collected and dried on a hot floor, a stream of hot air being allowed also to pass over it. There is some little difficulty in drying it, and it is said to be expensive both in labour and fuel and there is a liability of nuisance through offensive odours. In Birmingham the sludge, after precipitation with lime, is conveyed by the main conduit to the land and disposed of by ordinary irrigation. One acre a week is used, upon which 500 tons of sludge a day are put. It is then cropped for three years before being again used. At Leyton, West Ham and elsewhere the sludge, which contains 90 per cent. of water, is pressed in patent presses and dried until it contains only 21 per cent. of moisture. It is then in the form of solid dry-looking cakes, which may be taken for laying on land, making cement, &c. At Southampton, ferrozone is used as a precipitating agent, the effluent is expelled into the river by a Shone's ejector, and the sludge by a similar process is projected to the corporation works, where it is mixed with road sweepings and ashes. This mixture finds a sale at 2s. 6d. a ton among the farmers in the neighbourhood. In general, the deposit appears to possess small agricultural value, although it is occasionally saleable. The price obtained rarely exceeds one-third of the theoretical or chemical value. Thus the product by Anderson's process at Coventry is estimated *theoretically* at 16s. 9½d. per ton; the practical value is only 5s. 6d. to 8s. 4d. The profit is not large, and in some instances there has been even a loss.

Another method of disposal is to burn the sludge in a "destructor." At Ealing, where this practice is adopted, no difficulty has been found in disposing of the refuse and sludge by means of the destructor, the mass being reduced to clinker one-fourth the bulk of the original. A special furnace is found necessary to destroy the gases generated on their passage from the furnaces to the chimney shaft.

Instead of using the dried deposit as manure, Scott proposed to make cement, and for this purpose added lime and clay to the sewer water. The deposit contains so much combustible matter that it requires less coal to burn it than would otherwise be the case. Scott also proposed to use the burnt material as manure to *lime* the land in some cases.

The plan recommended for the treatment of the Thames sewage, as given by the Royal Commissioners on Metropolitan Sewage Discharge, was to adopt some method of precipitation at the outfalls at Barking and Crossness, to compress the sludge into cakes, and as a temporary measure let the effluent pass into the Thames. The plan now adopted is as follows: the chemical precipitants are added to the sewage in covered reservoirs; it is then transferred from the precipitating tanks to special settling tanks, from thence the sludge is pumped into a specially designed steamship and discharged under water far from land. The clarified effluent flows into the Thames. As an alternative method the sludge, left in the bottom of the tank after precipitation, may be got rid of by allowing it to flow in a semi-solid condition in raised carriers on to land, and there distributed, being ultimately dug into and incorporated with the soil; or it may be subjected to hydraulic pressure, getting rid of a large part of the moisture, and made into solid cakes, which are sold as manure.

Intermittent downward filtration is defined by the Metropolitan Sewage Commission as "the concentration of sewage at short intervals on an area of specially chosen porous ground, as small as will absorb and cleanse it, not excluding vegetation, but making the produce of secondary importance." The intermittency of application is a *sine quâ non*, even in suitably constituted soils, whenever complete success is aimed at.

The purification of sewage by the soil is due to (1) the soil acting as a mechanical filter, removing the suspended matters in the sewage, and (2) to the oxidising power of the soil by which the organic matters are converted into nitrites, nitrates, and carbonates. This oxidising power is partly due to the air contained in the interstices of the soil, but chiefly to the presence of a nitrifying ferment in the soil, and more especially in rich surface soils, such as mould and loam. Nitrification is confined to the same range of temperature, which limits the vital activity of these micro-organisms; it almost ceases near the freezing point and increases in activity with a rise of temperature until 37° C. is reached; the action then diminishes and ceases altogether at 55° C. These organisms are confined to the upper layers of the soil and are most abundant in the first six inches. Other conditions necessary for the due performance of their function are a supply of air, and the presence of a salifiable base, such as lime, soda or potash, with which the nitric acid as formed may be combined. Dyke, in explaining the system as carried out at Merthyr-Tydvil, lays down the following conditions as essential to ensure success:—There should be—*1st*, a porous soil; *2nd*, an effluent drain, not less than 6 feet from the surface; *3rd*, proper fall of land to allow the sewage to spread over the whole land; and, *4th*, division of filtering area into four parts, each part to receive sewage for six hours, and to have an interval of eighteen hours. He considers that an acre of land would take 100,000 gallons per day, equal to the sewage of 3300 people. At Merthyr-Tydvil 20 acres of land were divided into five plots, which sloped towards the effluent drain by a fall of 1 in 150. The whole of the 20 acres thus divided was underdrained at a sufficient depth to secure aëration 6 feet below the surface. The surface was ploughed in ridges, on which vegetables were sown; the sewage (strained) passed from a carrier along the raised margin of each bed into the furrows. The effluent water was stated to be pure enough to be used for drinking purposes. Since 1872 broad irrigation has been carried on as well. Another case of marked success with intermittent filtration is that of Kendal. The best soil for filtration appears to be a loose marl, containing hydrated iron oxide and alumina, but sand and even chalk produce excellent results. But in order that filtration shall be successful it is necessary that the amount of filtering material shall be large; it must not be less than 1 cubic yard for 8 gallons of sewage in twenty-four hours, and in the case of some soils must be more. If the drains are 6 feet below the surface, then an acre will contain 9680 cubic yards of filtering material, and at 8 gallons per yard an acre would suffice for 77,440 gallons, or the sewage of 2580 people at 30 gallons a head. These views are, however, subject to some modification, since it has been more recently shown that all the oxidation is carried out in the first two, or at the outside three feet of depth. It would, therefore, seem as if we could not greatly increase the amount of sewage in proportion to the soil. Beds 3 feet in depth would probably be found sufficient, but in this case the superficial extent must be increased in proportion as the depth of the underdrainage is diminished, in order to secure the necessary quantity of filtering material for purification. Crops may be grown on the land, and indeed it is desirable that they should be. The Rivers Pollution Commissioners state that one acre is required to purify the sewage of 2000 persons. According to Tidy, 1 acre is sufficient for the sewage of from 5000 to 7000, if it has been previously efficiently precipitated.

Condition of the Effluent Water.—When 5·6 gallons of sewage were filtered in twenty-four hours through a cubic yard of earth, it was found by the Rivers Pollution Commissioners that the organic carbon was reduced from 4·386 parts to 0·734, and the organic nitrogen from 2·484 parts to 0·108 part in 100,000. The whole of the sediment was removed. Nitrates and nitrites, which were not present before filtration, are found afterwards, showing oxidation of organic matters. The chlorine, however, remains unchanged, remaining in very much the same proportion in the effluent as in the sewage. The effluent water is clear and bright; it generally attains a high standard of cleanliness, and may be allowed to pass into streams otherwise clean and unpolluted.

Irrigation.—By irrigation is meant "the distribution of sewage over a large surface of ordinary agricultural ground, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage supplied." It is essential that the sewage should not merely run over, but through, the land, before passing out as an effluent. For this purpose it is desirable that the sewage should be brought to the land in as fresh a state as possible. The sewage is usually warmer than the air at all times, and will often cause growth, even in winter.

The effect on growing plants, but especially on Italian rye-grass, is very great; immense crops are obtained, although occasionally the grass is rank and rather watery. For cereals and roots it is also well adapted at certain periods of growth, as well as for market vegetables when the viscid parts are separated. When the sewage permeates through the soil there occur—*1st*, a mechanical arrest of suspended matters; *2nd*, an oxidation producing nitrification, both of which results depend on the porosity and physical attraction of the soil, and on the influence of micro-organisms; and, *3rd*, chemical interchanges. The last action is important in agriculture, and has been examined by Bischof, Liebig, Way, Henneberg, Warrington, and others. Hydrated ferric oxide and alumina absorb phosphoric acid from its salts, and a highly basic compound of the acid and metallic oxide is formed. They act more powerfully than the silicates in this way. The hydrated double silicates absorb bases. Silicates of aluminum and calcium absorb ammonia and potassium from all the salts of those bases, and a new hydrated double silicate is formed, in which calcium is more or less perfectly replaced by potassium or ammonium. Humus also forms insoluble compounds with these bases. Absorption of potash or ammonia is usually attended with separation of lime, which then takes up carbonic acid.

The best kind of soil is a friable loam; but other soils, such as sands, gravels, &c., when properly managed, are capable of purifying sewage.

The soil must be properly prepared for sewage irrigation; either a gentle slope, or a ridge with a gentle slope on each side, of about 30 to 60 feet wide, with a conduit at the summit, or flat basins surrounded by ridges, are the usual plans. The sewage is allowed to trickle down the slope at the rate of about 8 feet per hour, or is let at once into the flat basin. The water passes through the soil, and should be carried off by porous earthenware underdrains 2 inches in diameter, from 4 to 6 feet deep, and from 20 to 100 feet apart, according to the porosity of the soil, and thence into the nearest water-course.

The sewage should reach the ground in as fresh a state as possible; it is usually run through coarse strainers (and this is always advisable) to arrest any large substances which find their way into the sewers, and to keep back the grosser parts which form a scum over the land; it is then received into tanks, whence it is carried to the land by gravitation, or is pumped up; but this latter procedure is costly. The "carriers" of the sewer water are either simple trenches in the ground, or brick culverts, or concreted channels, and by means of simple dams and gates the water is directed into one or other channel as may be required. Everything is now made as simple and inexpensive as possible—underground channels and jets, hydrants, hose and jets, are too expensive, and overweight the plan with unnecessary outlay.

The amount of land required is, on an average, 1 acre to 100 persons; this is equal to a square of 70 yards to the side, and will take 2000 gallons in twenty-four hours. Later experience seems to show that with proper management less land is required. At Croydon, the sewage is applied in the proportion of about 200 persons for each acre; the soil, however, is rather retentive, which causes the sewage to flow over the surface of the land rather than percolate through it, the greater part of the purification being accomplished by exposure to the air and the action of vegetation. The effluent is clean and free from suspended matter before it passes into the stream. The sewage is applied intermittently when the plants are growing; but in winter it is sometimes used constantly, so as to store up nourishment in the soil for the plant-growth in the spring.

In Paris, part of the sewage is treated by irrigation without precipitation. At Gennevilliers, 20 millions of cubic metres of sewage are pumped on to specially prepared land, on which vegetables, fruit trees, rye-grass, &c., are grown. The sewage never touches the vegetation growing in the irrigated ground. It is distributed throughout the entire plain by furrows, and the practice of flooding the land is not resorted to. The land is thoroughly underdrained, and the effluent issues in a clear and bright stream in which fish are preserved. It is intended to treat the whole of the sewage by this method as soon as the necessary works can be erected and sufficient land made available. The same system is adopted at Berlin. One acre of land suffices for the sewage of 142 people, but the very favourable subsoil of the Berlin farms must be taken into account, as light land can undoubtedly receive more sewage than heavy land. In irrigating the plots the sludge goes on to the land with the sewage, except that where grass plots are sewaged the sludge is intercepted in shallow catch pits, as the sludge is found to interfere with the growth of grass. When dry, it is dug out, and finds a ready sale among the farmers.

Condition of the Effluent Water after Irrigation.—When the sewer water passes over and not through the soil, it is often very impure, and even suspended matters of comparatively large size (such as epithelium) have been found in the water of the stream into which it flows. It requires, therefore, that care shall be taken in every sewage farm that the water shall not escape too soon. Letheby rated the cleansing power of soil much lower than the Rivers Pollution Commissioners or the Committee of the British Association, and his analyses make it at any rate quite certain that the proper purification of the sewage demands very careful preparation of the ground in the first instance, and constant care afterwards. But the chemical evidence of the good effect of irrigation is too strong to admit a doubt to exist. The following table shows the standard of purity which was proposed by the Rivers Pollution Commission:—

Standard of Rivers Pollution Commissioners. Maximum of Impurity permissible in 100,000 *parts by weight of the liquid.*

Dry mineral matter in suspension.	Dry organic matter in suspension.	Colour.	In Solution.					
			Organic carbon.	Organic nitrogen.	Any metal except Calcium, Magnesium, Potassium, or Sodium.	Arsenic.	Chlorine.	Sulphur as SH_2, or sulphate.
3	1	Shown in a stratum of 1 inch in a white plate.	2	0·3	2	0·05	1	1

A certain degree of acidity or alkalinity is also ordered not to be surpassed. The objection to the plan is not merely the doubt about the substances represented by organic carbon or nitrogen, but also because the standard does not take into consideration the volume of water into which the foul water flows.

The Thames Conservancy Commissioners adopt a standard for effluent sewage as follows :—

	Must not exceed in 70,000 parts.	In 100,000.
Suspended matters,	3 parts.	4·3
Total solids,	70 ,,	100·0
Organic carbon,	2 ,,	3·0
,, nitrogen,	0·75 ,,	1·1

The following table gives the results of analyses of the Berlin effluents :—

Berlin Effluents.	Average Percentage of Dissolved Organic Pollution removed.	
	As expressed in parts of Permanganate of Potash reduced.	Organic Ammonia.
Broad irrigation : grass plots. Average of 71 samples,	93·89	98·15
Filtration beds. Average of 76 samples,	92·56	97·72
,, tanks. ,, 36 ,,	82·60	94·83

These figures show the great purity of the Berlin effluents, and prove the satisfactory results that can be obtained from a large and well-managed sewage farm.

Sanitary condition of the Population living on Sewage Farms.—That sewage farms, if too near to houses and if not carefully conducted, may give off disagreeable effluvia is certain ; but it is also clear that in some farms this is very trifling, and that when the sewage gets on the land it soon ceases. All those who have visited the farms bear testimony to the absence of any smell in the fields, and only in one or two places near a sluice-outlet could any unpleasant smell be perceived when the sluices were opened. As regards health, it has been alleged these farms may—1*st*, give off effluvia which may produce *enteric fever*, or *dysentery*, or some allied affection ; or, 2*nd*, aid in the spread of *entozoic* diseases ; or, 3*rd*, make ground swampy and *marshy*, and may also poison wells, and thus affect health.

The evidence of Edinburgh, Croydon, Aldershot, Rugby, Worthing, Birmingham, Paris, Berlin, Romford and the Sussex Lunatic Asylum, is very strong against any influence in the production of enteric fever by sewage farms' effluvia. Clouston records an outbreak of dysentery in the Cumberland Asylum; but the disease in this case appears to have been caused by the inefficient manner in which the irrigation was carried out, rather than to the process itself. Sewage is still applied to the grounds of this asylum, and from 1874 to 1887 no disease or nuisance of any kind was caused by the sewage farm. Letheby also records an outbreak of enteric fever at Copley, when a meadow was irrigated with the brook water containing the sewage of Halifax.

The statistics of the population residing on the Berlin sewage farms is almost conclusive evidence that they do not exert any influence in the production of disease. The average annual population during the five years 1885–89 was 1580: of these 968 or 61 per cent. were men, 285 or 18 per cent. were women, and 327 or 21 per cent. were children under fifteen years of age. The death-rates per 1000 from all causes were 11·24 in 1885, 9·22 in 1886, 14·83 in 1887, 6·79 in 1888, and only 4·81 in 1889. Of the total deaths 16 per cent. occurred among men, 9 per cent. among women, and 75 per cent. among children. The death-rate from the seven principal zymotic diseases was 4·32 in 1885, 3·69 in 1886, 4·15 in 1887, 1·13 in 1888, and nil in 1889, the mean rate during the period from these causes being 2·53. Only one death was due to enteric fever during the period under review.

Evidence of this kind is so strong as to justify the view that the effluvia from a well-managed sewage farm do not produce enteric fever or dysentery, or any affection of the kind. At Eton, where some cases of enteric fever were attributed to the effluvia, Buchanan discovered that the sewer water had been drunk; this was probably the cause of the attack.

With regard to the second point, the spread of entozoic diseases by the carriage of the sewage to the land was at one time thought probable, though as solid excreta from towns have been for some years largely employed as manure, it is doubtful whether the liquid plans would be more dangerous. The special entozoic diseases which it is feared might thus arise are *Tapeworms*, *Round worms*, *Trichina*, *Bilharzia*, and *Distomum hepaticum* in sheep. Cobbold's latest observations showed that the embryos of *Bilharzia* die so rapidly that, even if it were introduced into England, there would be little danger. The *Trichina* disease is only known at present to be produced in men by the worms in the flesh of pigs which is eaten, and it is at least doubtful whether pigs receive them from the land. There remain, then, only *Tapeworms* and *Round worms* for men and *Distomum hepaticum* for sheep to be dreaded. But, with regard to these, until positive evidence is produced, this argument against sewage irrigation may be considered to be unsupported. It is not improbable that alkaline sewage may destroy organisms, like the ova of tapeworms, whose natural habitat is the acid secretion of the human intestine. An epidemic of "Enterocolitis," due apparently to the presence of *Trichocephalus*, occurred at Pierrefeu (Var) amongst the patients of an asylum. Between Jan. 1888 and March 1889 there were 137 cases amongst the inmates (more than half), together with 17 *employés*. There was no epidemic outside the asylum. It was attributed to the watering of the gardens with sewage water; the use of the vegetables was stopped, and the illness ceased.

The third criticism appears to be true. Unless the system is properly carried out the land may become swampy, and the adjacent wells polluted, and possibly disease be thus produced. But this is owing to mismanagement, and when a sewage farm is properly arranged it is not damp and the wells do not suffer.

MODIFICATIONS OF THE WET METHOD OF REMOVING EXCRETA.

The Separate System.—By this term is meant the arrangement which carries the rain-water in separate channels into the most convenient watercourse. Ward's celebrated phrase, "the rain to the river, the sewage to the soil," is the principle of this plan. Its advantages are that the sewers can be smaller; that the amount of sewer water to be dealt with at the outflow is much less in quantity, more regular in flow, more uniform in composition, and richer in fertilising ingredients, and is, therefore, more easily and cheaply disposed of. The grit and débris of the roads also are not carried into the sewers; and the storm waters never flood the houses in the low parts of the town.

The disadvantages are, that separate channels and pipes have to be provided for the rain; that the rain from all large cities carries from roofs and from streets much organic débris which pollutes streams, and that the scouring effect of the rain on sewers is lost, though this last is a very questionable objection.

The adoption of one or other system will probably depend on local conditions. If a town in Europe lies low, and it is expensive to lift sewage; if land cannot be obtained; or if the natural contour of the ground is very favourable for the flow of rain in one direction, while it is convenient to carry the sewage in another, the separate system would be the better. So also in the tropics, with a heavy rainfall and a long dry season, the providing of sewers large enough to carry off the rain would be too expensive for all except the richest cities, and the disposal of the storm water would be difficult.

In all cases in which rain enters the sewers, some plan ought to be adopted for storm waters. If irrigation is the plan carried out, the sewage becomes so dilute and so large in quantity in storms, that the application to land is usually suspended, and the sewage is allowed to pass at once into streams.

In this way the evil which irrigation is intended to prevent is produced, though, doubtless, the sewage is highly dilute. In London the storm waters mingled with sewage are allowed to flow into the Thames, special openings being provided.

The Liernur System.—A Dutch engineer, Captain Liernur, proposed some years since an entirely novel plan. No water or deodorising powders are used; the excreta fall into a straight earthenware pipe, leading to a smaller iron siphon pipe, from which they are extracted periodically by exhaustion of the air. The extracting force which can be used (by an air pump worked by a steam engine) is said to be equal to a pressure of 1500 ℔ per square foot, which is sufficient to draw the excreta through the tubes with great rapidity. The plan has been tried on a small scale at Prague, Rotterdam, Amsterdam, Leyden, and Hanau, also at Brünn, Olmutz, and St Petersburg, and the opinions concerning it are very various. It does not rénder sewers unnecessary; indeed, the system contemplates that every house is provided with two sets of drains—one for household waste waters and rain-water, and the other for the fæcal matters from closets without water-supply, and for bed-room slops containing urine. The first set of pipes are connected with the drains in the street which receive rain-water and the waste waters from factories, and which finally discharge their contents into the nearest river or water channel. The second set of pipes, as described above, are connected with an iron reservoir placed below the surface of the level of the street, from which the sewage is sucked into reservoirs outside the town, where it is further concentrated by heat, and dried in revolving cylinders, whence it passes out as a powder, and is sold for manure. The system is not a good one, as the pipes get clogged sooner or later with fæcal matter. There is also evidence of offensive odours being generated, either from the street reservoirs or from the closets; to prevent this water is used, which interferes with the proper working of the system.

The Berlier system, a modification of the preceding, is in use in one of the districts of Paris. The principle is extraction by exhaustion of air. The solid matters are separated by an intercepting wire basket, called a *receiver*, and the liquid sewage flows into an air-tight *evacuator*, to which an exhaust is attached, which works automatically, and is therefore an improvement on the Liernur system.

Shone's Ejector System.—This is an opposite plan to Liernur's, the agent being compressed air instead of exhaustion. The leading feature of the system is the method of raising the sewage by means of compressed air at such points as are convenient on its course to the outfall. The sewage is received into "ejectors," and after a certain quantity has entered, it is acted upon by compressed air, and, by an arrangement of valves acting automatically, is forced either to an outfall direct, or into a closed iron main. It has been applied at Wrexham, at Eastbourne, at Southampton, the Houses of Parliament, and elsewhere. It seems especially useful where the ground is flat and where it is difficult to get a fall. It works automatically, and gives very little trouble.

Webster's Process—Electrolysis.—This process consists in allowing ordinary sewage to flow through channels in which are placed iron plates or electrodes, set longitudinally, with the usual battery connections with the positive and negative terminals of a dynamo. The sewage in its passage through these channels is said to become entirely split up by the action of the electric current upon the chlorides always present in the sewage. At the positive pole the chlorine and oxygen given off combine with the iron to form a salt which is probably hypochlorite, and at the same time carbonate of iron is assumed to exist in solution, which not only deodorises the fæcal matter by removing sulphuretted hydrogen, but also acts as a carrier of oxygen from the air by being alternately reduced to ferrous and oxidised back to ferric oxide. The process, therefore, although an electrical one, depends upon the production of certain chemical salts. The continuous formation of the iron oxides, in their nascent state, and the thorough mixing of them with the sewage, are the special features of the process. This method of treating sewage adds but little to the sewage itself, and therefore limits the quantity of sludge to the lowest amount consistent with the removal of the suspended solids from the sewage. This system has been under trial at Crossness and Bradford; the sewage of the latter town contains a large proportion of manufacturing refuse, and is considerably altered by the admixture of dyes, acids, alkalies, organic matters, and grease from the woollen manufactories. The average composition of the Bradford sewage before the electrical treatment, and of the effluent after it, are as follows:—

	Sewage before the Electrical Treatment.	Effluent after the Electrical Treatment.
Total solids,	127 grains per gallon.	66 grains per gallon.
After ignition,	69 ,, ,,	47 ,, ,,
Loss on ignition,	58 ,, ,,	19 ,, ,,
Chlorine,	10 ,, ,,	9 ,, ,,
Free ammonia,	32 parts per million.	21 parts per million.
Albuminoid ammonia,	15 ,, ,,	5 ,, ,,

This analysis shows that something like 70 per cent. of the putrescible and noxious portion of the sewage is removed by electrolysis. The microscopic examination of the sewage before treatment revealed an abundance of infusoria, bacteria and low forms of organic life, while in the effluent no living organisms could be detected. From investigations conducted in Paris, the micro-organisms were reduced in number from 5,000,000 per cubic centimetre of raw sewage to 600 in the effluent.

There is, therefore, every reason for believing that in electricity as used in Webster's patent we have an agent capable of purifying even the worst sewage to such a degree as to render it fit to enter an ordinary stream. The cost involved is, however, large, on account of the immense quantity of iron employed and the large amount of tank room necessary.

The Hermite Process.—This method consists in the electrolysis of sea-water and the subsequent flushing of the contents of water-closets with a definite quantity of the resultant fluid. The Hermite fluid is a chemically active fluid prepared by electrical means. The sewage is never in contact with the current, as is the case in the Webster process, nor does the process pretend to secure the precipitation of organic matters. It claims rather to effect the complete deodorisation and sterilisation of sewer contents.

The system is based upon the electrolysis of sea-water. The electric current decomposes the chloride of magnesium, while the chloride of sodium acts as a conductor. The result is a liquid disinfectant of some power. It is almost odourless, leaves no residuum when used for purposes of flushing, and is perfectly inoffensive. The solids in the sewage are nearly all dissolved, and the organic matter rendered for the most part innocuous. The resultant liquid is odourless, does not readily decompose, and contains little else besides the disinfectant and a little phosphates. Experiments at Worthing go to show that this fluid deodorises but does not destroy or remove organic matters, although there is little doubt that certain of them are partially changed and most probably those which are more readily putrescible. While these things are true and are so far satisfactory, there must also be certain drawbacks in the system which were indicated in these experiments. Electrolysed sea-water is rapidly reduced in strength by common newspaper, and as this is always present in a sewer, it must seriously affect the activity of the liquid, even if it does not withdraw the active constituent entirely. Soap or domestic waste has the same effect, so that the entire contents of the sewer rapidly appropriate the chlorine strength of the liquid. Again, if the chlorinated body be in excess, when its action is complete, it is not admissible to pour an effluent containing free chlorine or its equivalent into rivers. For many purposes the use of electrolysed sea-water will be of advantage; it could be used, for example, to flush the heading of drains and sewers, or it could be discharged into sewage outfalls. The method would, however, appear to be an expensive one.

Bacteriological examination of the effluent showed that although it was not absolutely free from micro-organisms, their numbers were reduced to such an extent that it was practically sterile; colonies of the *Bacillus coli communis* were absent, and it is therefore probable that the *Bacillus typhosus* or the bacillus of cholera would be unable to resist the action of the Hermite fluid. A strength of from 0·5 to 0·6 gramme of chlorine per litre is all that is considered necessary to destroy these micro-organisms by this method of sewage treatment. This system possesses many advantages and is well worthy of a more extended trial.

Scott-Moncrieff Process.—Instead of endeavouring to sterilise the sewage, Scott-Moncrieff proposes to facilitate the processes of putrefaction by placing the sewage under specially favourable conditions to bring about that end, so that complex organic matters may be broken down as rapidly as possible into a series of lower compounds. This method consists essentially in passing the sewage upwards through a filtering medium 14 inches in depth and composed of successive layers of flint, coke, and gravel. The process is not a new one, and upward filtration has long since been abandoned in favour of downward filtration through the soil.

The vigorous action of the putrefactive organisms are relied on, and the conditions produced by them to destroy or render inert any pathogenic micro-organisms which may happen to be present. So far, the results obtained by this method are not such as to lead us to expect that it will be adopted generally.

The Influence of Sanitary Works upon Public Health.—Reference has elsewhere been made to the possibility of sewers being the channels by which enteric fever and cholera have been propagated from house to house, and from which emanations, causing diarrhœa and other complaints, may arise. Admitting the occasional occurrence of such cases, it remains to be seen whether the sanitary advantages of sewers may not greatly counterbalance their defects. The difficulty of proving this point statistically consists in the number of other conditions affecting the health of a town in addition to those of sewerage. Buchanan has, however, given some valuable evidence on this point, which has been well commented on by Sir J. Simon. He inquired into the total death-rate from all causes, and the death-rate from some particular diseases, in twenty-five towns before and after sanitary improvements, which consisted principally of better water-supply, sewerage, and town conservancy. The general result is to show that these sanitary improvements have resulted in a lowering of the death-rate in nineteen out of twenty-five towns, the average reduction in these nineteen cases being 10·5 per cent. The reduction of enteric fever was extremely marked, and occurred in twenty-one towns out of twenty-four, the average reduction being 45·4 per cent. in the deaths from enteric fever. In nine towns the reduction exceeded 50 per cent., being highest in Salisbury, where the former rate of 0·75 per 1000 was reduced to 0·175 per 1000—a reduction of over 75 per cent. In ten towns the reduction varied between 33 and 50 per cent.; in two there was only a slight reduction. In three cases there was an augmentation of enteric fever. The reason of the increase in these towns (Chelmsford, Penzance, and Worthing) is explained by the fact of insufficient ventilation of the sewers, combined with backing up of sewage in them, so that sewer gases found their way into the houses; these cases afford excellent instances of the unfavourable part badly-arranged sewers may play in this direction. In 1869 (the first year in which enteric fever is shown in the Registrar-General's returns as separate from "fever") the death-rate from enteric fever in England and Wales was 0·39 per 1000 of the population, and has steadily declined to the present time, the death-rate in 1890 being only 0·179 per 1000; in 1891, 0·169 per 1000; in 1892, 0·137 per 1000, and in 1893, 0·229 per 1000, a reduction of nearly 50 per cent. in twenty-five years. Soyka has given some interesting statistics of German towns with regard to this point. In Hamburg the enteric deaths per 1000 total deaths have fallen from 48·5 to 10·5; in Dantzig from 26·6 to 2·3. In Munich the enteric deaths per 1000 living have fallen from 1·15 (1866–1880) to 0·16 (1881–1888), the city drainage having been completed in 1888. During this period, the population of Munich had increased from 152,000 in 1866 to 278,000 in 1888, or nearly doubled. The sudden lowering of the enteric fever mortality took place immediately after the drainage was completed in 1881: the new water-supply was not provided until some years after.

Diarrhœa has also been reduced, but not to such an extent; and in some towns it has increased while enteric fever has simultaneously diminished. But the term diarrhœa is so loosely used in the returns as to make any deduction uncertain. Cholera epidemics Buchanan considers to have been rendered "practically harmless." The immense significance of this statement will be at once appreciated. Whether the result is owing solely to the sewerage or to the improved water-supply, which is generally obtained at the same time, is not certain. Phthisis, which Buchanan and Bowditch find to be so much influenced by dampness of soil, does not appear to have been affected by the removal of excreta *per se*,—at least towns such as Alnwick and Brynmawr, which are thoroughly drained, show no lowering in the phthisical mortality. In fifteen towns out of the twenty-five examined, the phthisis death-rate exhibited a very considerable reduction. This reduction can only be attributed to the drying of the subsoil which followed on the laying of the main sewers in these towns. Where the drying of the subsoil was greatest and where it was most needed, as in Salisbury, Banbury, Rugby, and Ely, there the mortality from phthisis showed the greatest reduction.

Buchanan states that croup and diphtheria had increased in all the twenty-five towns during or after their sanitary improvements. In many cases it was coincident with the introduction of the new system and increased after their completion. That diphtheria figures largely in the mortality returns of towns can no longer be denied; the explanation of its increase is still wanting, but it is evident that the sanitary improvements which have had such a marked effect on enteric fever have had hitherto little influence in controlling this disease.

As far as can be seen, the effect of good sewerage has therefore been to reduce the general death-rate, especially by the reduction of deaths from enteric fever and from cholera (and in some towns from diarrhœa), but partly, in all probability, by general improvement of the health. Their action has been, in fact, very much in the direction we might have anticipated.

It may be observed that this inquiry by Buchanan does not deal with the question as between sewers and efficient dry methods of removing excreta (on which point we possess at present no evidence), but between sewerage and the old system of cesspools.

Comparison of the different Methods.—Much controversy has arisen on this point, though it does not appear that the question of the best mode of removing excreta is really a very difficult one. It is simply one which cannot be always answered in the same way.

It will probably be agreed by all that no large town can exist without sewers to carry off the foul house water, some urine and trade products, and that this sewage must be purified before discharge into streams. The only question is, whether fæcal excreta should also pass into the sewers.

It will also be, no doubt, admitted that no argument ought to be drawn against sewers from imperfection in their construction. The advocate of water removal of solid excreta can fairly claim that his argument presupposes that the sewers are laid with all the precision and precaution of modern science; that the houses are thoroughly secured from reflux of sewer air; that the water-closets or water-troughs are properly used; and that the other conditions of sufficient water-supply and power of disposal of the sewage are also present. If these conditions are fulfilled, what reason is there for keeping out of the sewer water (which must, under any circumstance of urban life, be foul) the solid excreta, which, after all, cannot add very greatly to its impurity, and do add something to its agricultural value?

That it is not the solid excreta alone which cause the difficulty of the disposal of sewer water is seen from the case of Birmingham. That town is sewered; when it contained nearly 400,000 inhabitants, it was in the greatest difficulty how to dispose of its sewer water; yet the solid excreta of only 6 per cent. of the inhabitants passed into the sewers, while the solid excreta of the remainder were received into middens. The problem of disposal was as serious for Birmingham as if all the excreta passed in. This difficulty has now been overcome, by the use of the lime precipitating process and the passing of the sewage on to land. An innocuous effluent is obtained, and the sewage of over 606,000 people is dealt with, the excreta of the whole population passing into the sewers.

The great difficulty, in fact, consists not so much in the entrance of the solid excreta into sewers as in the immense quantity of water which has to be disposed of in the case of very large inland towns with water-closets. If water-closets are not used, the amount of water supplied to towns, and the amount of sewage, are both considerably lessened.

Looking to all the conditions of the problem, it appears impossible for all towns to have the same plan, and the circumstances of each town or village must be considered in determining the best method for the removal of excreta. London is particularly well adapted for water sewerage, on account of the conformation of the ground north of the Thames, of the number of streams (which have all been converted into sewers), and of the comparative facility of getting rid of its sewage. The same may be said of Liverpool and many other towns.

In many towns where land is available, the immediate application to land, either by filtration or irrigation, may be evidently indicated by the conditions of the case, while in others precipitation may have to be resorted to before application to land. It does not appear that precipitation should in all cases precede irrigation or filtration, though mechanical arrest of the large suspended matters is necessary. There may be some towns, again, in which the impossibility of getting water or land may necessitate the employment of dry removal; and this is especially the case with small towns and villages, where the expense of good sewers and of a good supply of water is so great as to render it impossible to adopt removal by water. It may, indeed, be said that, in small towns in agricultural districts, the dry removal, if properly carried out, will be the best both for the inhabitants and for the land.

The view here taken that no single system can meet all cases, and that the circumstances of every locality must guide the decision, is not a compromise between opposing plans, but is simply the conclusion which seems forced on us by the facts of the case. It does not invalidate the conclusion already come to, that, where circumstances are favourable for its efficient execution, the water-sewerage plan (with or without interception of rainfall) is the best for large communities.

BIBLIOGRAPHY AND REFERENCES.

ANGELL, "The Treatment and Disposal of Sewage and Sewage Sludge," *Trans. San. Instit.*, vol. xiii. p. 209.

BAILEY-DENTON, *Handbook of House Sanitation*, Lond., 1882; also *Sanitary Engineering*, Lond., 1877. BERRINGTON, "Report on the Wolverhampton Sewage Works," *Proc. Inst. Civil Engineers*, Paper No. 2576, vol. cx., 1891-92; also Part iv., 1892. BOWDITCH, *The Siphonage and Ventilation of Traps*, being a Report to the National Board of Health, New York, 1882. BROWN, *Report on Experiments in Trap Siphonage at the Museum of Hygiene, Navy Department, U.S.A.*, Washington, 1886.

CHADWICK, Sir E., "Sanitary Sewage and Water Supply," *Trans. San. Instit.*, vol. ix. p. 343. CORFIELD and PARKES, *Treatment and Utilisation of Sewage*, Lond., 1887; also Article in Stevenson and Murphy's *Treatise on Hygiene*, vol. i. p. 805. CRIMP, *Sewage Disposal Works*, Lond., 1894; also *Sewage Treatment*, Lond., 1893.

DYKE, "On the Downward Intermittent Filtration of Sewage at Merthyr-Tydvil," *Brit. Med. Journal*, Aug. 25, 1888.

FISCHER, "Die Menschliche Abfallstoffe," published as a Supplement to *Deutsche Viertelj. f. Offentl. Gesundht.*, 1882.

HANSON, "The Use of Black Ash Waste in the Treatment of Sewage and Foul Water," *Trans. San. Instit.*, vol. xi. p. 201.

LATHAM, *Sanitary Engineering*, Lond., 1873. LETHEBY, *The Sewage Question*, Lond., 1872.

MAGUIRE, *Domestic Sanitary Engineering and Plumbing*, Dublin, 1890. MIDDLETON, "House Drainage," *Trans. San. Instit.*, vol. ix. p. 273.

PALMBERG, *Public Health and its Application*, edited by Newsholme, Lond., 1895.

RATCLIFFE, *Report on the Dry Methods of Removal of Sewage*, Twelfth Report of the Med. Off. to the Privy Council, Lond., 1870, pp. 80 and 111. REID, *Practical Sanitation*, Lond., 1895. *Report of Commission on the Sewage of Towns*, Lond., 1861. *Report of East London Water Committee*, Lond., 1867. *Reports of Rivers Pollution Commissioners*, since 1870, vols. i. to vi. *Report of the Birmingham Sewage Inquiry Committee*, 1871. *Report on Town Sewage*, issued by Loc. Govern. Board, 1876. *Report on Metropolitan Sewage*, Lond., 1884. *Report on the Purification of Sewage*, by the State Board of Health, Massachusetts, Boston, 1890. *Report on Quantity of Water necessary for Water-Closets*, by the Committee of the Sanitary Institute, Lond., 1893. *Report of Royal Commission on the London Water Supply*, 1894. ROBINSON, "Sewage Disposal," *Trans. San. Instit.*, vol. x. p. 194. ROECHLING, "The Sewage Farms of Berlin," *Proc. Inst. of Civil Engin.*, vol. cix., 1891-2; also Part iii., 1892.

SIMON, Sir J., *Public Health Reports*, republished by Sanitary Institute, 1887. SMITH (ANGUS), *Report on the Rivers Pollution Prevention Act*, Lond., 1882. SOYKA, "On the Health of German Towns," *Deutsch. Viertelj. für Offentlich. Gesundheit*, Bd. xiv. Heft 1, 1882, p. 33.

CHAPTER XI.

PARASITES.

In its widest sense, the name of parasites has been given to all those creatures which are nourished wholly or partially at the expense of other living organisms. As thus understood, parasitic life is, therefore, an exceedingly widespread phenomenon, and includes not only vegetable and animal parasites, but also parasites on vegetables and on animals. The length of parasitic existence, and the degree and nature of the benefit which the parasite thus obtains, varies greatly with different species; and the effect produced by the parasite upon its host ranges from an almost imperceptible one to complete destruction. At one extreme are certain forms which, while drawing the nourishment necessary for life from their hosts, yet do so in such fashion that both organisms continue to live in intimate association, and apparently with mutual advantage. From these we can pass, by a series of gradations, to parasites of such destructive influence as to cause widespread death to certain animal and vegetable forms of life. This physiological and pathological group is closely related to another, the saprophytes, which obtain their nourishment from the dead remains of organisms.

From the foregoing necessarily abbreviated statement we observe not only the enormously wide prevalence of parasitism—"the number of parasitic individuals, if not indeed that of species, probably exceeding that of non-parasitic forms"—but its very considerable variety in degree and detail. The majority of parasites, indeed, derive their main support from their host, but of these some are free, wandering about from animal to animal, some are attached permanently to the exterior of their victim, while others again are concealed within its body. In some cases, the parasitism is only temporary, in others it is a life-long habit. The majority are free in their youth, while some pass their early life as parasites, becoming free in their mature state, and others again spend their whole life on their host.

Some classification of these various parasitic forms is necessary. Van Beneden introduced the term *commensals* or messmates, including fixed and free partners, as distinguished from true parasites. In this classification there is no attempt to define the degree of dependence or the closeness of association, except in the general distinction between parasites and messmates. Leuckart distinguishes parasites as ecto- and endo-parasitic, and divides the former into temporary and permanent. Endo-parasites he divides according to the nature and duration of their strictly parasitic life. (1) Some having free-living and self-supporting embryos, which become sexually mature either in their freedom, or only after assuming the parasitic habit. (2) Others with embryos which, without having a strictly free life, yet pass through a period of active or passive wandering, living for a while in an intermediate host. They may either (*a*) escape to pass their adult life in freedom, or (*b*) they may become sexual, or (*c*) they may bore their way to another part of the body, or (*d*) most frequently they pass to their final host either directly when their intermediate host is devoured as food, or indirectly seeking for themselves another intermediate host, or producing asexual forms which do so. (3) Others again having no free-living or even migratory embryonic stage, but passing through their complete life-cycle in one host. This somewhat detailed classification has at least the advantage of clearness, and of showing to some extent the various degrees of parasitism: but it is confined, like Beneden's, entirely to animals living as parasites upon other animals, and fails to include those vegetable forms which inhabit a living organism and obtain nourishment from its body.

A more physiological classification has been proposed by Kossmann, dealing with the organisation and habit of the parasite. Briefly explained, it consists of two great classes: (1) vegetative forms, or those without independent digestive organs; and (2) those with independent digestive systems which include, however, such a variety of details, as to make it almost impossible to establish any logically accurate divisions. Any strict classification of such a variety of organisms as the parasites, having only in common the physiological correspondence of their mode of life, is almost impossible, and the most that can be done is to point out the existence of a series of adaptations varying with the intimacy and constancy of the association, and the degree of dependence.

The history of the medical aspects of parasitism is not extensive. Although from the time of the ancient Arabian physicians some diseases, such as itch, have been referred to parasites, it was not till within the last forty years that, with the rise of experimental helminthology, a scientific conception of the parasitic theory of disease elaborated that systematic warfare against all forms of parasitism which now occupies so important a place in preventive medicine.

The parasites of man cover a wide range in the animal and vegetable world, and embrace species from such diverse organisms as the Schizomycetes, the Blastomycetes, the Hyphomycetes, the Protozoa, the Insecta, the Arachnida, the Suctoria, the Nematoda, the Cestoda, and the Trematoda. Of these the parasitic bacteria or Schizomycetes will not be included in this article, as their importance in morbid processes, and particularly in the infective diseases, is such as to require separate and very special treatment. Some further reference to them will be found in the chapter which discusses the infective diseases.

BLASTOMYCETES, OR YEASTS.

A familiar example of this group is *torula*, which is capable of producing alcohol when growing in substances containing glucose. By torula is understood an oval micro-organism, varying in size from 3 to 6 μ, and consisting of a membrane and protoplasmic contents, including often one or two vacuoles. A characteristic feature of these organisms is that they multiply by budding and not by fission. A very large number of different species of torulas have been described, especially in connection with alcoholic fermentation. These organisms are of interest to the hygienist in two ways: (1) by their constantly being present in the air, soil, and water; and (2) by a species of torula being connected with a well-defined disease known as *thrush* in infants.

Oïdium albicans, or the active cause of thrush, is a torula morphologically identical with the species connected with alcoholic fermentation. Upon saccharine cultures, poor in water and cut off from the air, this torula grows like yeast and excites fermentation. Upon nutrient media, rich in nitrogen and water, it forms articulated filaments, longer or shorter, which in many places support rounded or oval conidia. Upon gelatin plates, it develops as coarsely granulated growths, reminding one of yeast colonies; it does not liquefy the gelatin. It is pathogenic for poultry and pigeons on inoculation in the crop, where it develops a characteristic aphthous membrane.

HYPHOMYCETES, OR MOULDS.

This group comprises organisms "which consist of cells multiplying by fission, and which, by continued linear and lateral multiplication and by elongation, form branched mycelial threads; each of these is composed of cylindrical cells." The actual mature cells consist of a faintly granular protoplasm contained in a cellular sheath. The ripe cells are separated from one another by transverse septa; this is, however, not present in the young cells.

In some species of this group, the terminal threads, by a simple process of fission, produce free cells which are conidia or spores. These species are known as oïdium, the chief being oïdium lactis, the oidium of favus, the oïdium of ringworm and of pityriasis versicolor. The spores, by germination, elongate, grow, divide, septate, and ultimately give rise to a branched mycelium of cylindrical cells.

Other species, like Aspergillus, Mucor, and Penicillium, under favourable conditions with free exposure to the air, present a more complicated mode of spore formation; but when unfavourably situated behave like an oïdium, forming spores by simple fission of the terminal cells of the filamentous threads.

Oïdium lactis is an often abundant inhabitant of sour milk, bread, paste, potato, and gelatin. It is said to have no pathogenic properties. It appears as a whitish filamentous growth, with spherical or oval spores, measuring 7 to 10 μ.

Achorion Schönleini is the oïdium of favus, and like that of ringworm (*Trichophyton tonsurans*), and of pityriasis versicolor (*Microsporon furfur*), closely resembles, both in its cultural and morphological characters, the oïdium lactis. Upon serum, it forms elliptical conidia without special supporters. Upon gelatin, it grows slowly with gradual liquefaction, first as a whitish, flocky layer, and then thick, dry, and white. It grows also on agar and potato. The *Trichophyton tonsurans* is very like the above, but the filaments are more rectilinear. It only grows at an incubation temperature and on an alkaline medium. It liquefies gelatin, grows on agar and serum but not on potato.

Aspergillus.—The various forms of Aspergillus are only observed saprophytically in man, especially in the lungs, external auditory meatus, and middle ear. The spores, introduced into the vascular system of animals, establish metastatic foci in the various viscera. To this group also belong Saprolegnia, Botrytis Bassiana, and possibly Actinomyces or the ray fungus.

Saprolegnia are colourless threads, forming dense radiating tufts which occur on living and dead animal and vegetable matter in fresh water. The filaments penetrate into the substratum, and branch more or less in the surrounding water. This parasite attacks fish and tritons, producing a diseased condition of the skin, which may be ultimately fatal. In salmon it produces the common disease of salmon.

Botrytis Bassiana.—This occurs as colourless hyphæ and spores, the former being usually simple, but sometimes united in arborescent stems. This fungus is the cause of muscardine, a fatal disease of silk-worms, and occurs also in various other caterpillars and insects.

An obscure mycelium, which, penetrating the skin and subcutaneous tissue, sets up suppuration and ulceration, has been described as the cause of a disease known in India as "madura foot." According to Kanthack, it somewhat resembles, if it is not actually, the following:—

Actinomyces.—This is a fungus, commonly called the "ray fungus," which is common to both man and animals, producing a pathological condition known as *actinomycosis*. The parasite appears in the form of a rosette of pyriform or club-shaped elements. The little masses are colourless, white, or of a yellowish-green tint and visible to the naked eye. Having gained access to the living organism, this fungus sets up inflammation in its neighbourhood, resulting in the formation of a neoplasm, composed chiefly of round cells, resembling a tuberculous nodule. These nodules may break down and suppurate, or may go on increasing in size. In cattle, the jaws are usually affected. The organism may also occur in the alimentary tract, the lungs, subcutaneous and intermuscular tissues. The various situations in which this organism is found suggest that its usual habitat is in the outside world, and that it is introduced into the body from without. The most generally accepted view now is that the natural habitat of the ray fungus is on the cerealia, that it lives on these parasitically (especially upon barley), and through and from these enters the animal body through wounds, abrasions, &c.

Microscopic examination of the actinomycotic masses shows the central part to be made up of fine granules, or of fine branched threads; next is a zone of coarser granules, due to optical sections of the fine fibres, while at the periphery of the mass are glistening, radially aggregated, flask or club-shaped bodies. Occasionally, the central zone is found calcified. Considerable controversy has existed as to the precise nature of this fungus. In the present day, it is very generally accepted that the club-shaped bodies are sprouting parts and conidia-bearing ends, the threads being analogous to the mycelium of an oïdium-like fungus.

Actinomycosis has been transmitted from cattle to cattle by inoculation, and a rabbit has been infected by means of a piece of human actinomytic tumour, introduced into the peritoneal cavity. The actinomyces, on blood serum and on agar at 37° C., forms whitish granules, reaching its maximum growth in six days. The granules show branched mycelial threads with club-shaped bodies. Similar development can be obtained in broth and on gelatin; this latter, however, liquefies.

PROTOZOA.

Along with the vegetable parasites above described and the larger animal intruders, to be discussed subsequently, we have in the course of years become acquainted with a series of small pathogenic animals, not sufficiently known as yet from the zoological point of view, but probably belonging to the group of the lowest protozoa. Unfortunately, our methods of investigation are still imperfect; the forms of the organisms in question being scarcely distinguishable from leucocytes, or cell nuclei. Though the literature of this subject is very considerable, hitherto the significance of these organisms has been shown chiefly for some of the lower animals rather than for man. Some instances of these organisms are :—

Amœba dysenteriæ.—Various observers, notably Lösch, Kartulis, and Councilman, have described round or slightly oblong bodies, consisting of an outer pale homogeneous substance enclosing a somewhat greenish highly refractive mass, containing vacuoles and a nucleus, as being present in certain forms of dysentery. A characteristic feature of these amœba-like bodies is movement, consisting first of a progressive movement, and secondly of a protrusion and withdrawal of pseudopodia, both of which vary in activity. Entering probably with the food, these protozoa pass on until the large intestine is reached, where the alkalinity necessary to their growth is obtained. Here they penetrate and undermine the mucous membrane, producing their effects by liquefying the tissues, and thus causing ulceration and necrosis. In the mucous membrane they are found chiefly in the lymph spaces, blood-vessels, and in the gelatinous contents of the ulcers. They may penetrate to the liver. Kartulis succeeded in obtaining pure cultures in alkaline infusion of straw by inoculation from a case of dysentery, and injections of these cultures into the rectum of cats produced local symptoms of the disease; no results followed when the amœbæ were administered by the mouth.

Miescher's Tubes.—Sometimes in the muscles of mice and other animals, white streaks are visible to the naked eye, as fine white streaks between the muscle fibres. Examination with a low power shows them to be composed of tubular granular masses, several millimetres long and about twice as thick as the muscle fibres. They all taper towards the extremities. Under a higher power, a capsule can be made out, while the contents are pale, crescentic, reniform corpuscles, rounded and slightly attenuated at the ends, and often containing a vacuole. In the larger capsules, there are formed tubes of the second and third degree, or spherical masses, each surrounded by a thin capsule, one within the other. On teasing out a part of the fresh muscular tissue, many of the tubes become broken, and innumerable isolated crescentic spores are obtained. No movement is possessed by the tubes or individual spores. From the crescent-shaped bodies, which are considered as the typical contents of the tubes, there proceed nucleated forms resembling gregarines, which on the addition of an acid emit two filaments from one end. The transfer of these structures to other warm-blooded animals by inoculation, or in food, has hitherto failed. The prevalent belief is that they enter the animals by an intermediate stage of development, probably passed in a snail.

In man only isolated cases of this infection have been observed Nuverricht has described a fatal case which had the aspect of a polymyositis, as in an infection of trichinæ. How such parasites enter the human system is obscure, though Rabe states that he has observed a case after eating pork containing psorospermia; there is some reason to think, however, that in Rabe's case more complicated causes existed. Fowls sometimes contain the same tubes, but Leuckart does not feel satisfied that these parasites are real psorospermia.

Coccidia.—By coccidia we understand a large group of parasites which live parasitically within the cells, and which have hitherto been observed chiefly in rabbits, where the full-grown parasite (*Coccidium oviforme*) is 35 μ long and 15 μ broad; similar forms have been found in dogs, calves, sheep, and birds. Their entire development appears to take place in the epithelium cells of the liver and bowel. Coccidia have also been described by Podwyssozki as occurring in the human liver.

The life history of *Coccidium oviforme* has been largely explained by the two Pfeiffers. The earlier known form is that of the young amœboid parasite, which penetrates into an epithelial cell of the bowel or liver, and when fully grown becomes encapsuled as a thin bladder. Within this develop numerous daughter cysts or cells, at first of a rounded shape, each of which becomes a falciform body. The falciform cyst bursts, the enclosed bodies become free amœboids, penetrate at once new cells, and begin afresh their destructive activity. If the disease involve the liver, larger sections of the liver tissue constantly become involved, degeneration by pressure of many liver lobules takes place, leading ultimately to death. Outside the body, coccidium undergoes similar changes, and when the encysted organism finds access, again, through water or food to the alimentary canal, the capsule becomes dissolved, the spores are set free, and these germinate into granular, spherical bodies to form the typical oval coccidium. The contagious epithelioma of poultry and pigeons is occasioned by a similar organism, whilst the *Molluscum contagiosum* of man is due to the same or similar parasites (Neisser). Coccidia have also been described by Pfeiffer and others in the epithelium in cancer, variola, vaccinia, varicella, herpes zoster, and other vesicular eruptions; the weight of opinion, however, in this country inclines rather to regard these bodies as derivatives of the cell nucleus than as of the nature of extraneous parasites.

Flagellate Protozoa.—More highly differentiated are the forms *Trichomonas* and *Circomonas* and other flagellated monadinæ known to inhabit the bodies of vertebrate and invertebrate animals. The genus Trichomonas has been found by Pfeiffer in the oral and pharyngeal mucus of pigeons affected with the chronic necrotic thickening of the mucous membrane called diphtheria. He regards Löffler's bacilli in this affection as a septic complication, and maintains that the disease is caused by the trichomonas, though the same organism is constantly to be found in healthy pigeons. The mature organisms are oval or semi-lunar, with four flagella at the head, a divided one at the tail and an undulating marginal membrane. By losing their tails, these organisms pass into an amœbic condition of great contractility, ending in final encystment and spore formation.

The genus Circomonas, a minute club-shaped ciliated protozoon, smaller than Trichomonas, possessed of no envelope and having a pointed prolongation at one end and a fine flagellum at the other, has been found in the intestine of man in cholera, diarrhœa, and dysentery. Other species of flagellate monadinæ have been described by Lewis, Evans, Koch, and Crookshank as occurring in the blood of horses, camels, dogs, rats, and badgers. Allied to the forms described above are those detected by Laveran and now universally recognised as exciters of malaria. The more important characters of these hæmatozoa will be mentioned in the next chapter, under the head of Malaria.

INSECTA.

Instances of the so-called free parasitism, partial parasitism, and of true parasitism, due to insects, are by no means uncommon in man. Flies, bugs, fleas, and lice come under this category: these exercise their parasitism either by making man the host of their larvæ, for which a temporary sojourn in the organs of a warm-blooded animal is a necessary factor for their development, or play the parts of free and true parasites by temporary or permanent attachment to the person, for the purpose of deriving sustenance. Thus it is by no means a rare occurrence—particularly in tropical countries—to find larvæ developing in wounds or sores, or in such accessible but sheltered parts as the nostrils, ears, and even conjunctival sacs. Some of these larvæ become a source of very great danger, owing to the rapidity with which they rapidly destroy the tissues in which they are lodged. Other larvæ proceed to development by penetrating under the skin of their temporary host, lodge there, and grow at the expense of the tissues on which they feed, causing pain, irritation, and not infrequently sores which in unhealthy climates are not without danger. Of this kind of ecto-parasitism, the following are the chief forms:—

Blaps mortisaga, or churchyard beetle, has on several occasions been found to be present in the human body. Cobbold records a case in which several perfect insects and 1200 larvæ were passed by the bowel. The **Tenebrio molitor** is a closely allied species whose larvæ have been found passing from the human body.

Œstrus hominis.—This insect, in the so-called "bot" condition, and also several other varieties, have been found in man. The late Dr Livingstone is known to have been afflicted with the larvæ of a species of this fly during the course of his African travels.

Cuterebra noxialis.—The larva of this fly is the so-called Macaco worm of Central America. The perfect insect is about 17 mm. long, has a yellow head and face, a brown body striped with grey, and a blue abdomen. It frequents the outskirts of woods, depositing its eggs on man, cattle, and dogs. The larvæ, when hatched, penetrate the skin, giving rise to much irritation: they attain a length of about a quarter of an inch, and possess two strong buccal hooklets and a series of spines on the front half of the body.

Anthomyia canicularis.—The larvæ of this fly are quite common in man: while several cases of parasitism from the maggots of the bluebottle, or *Musca vomitoria*, have been recorded by Sells and Cobbold.

Lucilia hominivora.—The revolting parasitic habits of the maggots of this species are difficult to realise. It is an inhabitant of America, being found from the United States in the north to the Argentine Republic in the south. An allied species has been met with in India. The perfect insect is about 10 mm. in length, with a blue thorax and brown wings. The larvæ measure 12 to 15 mm. The fly deposits her eggs in wounds, sores, the nose and ears of men and animals. On being hatched, the larvæ, by means of two powerful buccal hooks, attack the tissues, which they devour rapidly, producing often extensive mutilations. They have been known to devour the soft parts at the back of the mouth and nostrils, including the pharynx, glottis, tympanum, deep structures at the base of the cranium, and even passing into the frontal sinuses.

Ochromyia anthropophaga.—This is a native of Senegambia, where its larva is known as the cayor worm. The insect is believed to lay her eggs in the sand, whence the larvæ emerge, and, an opportunity occurring, penetrate the skin of man or animals. Underneath the skin the larvæ grow, giving rise to inflamed swellings: in seven days they leave their temporary host and pass into the pupa stage. Once the larvæ have emerged, the sores so produced quickly heal.

As examples of free parasitic insects we may quote the midge, the flea, many well-known gnats and bugs, and also the following:—

Culex anxifer, or mosquito. Probably many species attack man as well as animals. The importance of these insects as intermediate bearers of human filariæ will be alluded to elsewhere.

Glossina morsitans, or tsetse fly, is a notorious insect found in South Africa, where it is terribly destructive to horses, oxen, sheep, and dogs. Its bites, however, though very annoying, do not prove fatal to man.

Pulex penetrans.—Under the name of the jigger or chigoe, this is a well-known and excessively troublesome insect, found in the West Indies, tropical America, and some parts of Africa, particularly Algeria, the Soudan, and Zanzibar. The chigoe lives on the ground, and is most abundant in dry sandy soils, particularly near the sea shore. Dirty native cabins are a very favourite haunt for this insect. It attacks all warm-blooded animals, fixing itself indifferently on the first that comes in its way. In size, the chigoe is smaller than the common flea: it is reddish-brown in colour and has a large head with a broad, deep abdomen. Both the male and female are, for the most part, free parasites, the male being always so, and the female up to the time of impregnation. They suck the blood by piercing the skin on every available chance, dropping off when gorged. While the male retains the ordinary habits and form of a flea, the female, when she has been impregnated, bores her way into the skin of the foot, leg, thigh, scrotum, or other parts of the body, and becomes by the enormous development of the ovary, a simple motionless bladder embedded in the flesh, around which, in course of time, when the eggs have to be extruded, a certain amount of inflammation arises. In due time, these are hatched, producing a larva which, after enclosing itself in a cocoon and passing through a nympha stage, emerges in eight or ten days time as the perfect insect.

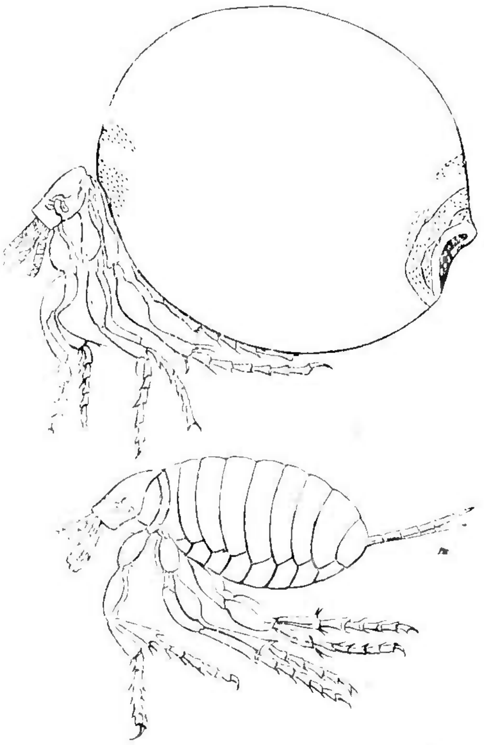


Fig. 95.—*Pulex penetrans.* Female and male.

Of the true parasitic insects affecting man, the chief is the **Pediculus** or louse. Five distinct species are recognised as human parasites, namely, the head louse, the clothes louse, the distemper louse, the pubic louse, and the louse of the eyelids. The lice found on negroes and other native races were at one time thought to be distinct species: this, however, is not so. Occasionally one or more species of bird lice have been found on man, and may be regarded as human parasites. This has occurred particularly in the case of *Ornithomyia avicularis*, which frequently infests cage birds. In like manner, one or more forms of lice infesting common fowls may attach themselves to man.

ARACHNIDA.

Amongst the trachearian section of this great class of arthropodous invertebrates there are numerous parasitic species which attack man and animals. They are more familiarly known as mites (acaridæ), ticks (ixodidæ), and pentastomes (pentastomidæ).

Of the mites, the chief human parasite is the common itch insect.

Acarus scabiei, or human itch insect, has been described under a number of synonyms: it is probable that most of the so-called species infesting our domestic animals, as well as that called the Norway itch insect, are mere varieties of the common species (fig. 96). The burrowing of this insect causes much itching and some rash. It is the female only which thus penetrates the skin and causes the characteristic symptoms of the disease known as scabies: for burrowing beneath the cuticle, she lays her eggs at the end of the burrow, where they hatch, and the young insects then commence to burrow afresh in other directions.

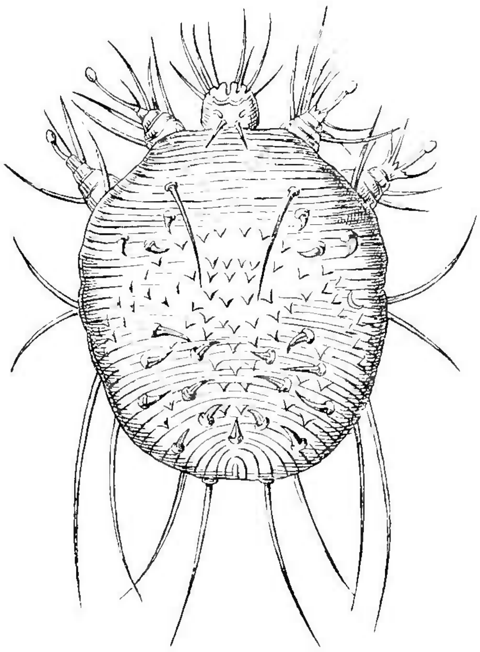


Fig. 96.—*Acarus scabiei.*

In France, the face mite, or *Demodex folliculorum*, is a fruitful source of personal disfiguration. A variety infests the dog.

The ticks are less frequently met with, as human parasites, in this country than in some parts of the tropics. Some of these arachnidans are terrible blood-suckers, more particularly **Argas persicus** and **A. chinche**, found respectively in Persia and Columbia. The camel tick and the various forms of ixodes are disgusting and highly venomous species occasionally found on man, producing severe pain; they are probably identical with one or other of the ticks known to infest domesticated animals.

Man is occasionally the host of sexually incomplete forms (pentastomidæ) of as yet incompletely known arachnidans.

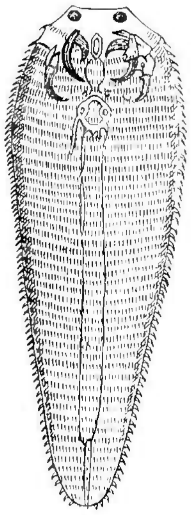


Fig. 97.—*Pentastomum denticulatum* (after Leuckart).

Pentastomum denticulatum.—This is the sexually incomplete state of the mature form known as *P. tænioides*, which resides in the nasal chambers of the dog and other animals. In the larval form, as *P. denticulatum*, it infests the liver and lungs of man. Formerly, these two pentastomidæ were thought to be distinct, until Leuckart succeeded in rearing the so-called *P. denticulatum* in the intestine of the rabbit from the eggs of *P. tænioides*, and traced the development of the young *P denticulatum* into the adult *P. tænioides* by placing the embryo in the nasal cavity of the dog. The life history of this parasite appears to be briefly this. The young form inhabits cysts in the liver and lung of herbivorous mammals: presently the young animal breaks through its cyst and makes its way into the body cavity, after causing considerable injury to the tissues during its transit, and occasionally even causing the death of its host. Sometimes it wanders again into the viscera or into the lymphatics. If the body of its host be devoured by a dog or some carnivorous animal, the young *Pentastomum*, if not already encysted, finds its way directly through the nares into the olfactory cavity, where it attains sexual maturity. The

P. denticulatum has often been found in the liver and lungs of man in various parts of Europe: its organs of locomotion are hooks and spines which are developed towards the close of the resting stage, and finally laid aside after they have served their purpose.

Pentastomum constrictum.—This parasite is not uncommon in Egypt, the Soudan, and West Coast of Africa. It is the larval form of an arachnid, of which the adult stage is still unknown. It has a white, annulated, cylindrical body, with a rounded anterior, but rather conical posterior end. The ventral surface is flattened, the entire parasite measuring about 15 mm. in length by less than 3 mm. in breadth. It has four foot-claws near the mouth. The elongated abdomen displays twenty-three rings, placed at tolerably regular intervals. It differs from *P. denticulatum*, which we have seen to be the larval form of *P tænioides*, in not possessing integumentary spines, and in being a much larger parasite. It is found coiled upon itself in a cyst, situated generally near the surface of the liver, in such a way as to be perceived through the fibrous capsule of the organ.

Fig. 98.—*Pentastomum constrictum* (after Aitken).

SUCTORIA.

A vast number of suctorial annelids attack man in such a way as to deserve the title of parasites. In this category come the ordinary leeches, besides numerous aberrant forms which have only been imperfectly described.

Hæmopis sanguisuga.—This, the common horse leech, is found in all parts of Europe, in Egypt, and throughout North Africa. This species often attacks man in warm climates, attaching itself to the mucous surfaces of the nose and pharynx, and even entering the larynx and air passages. Men are much debilitated by them at times: and in the event of their entering the air passages, death by asphyxia may ensue. There is no doubt that these leeches enter the mouth by means of foul drinking water.

Sanguisuga tagalla is a land leech found in Ceylon, where it lives in woods and in damp undergrowths. It is about an inch long, little thicker than an ordinary knitting needle, but extremely active. It lies among the leaves and grass, and attacks any man or beast which passes near it. Similar land leeches are found in Java, the Philippines, in the Himalayas, Africa, Australia, and Chili. All varieties appear to possess great suctorial powers, and if disregarded, by producing repeated hæmorrhages, may bring about a state of great debility.

NEMATODA.

The nematoid parasites are probably better known than any of the other parasites of man. This arises partly on account of the excessive prevalence of some members of the group, particularly the little thread-worm, partly from the circumstance that the large round worm bears a marked resemblance to the common garden worm, and partly because the spiral flesh-worm plays an important *rôle* in the production of the epidemic disease known as *trichinosis*. In the case of those whose experience has been in the tropics, this group is further familiar as embracing the Guinea worm, various filariæ, and other less common forms.

Oxyuris vermicularis.—This is the common thread-worm, a well-known human parasite occurring in large numbers in the cæcum and upper part of the colon. The female is about $\frac{1}{2}$ inch long, and the male $\frac{1}{4}$ inch. The female gives off enormous numbers of colourless, oval, unsymmetrical eggs, each being 50 μ in length and about half as broad. These eggs have a rather thin shell with a double outline (fig. 1, Plate VI.), and may contain a well-developed embryo, which, at first tadpole-like, rapidly assumes, under suitable conditions of heat and moisture, a vermiform character. For the purposes of infection it is alone necessary that the eggs of the worm be conveyed to the mouth and swallowed. Their previous immersion in water for any length of time secures their destruction, by the bursting of the shell consequent upon endosmosis. The eggs are conveyed to the mouth in various ways. Ordinarily children become infested by biting their nails, beneath the margins of which the eggs lie concealed. Occasionally, the eggs are swallowed by accident during sleep, or the whole parasite may be conveyed to the mouth in a similar manner. In whatever manner they may have been carried to the bearer, when once the eggs have gained access to the stomach, their shells are dissolved by the gastric juice, and the larvæ liberated. In the upper intestine, the larvæ grow rapidly: here they undergo one or more changes of skin, acquiring sexual maturity within a period of less than a month. Improperly cooked or raw vegetables and water are the vehicles by which they directly reach man from outside.

Ascaris lumbricoides.—This is the common round worm, being in general appearance very like the ordinary earthworm. It is pinkish in colour, tapering at each end, and measuring some six inches long in the case of the males, and twelve inches in the case of the females. In man it usually infests the small intestine, where it gives off large numbers of eggs. These, though colourless when within the worm, are usually brown when seen within fæces, owing to the action of the bile upon the outer shell, which is, moreover, characteristically nodulated (fig. 2, Plate VI.). In shape they are not unlike a barrel, and measure 65 μ long and about 45 μ broad. The inner layer of the shell is transparent, colourless, and rather thick, with a multiple outline. How and where the eggs develop is not known, but it is supposed to be in water or possibly in an intermediate aquatic host. Undoubtedly it is chiefly by means of water that they reach man. Development extends over three or four months. Pigs being infested by the same worm, the water from streams or ponds in the neighbourhood of pig-sties becomes a dangerous source of infection, if employed for domestic purposes.

The large lumbricoid worm of the horse is an entirely distinct species.

Ascaris mystax.—This nematode is probably identical with the *A. alata* of Bellingham. Its stages of growth have been traced by Leuckart in the cat, in whose stomach specimens of the larvæ were found measuring only $\frac{1}{62}$ of an inch. From Hering's observations, it would seem probable that a period of three weeks is amply sufficient for the production of sexual maturity after the larvæ have gained access to the body of the ultimate bearer. The bearer may be either man himself, or more commonly a cat, dog, or some carnivorous animal.

Tricocephalus dispar, or the "whip-worm," is possibly the most common of all intestinal parasites affecting man in the tropics, and not infrequently met with in Europe. Its eggs are so characteristic (fig. 3, Plate VI.) that having once seen them it is not possible to mistake them for any other. Their usual size is 36 μ in length by 26 μ in breadth: in colour they vary from a yellowish-brown to red. The eggs are commonly voided by the worm into the bowel, and when discharged from the bowel the embryo is not differentiated within them. Its development remains in abeyance until the egg is carried into water or other damp medium. This happening, development proceeds, and on the egg being swallowed by man in drinking water, the embryo is liberated in the alimentary canal, where it attaches itself to the mucous membrane of the cæcum by means of the whiplash-like anterior part of its body (fig. 99). The development of this worm is slow, probably being rarely completed within the year.

The intermediate host is unknown, but the experiments of Davaine render it probable that infection takes place in a direct manner some time after the eggs have escaped the human bearer. The embryos will live for many years in the free eggs, even if exposed to dryness.

Trichina spiralis.—The larval forms are commonly spoken of as flesh-worms. The adult is a small worm, varying from $\frac{1}{18}$ to $\frac{1}{8}$ inch in length, which not only attacks man, but also pigs and other animals, producing the disease known as trichinosis. In this disease, the muscles present a number of ovoid cysts, about $\frac{1}{70}$ inch in length, just visible to the naked eye, within each of which is coiled an immature trichina, not much more than $\frac{1}{40}$ inch long (fig. 100). If by chance the tissue or muscle containing the capsules be eaten, the capsule is dissolved, and the young worm is set free. This rapidly develops, and breeds so rapidly that within a week the embryos of the trichina, by burrowing through the intestinal walls, are able to find their way into all parts of the consumer's body, especially the muscles, in which they soon get encapsuled, to go through the same history again. When trichinosis occurs in man, it is generally due to the eating of the imperfectly cooked flesh of pigs suffering from the disease. It is somewhat common in Germany, where sausages, hams, and pork are more often eaten than in this country. The symptoms of trichinosis are sickness, prostration, fever, and muscular pains. The mortality is often slight, but occasionally very high.

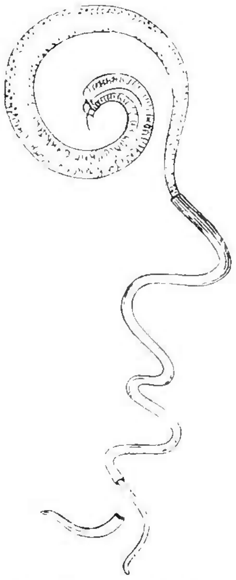


Fig. 99.—*Tricocephalus dispar.*

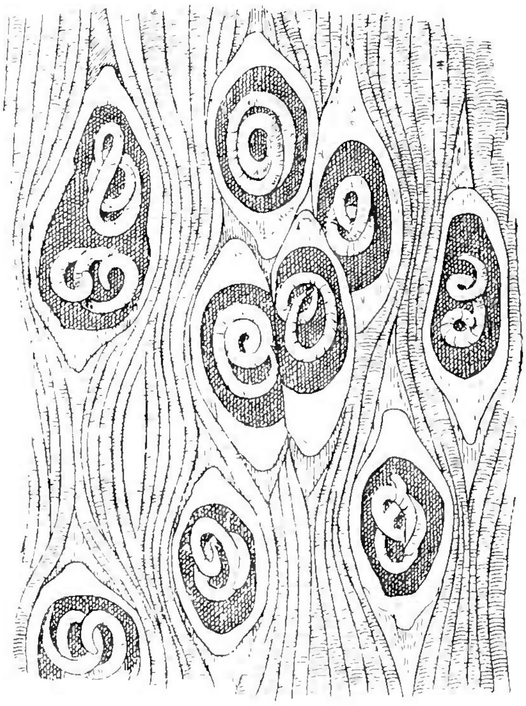


Fig. 100.—Muscle containing *Trichinæ spiralis.*

Dracunculus medinensis, or Guinea-worm, and sometimes called *Filaria* *medinensis*, is a parasite endemic in many parts of India, Persia, Arabia, Egypt, the West Coast of Africa, Demerara, the Brazils, and other tropical countries. The Guinea-worm disease is undoubtedly the same disease as the dracontiasis of Plutarch, and corresponds also with the Israelitish endemic affection described by Moses as due to fiery serpents. The curiously limited prevalence of this parasite in certain districts was for many years inexplicable, until Fedschenko discovered the fact that a certain species of fresh-water cyclops, having apparently a very capricious distribution, is a necessary factor in the life history of the filaria. Consequently, the distribution of the Guinea-worm is bound up with and dependent on the distribution of the particular species of fresh-water crustacean which, in reality, acts as its intermediate host.

Not only man, but oxen and some other animals, are affected with this filaria, or a parasite very closely allied to it. As yet, the female dracunculus alone is known with certainty, though Charles has described structures in connection with two female dracunculi which are suggestive of the male dracunculus *in coitu*. Immature specimens of Guinea-worm vary in length from a few inches to as many feet. The mature worm is a long, milky-white, slender, cylindrical organism, having a thickness of about $\frac{1}{10}$ inch, and not at all unlike a thick fiddle-string. Its actual length varies from 1 to 12 feet. The head of the worm is short and tapering, terminating in an oval irregular surface called the "cephalic shield." In the centre of this is a triangular buccal orifice, which leads to an alimentary canal, extending along the whole length of the creature, and ending blindly. Close to the buccal orifice are two papillæ, with six others at the circumference of the shield; these are generally regarded as sensory organs. The posterior end of the parasite terminates in a blunt point which is often bent, like a hook, towards the ventral surface. Nearly the whole of the worm is occupied by a long, tubular, and embryo filled uterus. No trace of a vagina can be detected in the mature worm, though there is evidence to suggest that originally there was one. The emission of embryos appears to take place by the buccal orifice.

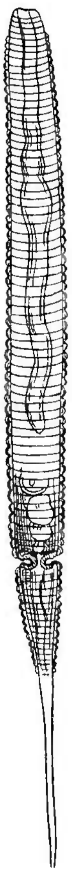


Fig. 101.—Embryo of Guinea Worm (after Bastian).

Like many other animal parasites, its presence in the tissues of man is but a portion of its life history, and to complete its cycle of existence it requires to pass into the tissues of some other living organism. The worm, having gained access to man's body, probably in a larval form, lying in the body of the cyclops, bores its way into the tissues. When or where the sexes come together, and what are the subsequent steps in the development of the female, and what becomes of the male worm, are unknown. After an interval of from nine months to a year, a stage of maturity appears to be reached, as indicated by the presence of a worm many inches in length, embedded in the cellular tissue of the host, with an enormously developed uterus packed with millions of embryos. The embryo which is emitted from man is aquatic in habit, and to further develop needs to pass into water. In size the embryos measure $\frac{1}{30}$ by $\frac{1}{1000}$ of an inch. They are distinctly flattened, tapering towards the head end, and terminating posteriorly in a long, slender, sharply-pointed tail (fig. 101). They are very active, swimming about like a tadpole: they can be kept alive in moist earth or water for some twenty days. In water, if it meets its necessary intermediary host, the cyclops, the embryo filaria penetrates the little crustacean, and in its body, in about five weeks, undergoes considerable development towards a more mature condition. Lying in the body of the cyclops, it is supposed that the filaria waits an opportunity of being conveyed in drinking water to the stomach of its human host or of some other animal, whence it can continue its cycle of existence, as already described.

The peculiar history connected with this parasite emphasises the value of a pure water-supply, as well as the importance of forbidding individuals washing in, or in the neighbourhood of, the drinking-water supply of a community.

Anchylostoma duodenale.—Sometimes called *dochmius duodenale*, this is a short worm which attaches itself, often in large numbers, to the villi of the small intestine. It is very widely distributed, being found in Europe, Egypt, Zanzibar, Gold Coast, West Indies, Brazil, Peru, Bolivia, Assam, Lower Bengal, Borneo, Java, and Australia. It is the cause of the pathological condition known as anchylostomiasis, marked by a serious and often fatal form of anæmia, the result of the large amount of blood abstracted by the parasite.

This entozoon is whitish in colour when empty, but reddish-brown when filled with blood. Its length is from 8 to 18 mm., with a breadth of about 1 mm. Both the males and females (fig. 102) are cylindrical with conical pointed heads. The females have also a pointed posterior, but the males are readily distinguished by having in this situation a peculiar bell-shaped *bursa copulatrix*. The mouth is provided with four strong claw-like teeth.

The adult animal lives generally in the jejunum or duodenum, the eggs (fig. 4, Plate VI.) being expelled with the fæces, and in which they can be readily detected by microscopical examination. The embryo is never found developed within the eggs in the fæces up to the time of their evacuation, but appears, on being discharged from the intestine, to undergo its primary development in wet soil, being much favoured by a high temperature and exposure to air.

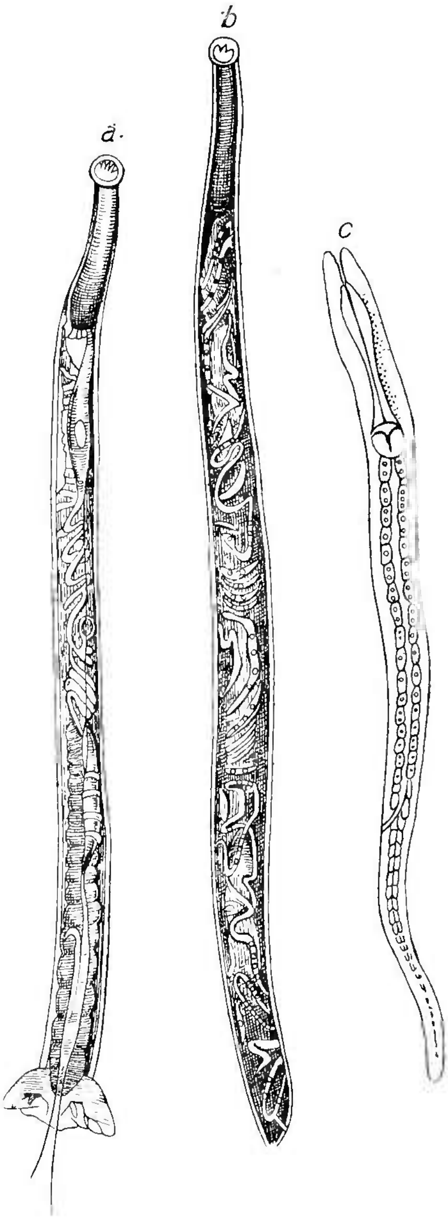


Fig. 102. — *Anchylostoma duodenale* (after Sonsino). *a*, Male; *b*, Female; *c*, Embryo.

The young worm is very different from the adult, and shows a typical rhabditic form, characterised by a spindle-shaped œsophagus ending in a chitinous bulb provided with three chitinous ridges, and an abruptly pointed tail. Under favourable conditions of warmth and moisture, the young larvæ rapidly undergo development marked by an incomplete kind of moulting, which gives them the appearance as if they were enclosed in a kind of case. The larva, having undergone some modifications, especially in the digestive canal by the loss of its chitinous bulb, gradually becomes capable of assuming the parasitic state, requiring only an opportunity of being introduced into the alimentary canal of man to grow there into the adult *anchylostoma.* This simple course of development has been questioned by Giles, whose observations in Assam suggest that, though the embryo born of the parasitic worm reaches an adult free stage, it is only the progeny of this latter or the grandchildren of the parasitic worm, which are capable, after having reached a certain degree of development, of assuming the parasitic life on introduction to the human body. Though a similar heterogenesis is not unknown in other nematodes, this account of the life history of anchylostoma is not as yet definitely accepted by helminthologists, as it is just possible that the free adult form observed by Giles may be only one of the many species of free nematodes known to live in mud, such for instance as *Rhabditis terricola.*

Notwithstanding some uncertainty about the life history of anchylostoma, it is certain that damp soil is the medium in which the eggs, when voided by man, undergo development. From the soil to the well is but a short step, and, either in water—especially muddy water—or in earth adhering to food, this worm is transferred to the human alimentary canal. That the soil plays an important part in the distribution of anchylostoma is further emphasised by the fact that certain classes are specially liable to contract anchylostomiasis, namely, those who handle earth, such as brickmakers, and those engaged in mining, tunnelling, and in general agricultural operations. These considerations indicate that prevention demands attention to rules applying both to the individual and to the community. The principal personal rules will be, careful washing of the hands and nails before eating, whenever mud has been handled; and the drinking of only filtered or boiled water. For the community, care needs to be taken that, in endemic areas, indiscriminate defecation over the country is not practised, coupled with suitable disinfection of the infected dejecta, and the promulgation of simple precepts of prevention suited to the understandings of native people in whom this parasite so extensively prevails.

Rhabdonema intestinale.—This nematode was discovered by Normand in excrements passed by French soldiers suffering from the so-called Cochin China diarrhœa. It has since been found in the West Indies, Brazil, Egypt, Ceylon, Italy, and Germany, and commonly associated with anchylostoma.

Of the adult parasitic form, only the female is known. She is a thin slender worm about 2 mm. long, the breadth being about $\frac{1}{50}$ of the length (fig. 103). In the intestine the embryos are quickly hatched from eggs expelled by the worm, thus differing markedly from *anchylostoma* whose embryos are only hatched after the eggs are voided from the human intestine. The embryos, which are to be found in large numbers in the dejecta of affected persons, are about 0·3 mm. long, and 15 μ thick. They possess a sharp-pointed tail, and being rhabditiform, have a short œsophagus with two dilatations, resembling somewhat the embryos of *anchylostoma.* When discharged with the fæces, on these decomposing, the embryos rapidly die. But if they gain access to foul water, the embryos live and assume one of two different forms of development, according to the temperature. Under a low temperature (20° C.) they become filariform larvæ, capable, if directly re-introduced into man, of growing into the adult parasitic form, without alternation into the adult free form. Under a higher temperature (30° C.) the embryo grows into the adult free form. This was formerly called *Anguillula* *stercoralis*, and consists of males and females. It is shorter and thicker than the parasitic form. From these breed rhabditiform embryos, like those from the parasitic worm, and these embryos then grow into filariform larvæ, which only need introduction into the human intestine to develop into the adult parasitic form. The source of infection by this parasite is probably the same as in *anchylostoma*, namely, soil or foul water.

Filariæ sanguinis hominis.—There are three definite species of embryo nematodes which have been found in the blood of man, and to which the term *Filaria sanguinis hominis* may be appropriately applied. Adopting the nomenclature suggested by Manson, to whose writings and investigations we are mainly indebted for the following facts, the three species of hæmatozoa are *Filaria nocturna*, *Filaria diurna*, and *Filaria perstans*. These names have been given on the basis of certain individual peculiarities of habit characteristic of each of the three species. Thus, *F. nocturna* is present in the general circulation only during the night, *F diurna* only so

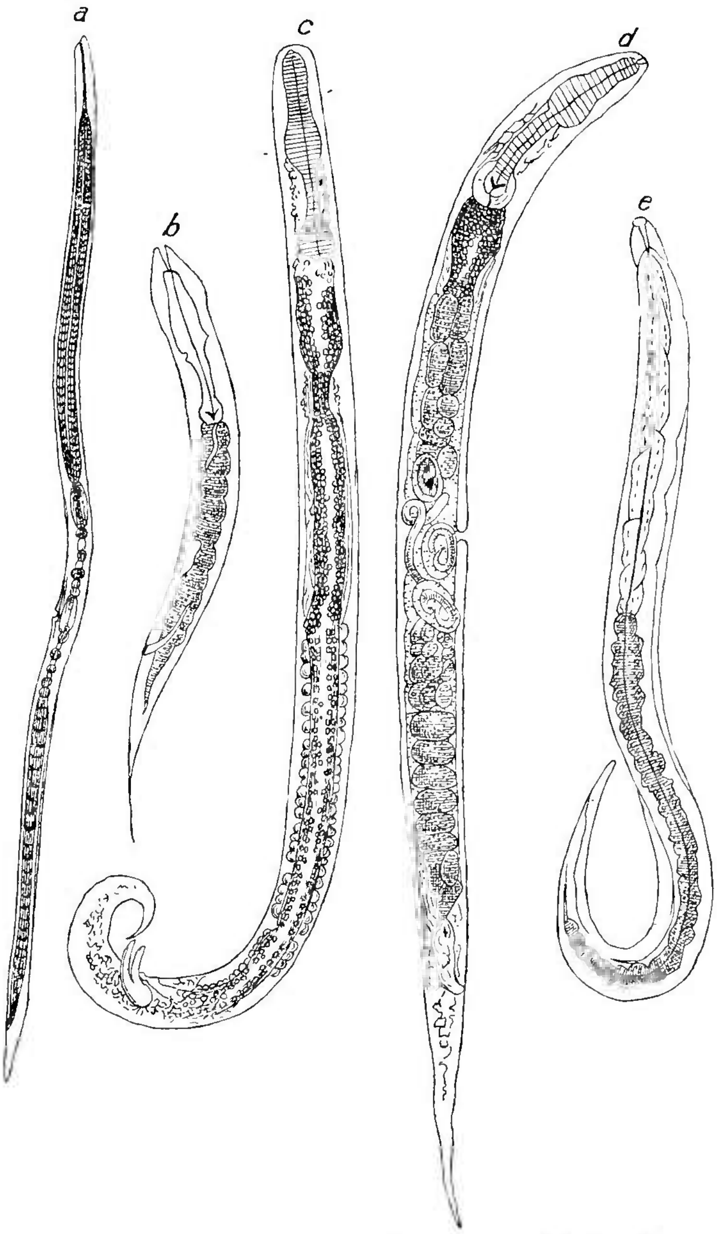


Fig. 103.—*Rhabdonema intestinale* (after Sonsino). *a*, Adult female parasitic form ; *b*, Embryonic form ; *c*, Male adult free form ; *d*, Female adult free form ; *e*, Larval form.

during the day, while *F. perstans* is present both by night and day. It is essential, for a right comprehension of the somewhat complicated subject of blood filariæ, to grasp the fact that all these organisms are only the embryos of certain other and mature parasites, which live and breed in remote parts of the body, and that, though the embryos may swarm within the blood, it is not necessary, in fact is exceptional, for the parent forms to be present in the circulation.

As seen in freshly drawn blood the *Filariæ sanguinis* are slender, long, transparent, and snake-like animals endowed with great activity. In the case of *F. nocturna* and *F. diurna*, this activity is exhibited chiefly as a constant lashing and wriggling without forward movement: whereas, with *F. perstans*, the wriggling is combined with a vermicular movement leading to distinct locomotion. The characteristic features of the three filariæ are well described in the following table by Manson:—

Filaria nocturna.	*Filaria diurna.*	*Filaria perstans.*
Measures $\frac{1}{75}'' \times \frac{1}{3500}''$.	Measures $\frac{1}{75}'' \times \frac{1}{3500}''$ or thereabouts.	Measures about $\frac{1}{125}'' \times \frac{1}{3500}''$.
Is provided with a sheath.	Is provided with a sheath.	Has no sheath.
Caudal end tapers gradually for one-eighth or one-fifth of the length of the animal and ends in a sharp point.	Caudal end tapers gradually for one-eighth or one-fifth of the length of the animal and ends in a sharp point.	Caudal end tapers more gradually for two-thirds of the entire length of the animal, and is abruptly truncated where it becomes reduced to one-third of the diameter of the thickest part of the body.
Cephalic end rounded off, and has obscure pouting movements produced by the movements of a six-lipped prepuce.	Cephalic end rounded off, and has distinct pouting movements. Minute anatomy not known.	Cephalic end is either conical or truncated, passing from one shape to the other by a peculiar jerking, extending and retracting movement.
From time to time a thick tongue-like organ, provided with a delicate retractile spine, is protruded at cephalic end.	Minute anatomy not known.	From time to time a minute tongue-like organ, provided with a rectractile spine, is protruded and withdrawn at cephalic end.
Appears in the blood at night, disappearing from it during day.	Appears in the blood during the day, disappearing from it at night.	Present in the blood both by day and by night.
Has a wriggling but no locomotive movement.	Has a wriggling but no locomotive movement.	Has a locomotive as well as a wriggling movement.
Well-marked granular aggregation about the junction of the middle with the posterior third of the body in some specimens.	Slightly marked granular aggregation about the junction of the middle with the posterior third of the body in some specimens.	Body homogeneous throughout, and no such aggregation.
Has a V-shaped organ or luminous point behind the head. Possibly is a rudimentary vagina.	Has a V-shaped organ or luminous point behind the head. Possibly is a rudimentary vagina.	Has no V-shaped organ.

All these filariæ exhibit a great tenacity for life, and can be seen alive for many days in ordinary slides, provided the blood be kept fluid by oiling the edge of the cover-glass. Mackenzie has shown that the curious phenomenon of filarial periodicity is in some way connected with the quotidian habits of sleeping and waking; and that if this habit of the host be inverted, so is

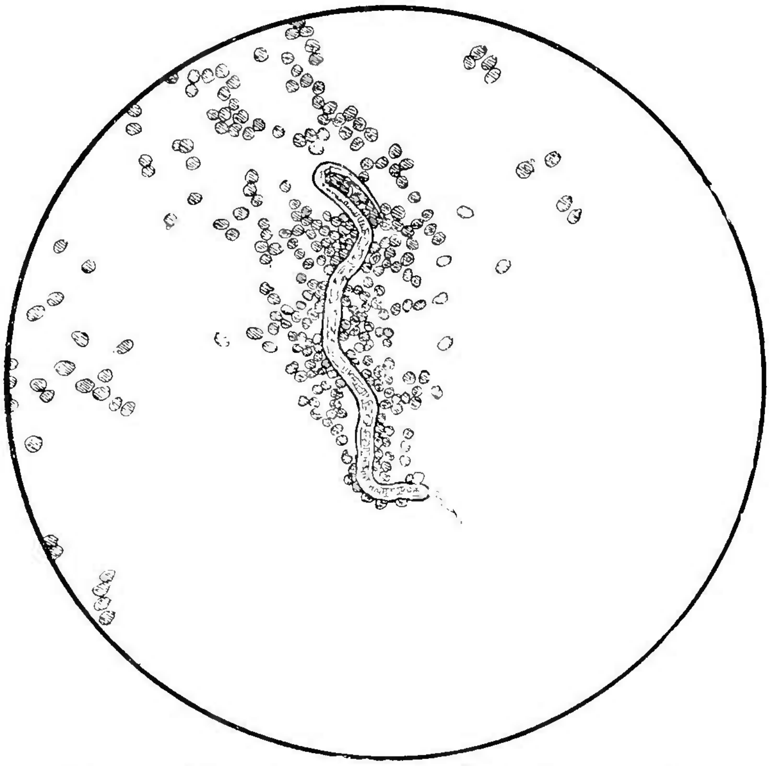


Fig. 104.—*Filaria sanguinis hominis diurna.* × 160.

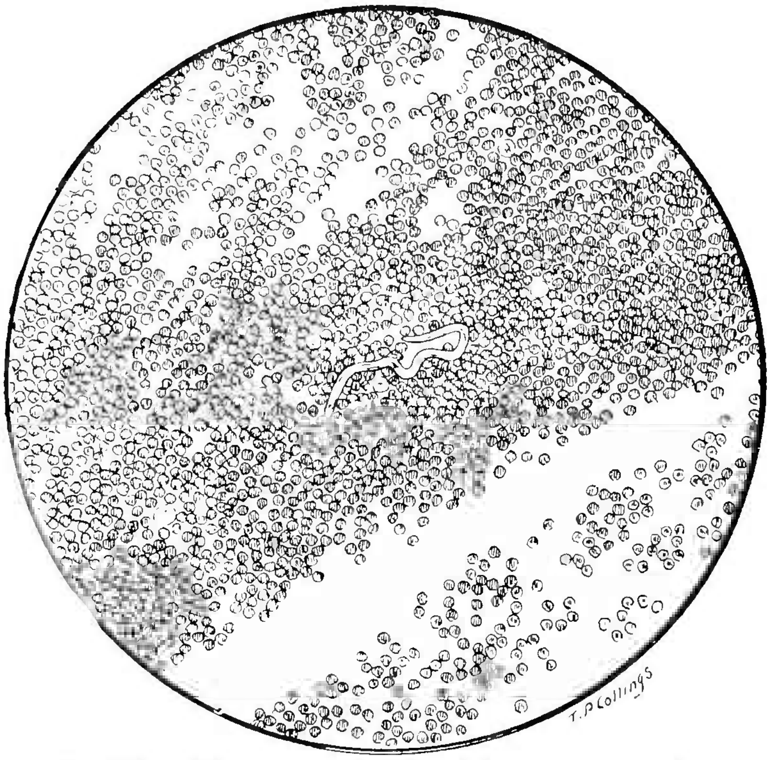


Fig. 105.—*Filaria sanguinis hominis perstans.* × 160.

the periodicity of the filarial parasite inverted. The precise cause of this periodicity is not known, but there is reason to think that it is neither due to any intermittent parturition on the part of the parent filaria, nor to any deficiency of oxygen in the blood, as has been suggested by Myers, but rather is an adaptation to the habits of their intermediate hosts.

The life history and parental forms of these filariæ have only been determined in regard to one of them, namely, the *F. nocturna*. The parent worm of this embryo is a peculiar nematode, usually associated with chyluria and elephantiasis, and known as the *Filaria Bancrofti.* As regards the mature forms of *F. diurna* and *F. perstans* practically nothing is known, though Manson has suggested that possibly the long but imperfectly known *Filaria loa* may be the parent form of *F. diurna;* and that certain hominivorous flies with diurnal habits may be its intermediary host. Manson has found a new and smaller variety of *F. sanguinis hominis* in a West Indian patient.

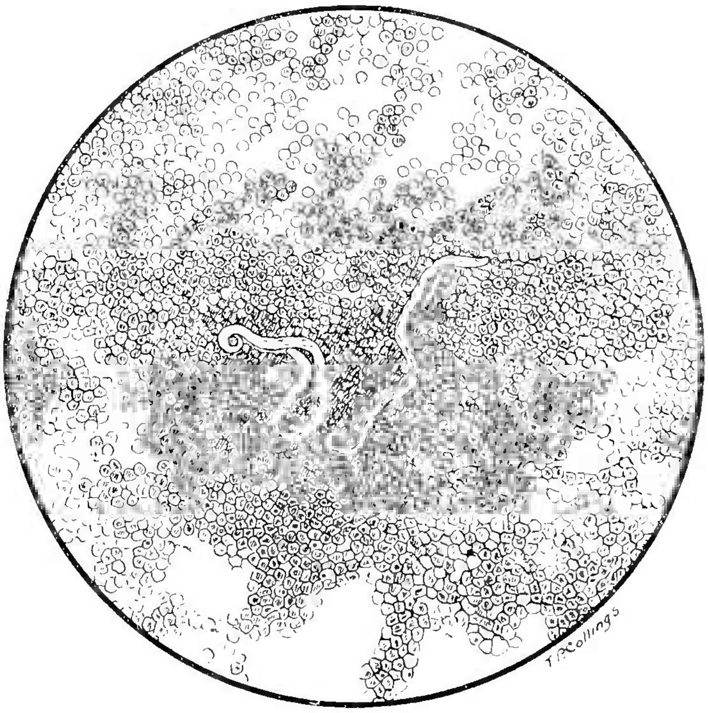
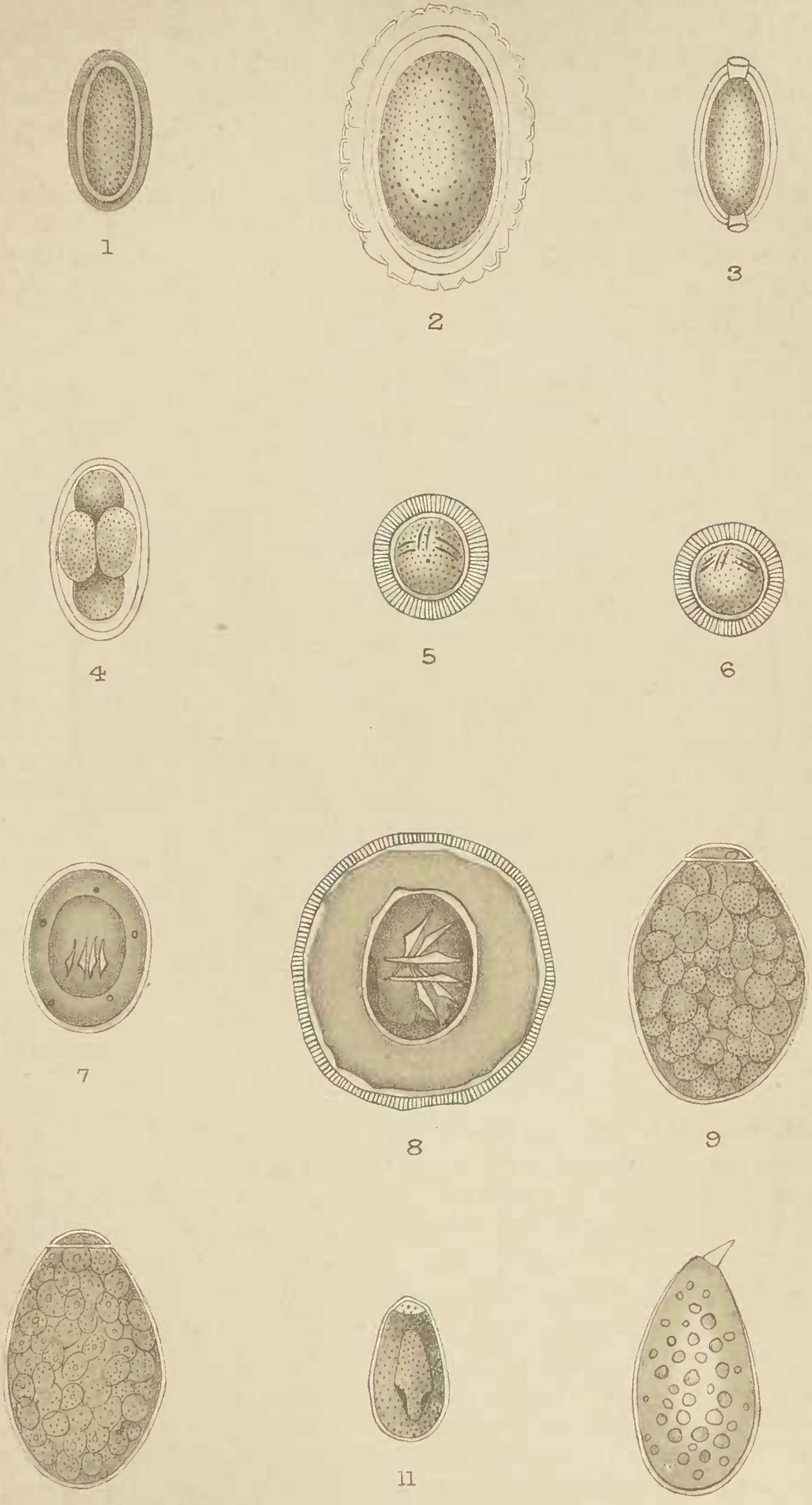


Fig. 106.—*Filaria sanguinis hominis nocturna.* × 160.

Filaria Bancrofti.—This is the mature or parent form of the *F nocturna*, having its habitat in the majority of instances, if not in every case, in the lymphatic system. Usually the male and female are found together, but as yet, owing to only imperfect specimens having been examined, the precise anatomy of the male is not well known. The female is commonly about 3½ inches long and $\frac{1}{100}$ inch thick, being smooth and cylindrical. The mouth is simple, circular, and destitute of papillæ: close to and behind the head is the reproductive outlet. The tail is simple, blunt pointed, with anus immediately above the tip. While the alimentary tube is simple, the main part of the animal is occupied by the double uterine or ovarian tubes, usually stuffed with myriads of embryo filariæ at all stages of development. The embryos on escaping from the parent within the lymphatic system pass periodically into the blood stream, where they are familiar as the *F. sanguinis hominis nocturna.* This periodical migration into the blood is apparently an adaptation to the habits of the mosquito, which is the

Plate VI.



West, Newman lith.

Ova of Parasites.

intermediate host of this parasite. The mosquito, as every one knows, is most active at night, and when it bites the human host, these filariæ either curl round or become entangled on its proboscis, and are then quickly transferred to its stomach. The greater number of the filariæ so swallowed by the mosquito are digested or destroyed, but a certain few undergo development inside its body, and, when the mosquito retires to some water to lay eggs, or to eventually die, these filariæ which have developed inside its body pass out by boring into the water, whence they get swallowed by man. Once inside the human stomach, the filariæ bore their way into the lymphatics, finally reaching their permanent abode in some distant lymph-vessel, where, as the *Filariæ Bancrofti*, they give rise to chyluria and elephantiasis, and breed, their progeny passing into the blood as before explained, till, released by the mosquito, they in their turn can complete their circle of development.

Filaria loa.—Very little is known of this parasite, although it is by no means uncommon on the West Coast of Africa. It chiefly affects the subcutaneous tissues, being possessed of considerable powers of locomotion. It is often found in the loose cellular tissue beneath the conjunctivæ, where it creates much irritation. Leuckart gives the length of this worm as from 30 to 40 mm., with the thickness of a fiddle string. One end is pointed, the other blunt, the latter probably being the head, as it is provided with a prominent papilla but no special armature. Nothing is known of its life history, but Manson, from the fact that it had been present at a previous date in a negro in whose blood he afterwards found *F. diurna*, has suggested that *F. loa* may turn out to be the female parental form of *F. diurna*.

CESTODA.

The Cestodes include the great group of tapeworms, which in reality are a multitude of organisms or zooids, arranged in single file. The head itself is merely the topmost zooid, modified in shape, and armed with sucking discs, so as to form a means of anchorage for the whole colony. An ordinary human tapeworm consists of about a thousand zooids or proglottides, each of which is sexually complete, and, when mature, capable of generating about 30,000 eggs. Assuming that the entire colony of a thousand zooids is renewed every three months, it follows that a single tapeworm annually disperses about 120,000,000 eggs. Fortunately, compared with the quantity distributed, the number of eggs that survive and come to perfection as tapeworms is infinitesimally small. The chief cestodes, parasitic to man, are the following:—

Tænia saginata, sometimes called *T. mediocanellata*, is the only cystic tapeworm with an unarmed head which occurs in man. It is, at the same time, the largest of the human tæniæ, being about 8 metres long when extended, and composed of from 1000 to 1300 segments. These segments are remarkable for their size, breadth, and firm appearance. The largest measure 20 mm. in length, and from 5 to 7 mm. in breadth. The head of this parasite is hookless, has a

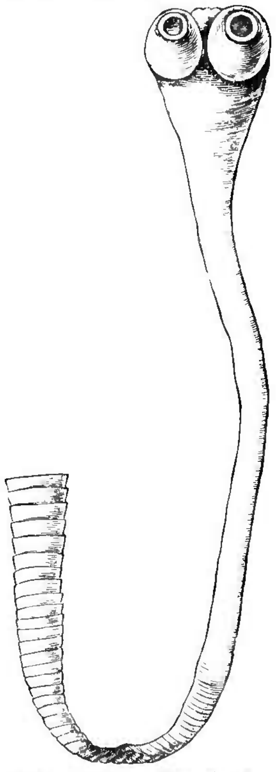


Fig. 107.—Head of *T. saginata*.

flattened crown, with a pit-like hollow in the middle, and has four large and very powerful suckers, which, however, usually project only slightly, and are frequently surrounded by a black, broad, pigmented border (fig. 107).

The complete development of the germ-producing organs takes place at about the 600th segment, while the embryos only attain maturity at about the 1000th segment. Each segment contains male and female organs, while the number of so-called "ripe" segments, present at any one time, averages about 200. The new formation or growth of the segments is so rapid that some ten proglottides are separated daily, even when, as is the rule, only a single worm is present. The eggs of this worm (fig. 5, Plate VI.) have a thick shell, with a border of little rods. They are generally oval, and provided with the primordial yolk-skin; their average size is 0·03 mm. The normal abode of this parasite is the small intestine, to the walls of which it is fixed, usually towards the upper end. The precise duration of its life is undetermined, but seems to be very long. The eggs are commonly expelled with the dejecta of the host, and the contained embryo does not undergo further development, unless it obtain access to the alimentary canal of the ox. From here the embryo passes into the voluntary muscles of the animal, where it remains as a bladder-worm, a simple scolex, known as the beef-measle or *Cysticercus bovis*. An ox, affected with this parasite, that is, acting as the intermediate host for the *T. saginata*, may contain many hundreds of the cysticerci, or bladder-worms, within its muscles. On the flesh of the animal (either raw or imperfectly cooked) so affected passing into the alimentary canal of man, the bladder-worms develop into the sexually complete adult form known as the *T. saginata*.

The cattle in Abyssinia and the Punjab appear to be specially infected with the cysticerci of the *T. saginata*, this parasite being by far the most common of the tapeworms found in man in those countries. The only animal, besides the ox and goat, which has hitherto exhibited the bladder-worm of *T. saginata*, is the giraffe.

How long the bladder-worm of *T. saginata* remains living in its host cannot at present be decided, but we may reckon the length of its stay there at several years. It, however, survives only some fourteen days after the death of its host, and if the parts putrefy, will only survive a still shorter time. As regards the term of infection in man, usually some nine to twelve weeks must elapse after the ingestion of the *cysticercus* before the *T. saginata* gives off the first proglottides.

Tænia solium.—This cestode, though usually regarded as the common tapeworm, is comparatively rare. It is chiefly found amongst the poor, who are large consumers of pork, which is often imperfectly cooked. In Iceland and Germany the pork tapeworm is rather more common than the beef tapeworm.

In size, thickness, and number of segments, this species is considerably less than the last. Extended, it rarely exceeds 3·5 metres in length, while its segments average 850, and of these not more than 100 are ripe proglottides. The size of the greatest of these segments is about 12 mm. by 5 mm. The head (fig. 108) is about the size of that of a pin, has a spherical shape with prominent suckers. The apex is often coloured black, and bears a medium-sized rostellum, with generally twenty-eight hooks. The sexual organs are usually fully developed at about the 400th segment. The eggs (fig. 6, Plate VI.) are almost round, being enclosed in a firm shell, whose outside is covered thickly with little rods. Sometimes the original clear egg-membrane persists within the shell. The course of development and life history of this parasite is analogous to that of *T. saginata*, with the exception that the corresponding bladder-worm (*Cysticercus cellulosæ*) has a special preference for the muscles of the pig, but, according to Leuckart, is occasionally found in other animals. Its occurrence in the pig is usually very abundant, where it constitutes measly pork (fig. 109). The great majority of the cysticerci average between 3 and 4 mm. in size, but some are both larger and smaller. They are killed by exposure to a temperature of 50° C.

It must not be overlooked that, although the pig is the most frequent intermediate host for this bladder-worm, man himself may become the intermediate bearer, as this cysticercus develops also within the human body. The above fact leads us to the question: By what way does man become infected by these embryos? An infection by some means must precede the appearance of *cysticerci*, and its channel can only be by the alimentary canal. The most direct and frequent source of infection is in the eggs, which are dispersed about the abode of the tapeworm, and also widely distributed in the open air with the excrement. These may reach man's digestive tract either by water, food, or by the hand. This latter vehicle of infection is by no means unknown in the case of children and the insane, while the normal adult tapeworm patient may readily infect himself with the proglottides of *T. solium* during sleep, by lifting the hand to the mouth.

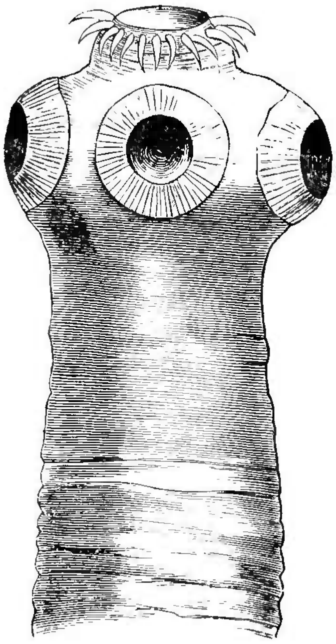


Fig. 108.—Head of *T. solium* (after Leuckart).

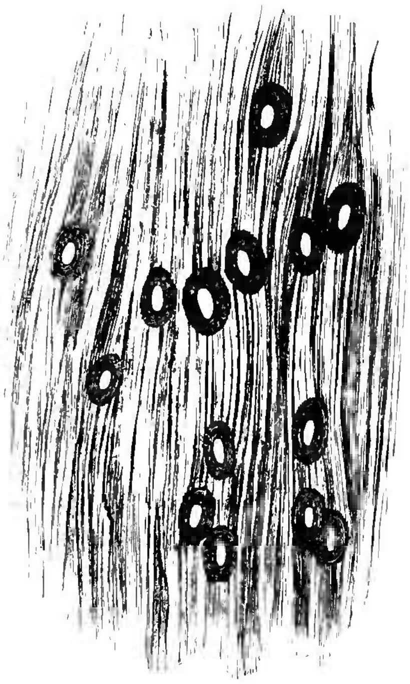


Fig. 109.—Muscle containing *Cysticerci cellulosæ* (after Leuckart).

These considerations suggest the special need of cleanliness when an inmate of the house suffers from this parasite. The linen of the patient should be frequently changed, the buttocks, perineum, and hands frequently washed, the excreta carefully removed, and all voided proglottides burnt without touching the hands. Of all persons, the patient is himself in greatest danger of infection. The experimental evidence of this danger of self-infection has been supplied by Küchenmeister, who reared both mature and immature tænia of this species in condemned criminals; while, under

Leuckart's auspices several persons voluntarily allowed themselves to become infected by swallowing fresh and living pork measles.

Tænia acanthotrias.—This is a somewhat uncommon parasite of man, and has hitherto only been observed in America. Only the bladder-worm is as yet known, being very like *Cysticercus cellulosæ*, and having its habitat in the muscles and brain of man. "It is distinguished by the arrangement and structure of the hook apparatus, which is composed of a triple circle of from fourteen to twenty-six slender hooks." Leuckart and Weinland both maintain that this *Cysticercus acanthotrias* represents an independent species. The related Tænia is unknown, but it probably lives in the human intestine like *T. solium;* if so, the bladder-worm may possibly be found in some animal, such as the ox.

Echinococcus hominis.—Man is occasionally affected with a dangerous parasite under the name of hydatid disease, which commonly affects the liver, but may occur elsewhere. It is really the cysticercus stage of a tapeworm, which lives in the intestines of the dog, jackal, and wolf, and called the *Tænia echinococcus.* The adult tapeworm (fig. 110) is of comparatively small size, its total length being only some 5 millimetres; and has only three or four segments, of which the last, when mature, exceeds all the rest of the body in size. Its head is characterised not merely by its small size, but also by the possession of a prominent crown which surrounds the bulging rostellum, on which are from 28 to 50 thick solid hooks, arranged in two series.

Fig. 110.—*Tænia echinococcus* (after Leuckart).

Behind the four suckers the head narrows to a neck, which then passes into the unsegmented anterior part of the body. The first segment is but faintly differentiated; the second is defined and contains elementary sexual organs. The third and last segment exhibits all the characters of sexual maturity, and contains some 500 spherical hard-shelled eggs, in which are the familiar six-hooked embryos. Before the last or ripe segment is liberated, a new joint appears; so that, for a while, four proglottides are distinguishable instead of three.

On the escape of the eggs, the contained embryo does not undergo further development unless received into the body of the pig, ox, or possibly some other animals, and man, in whom, after burrowing to various parts of the body, more particularly the liver, it assumes the larval stage of a *cysticercus* or hydatid cyst. Unlike other cysticerci, this bladder-worm increases indefinitely in size, and also forms within itself secondary cysts, some of which, the so-called brood-capsules, contain one or more echinococci (scolices) and remain minute, while others, containing no scolex, enlarge and form other or daughter cysts, which again may produce new cysts by a process of budding. Separately, these scolices, formed within the parent cysticercus, represent as many tapeworms, and collectively they amount to many thousands. Thus, when a dog or a wolf swallows one of these hydatid cysts and its contained offspring, all the heads of the colony become converted into sexually mature *T. echinococci* in the intestine of the new host. This metamorphosis of the echinococcus heads into tapeworms takes place with great rapidity. Leuckart's feeding experiments resulted in mature worms being found in the seventh week. How long the adult worm lives is not known, but analogy suggests that its period of existence within the intestine of the dog is not very short. Since the *T. echinococcus* especially inhabits the intestine of the dog, and the dog is one of the few animals in closest association with man, we are justified in regarding this animal as the only source of the human echinococcus disease. It is not difficult to understand how cattle become infected; for the proglottides and eggs of the echinococcus tapeworm, voided so constantly, and in such large numbers, by the dog, readily find access on to straw, grass, or even water, and with those articles of food and drink are consumed by the oxen. In the case of man, possibly the sequence of events is not much different. As with cattle, both proglottides and eggs of the tapeworm from the dog may in many ways be carried in food, especially uncooked vegetables, such as lettuces, or on the hands to the mouth, and thus reach the intestine. Probably a greater risk of infection lies in the habit which dogs have of licking the hands and faces of their masters, and that often after they have been smelling and snuffing about other dogs. These are considerations which should prevent our too familiar association with dogs, more particularly to avoid their licking us, and frequenting dwelling-rooms or kitchens, to say nothing of keeping them clean, and that their excrement is not allowed to remain about. Moreover, full precautions should be taken to prevent infection of dogs by embryos of echinococcus, as may occur in slaughter-houses, where the so-called bladder-worms, or echinococcus cysts, from slaughtered and infected animals are often carelessly thrown down. It is needless to say that dogs eating such echinococcus bladders would soon develop them into sexually mature echinococcus tapeworms.

Tænia nana.—Judging by the few cases which have been observed, this is an uncommon parasite of man. It was originally discovered by Bilharz in Egypt, who describes it as being a small tapeworm, from 12 to 20 mm. long, and with a maximum breadth of half a millimetre. The front half of the body is threadlike, but posteriorly it enlarges somewhat quickly. The head is spherical and bears four suckers and a central rostellum, provided with a single circle of from 22 to 28 extremely small hooks. The number of segments is not more than 170, of which the last contain thirty or more ripe eggs. Each segment is very short, being about four times as broad as long. The eggs (fig. 7, Plate VI.) are oval, with a thick but not radially striated shell. They measure from 30 μ to 50 μ in length, and 40 μ in breadth.

Very little is known of the life history and origin of this worm, but, arguing from what is known of some allied species, it is supposed that the larval stage is passed in some insect or snail.

Tænia flavo-punctata.—This is another very uncommon human parasite. Its length is about 1 foot. The front half of the animal consists of unripe segments, each of which exhibits posteriorly a central yellow spot: this is the distended *receptaculum seminis*. In the posterior half of the body the segments are longer and broader, and without the yellow spot. In this situation the segments are of a brownish-grey colour, owing to the abundant development of eggs. The eggs are very large (fig. 8, Plate VI.), having a diameter of some 70 millimetres. They have a smooth double envelope, which under

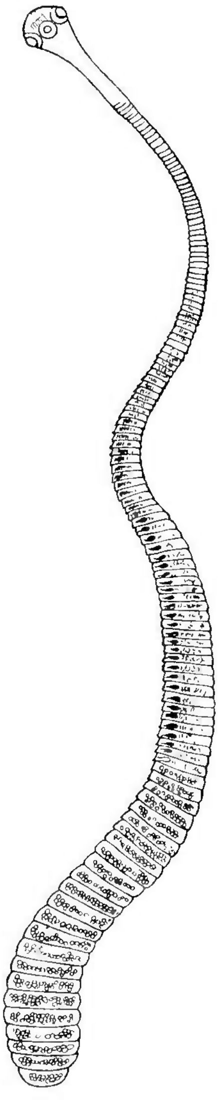


Fig. 111. — *Tænia nana* (after Leuckart).

high power can be seen to be radially striated. Nothing is known of the life history of this worm: nor has its head been satisfactorily examined.

Tænia Madagascariensis.—This intestinal cestode has only been met with in warm climates. It reaches a length of about 20 cm., with a breadth of 2·5 mm. It has usually 100 segments, in the interior of which are a number of small oval bodies, arranged in transverse rows, alternating with each other, but without touching at any point. These are balls of eggs, and amount in each proglottis to quite 150: the number of eggs in each ball being about 400. The head of this worm has a rostellum with about ninety hooks. The worm itself has only been met with in children, and its life history is unknown.

Tænia cucumerina.—This species of tapeworm is most frequent in cats and dogs; it has also been found in young children. Fig. 112 shows this worm in its natural size. The head is club-shaped, with a rostellum surrounded with four rows of hooks. While the first forty segments are insignificant in size, the remainder lengthen so much that they ultimately become four times as long as they are broad: the corners of these proglottides are rounded. The ripe segments are of a red colour, from the masses of brownish eggs shining through.

The intermediate host of *T. cucumerina* is the dog and cat louse, in which it passes its larval condition as a cysticercoid. The probable life history is somewhat as follows. The eggs of the adult tapeworm make their way sooner or later from the excreta to the hairy skin of the cat or dog, and thence to *Trichodectes* or lice living upon it, in the interior of which insects the eggs change into cysticercoids. Cats and dogs are constantly licking themselves and devouring the hosts of these bladder-worms; from them the infection of man takes place either from the tongue of the dog which returns caresses by licking, or through the hands, which stroke these animals. In children, who treat both cats and dogs with familiarity, the facilities for infection are even greater than in adults.

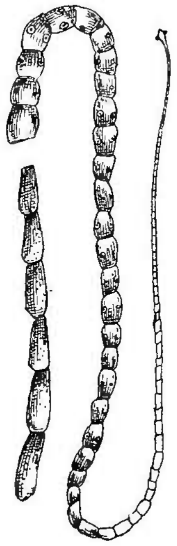


Fig. 112.—*Tænia cucumerina* (after Leuckart).

Bothriocephalus latus.—This is a short-jointed, broad and flat tænia of very considerable length, attaining usually some 27 feet. The number of segments may amount to as many as 3500. The body is thin and flat like a ribbon, especially towards the sides, while the median portion projects as a sort of pad or ridge. In the ripe proglottides, the uterus constitutes a characteristic feature of this tapeworm, being peculiarly stellate or rosette-shaped. The head is ovoid, $\frac{1}{10}$ inch long, and has two longitudinal grooves or suckers, but no hooklets. The eggs (fig. 9, Plate VI.) are oval, about $\frac{1}{400}$ inch in their shorter diameter, and provided with an operculum or lid at one end: the shell is brown in colour. The embryo is a ciliated organism with six hooks, and, in the free state, can live and swim about in water for more than a week. Subsequently the ciliated mantle is discarded. The intermediate host of this worm is believed to be certain kinds of fresh-water fish, particularly the pike, into which the embryos enter directly from without by boring. Although all attempts to bring about an immigration of these embryos of *bothriocephalus* into fish have failed, the observation of larval forms of this tapeworm in the pike

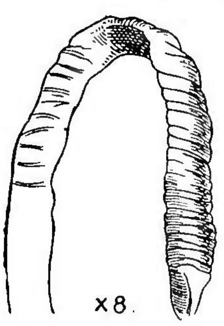


Fig. 113.—Head of *Bothriocephalus latus*.

and turbot are sufficiently definite to warrant the belief that the intermediate host is one of these fishes. Possibly there may be two intermediate hosts, the first being an aquatic invertebrate.

As found in the pike, the larval worm of *Bothriocephalus latus* is not cystic, but round, long, narrow and distended. Its length varies in this stage from 1 to 2·5 mm. Not only in man, but in cats and dogs, feeding experiments have given positive results.

TREMATODA.

The members of this group are popularly called flukes, from the fact that the commoner species are flat, like the flukes or blades of an anchor. The name trematodes was given them because they exhibit perforations or pores (*trema*, a pore) which we now recognise as suckers. The flukes are usually of small size, the largest being not more than 3 inches in length, and the smallest scarcely visible to the naked eye. Sexually, they are for the most part hermaphrodites, but in some the sexes are separate. Most of them have a simple divided intestine with two cæcal ends.

Fasciola hepatica.—This is the common fluke, and measures from half to three-quarters of an inch in length. Its habitat is in the gall ducts and gall bladder of man, of sheep and other ruminants. The number of cases of human infection by this parasite are not large, but they are sufficiently numerous to indicate that it may be the cause of severe disorders, though not always fatal. The free life of the embryos is generally short, and in place of making their way into some intermediate host, such as one or more species of fresh-water snails, as do some allied forms, the embryos become encysted upon water plants and other objects, attached to which they are transferred to their final host, in whose body they attain maturity. The eggs of *F. hepatica* (fig. 10, Plate VI.) possess a thin brownish shell; they are operculated, and measure 140 μ by 90 μ.

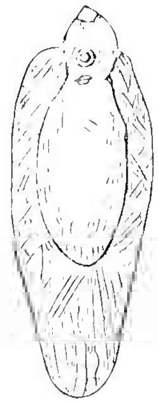


Fig. 114.—*Fasciola hepatica* (after Leuckart).

Distomum lanceolatum.—This is the smallest common European fluke, being about one-third of an inch long, and in the few cases in which it has been found in man has been once associated with the last species. Its life history is not accurately known, but is similar to that of *F. hepatica*. The eggs of this parasite measure from 40 μ to 45 μ in length by about 20 μ in breadth; they have a thin brown operculated shell, and generally contain an already formed, partially ciliated embryo (fig. 11, Plate VI.).

Distomum sinense and **D. conjunctum.**—The first of these is a small fluke, measuring seven-tenths of an inch in length, and found infesting the livers of Chinese and Japanese, in whom it often causes a severe hepatitis. Its cercaria, or larval stage, is not known, but probably infests a fresh-water mollusc. The eggs of the entozoon are oval with a double contour and an operculum. Their average size is about 30 μ, or say $\frac{1}{800}$th of an inch. *D. conjunctum* is only three-eighths of an inch in length, and has been found in the livers of both dogs and man. No more is known of its life history than of *D. sinense*. Its eggs are similar in shape and appearance to those of the latter, the only distinction between them being that the eggs of *D. conjunctum* are slightly the larger of the two.

Distomum crassum, sometimes called *D. Buskii* from the name of its first discoverer, is the largest fluke found in man, measuring from 1 to 3 inches in length. Its favourite habitat is the duodenum. Neither its larval state nor intermediate host are known, though this latter is thought to be a species of Chinese oyster. The eggs of this fluke are large, 125 μ by 75 μ, thin-walled, oval, and filled with granular and somewhat high refracting matter.

Distomum heterophyes is a very minute fluke, measuring no more than from 1 to 1·5 mm. It has only been twice found in man; on both occasions in Egypt. Its eggs are minute, oval, reddish-brown and with a thick shell. Size, about 25 μ by 15 μ.

Amphistomum hominis.—Very little is known of this parasite, which, until now, has only been found in India. The eggs possess a shell with operculum, are oval-shaped, and measure 150 μ long by 72 μ broad. Its habitat is the intestine, but nothing is known of either its larval stage or life history.

Distomum Ringeri.—Discovered first by Ringer in North Formosa, it has since been found also in Japan and Corea, usually inhabiting the lungs, but also the brain and sub-peritoneal tissues. It is a small, oval, thick, reddish-brown fluke, measuring about one-third inch in length by one-fourth inch in breadth. It has two suckers, the oval, which is terminal, being slightly the larger; the ventral sucker is placed about one-third of the animal's length posterior to the oval one. This parasite gives rise, when situated in the lungs, to severe hæmoptysis, and the diagnosis of this pulmonary helminthiasis depends mainly upon the recognition of the ova of this fluke in the sputum. These ova are dark brown bodies, measuring about $\frac{1}{300}$ inch by $\frac{1}{500}$ inch. They have a plain thick shell, the broader end being closed by a lid. Under suitable conditions of moisture, a ciliated embryo develops within each egg. Manson, who has closely studied the eggs of this fluke, considers that, in water, the embryo distome seeks out an intermediary host in the shape of some mollusc or other fresh-water animal; and "that, after entering this, either by being swallowed or by penetrating its integument, it undergoes the complex metamorphosis peculiar to the distomes. When this is completed it is either swallowed by man, while still in its intermediary host; or, escaping from this, it attaches and encysts itself on some vegetable or other animal, and there awaits the chance of being transferred to a human stomach, from whence it afterwards works its way to the lungs of its definitive host."

Bilharzia hæmatobia.—This is a trematode worm, which differs from those previously described by having the male and female reproductive organs in separate individuals. The male is opal white, and measures about $\frac{6}{10}$ inch in length, by $\frac{1}{25}$ inch or more in breadth. The female is grey or brownish in colour and both longer and thinner than the male worm. Both male and female possess two suckers; the body of the male assumes a cylindrical shape, due to the lateral borders being bent inwards, constituting in this manner a sort of gynæcophoric canal for the female. The adult worms are generally

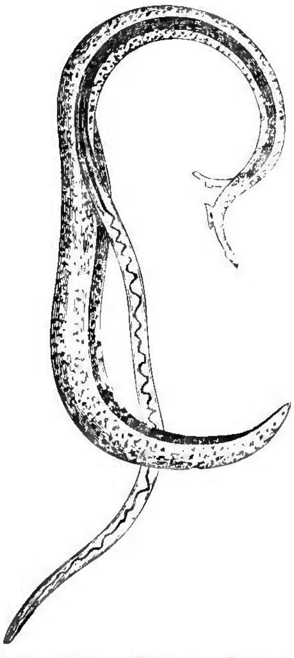


Fig. 115.—Male and Female Bilharzia (after Leuckart).

found in the portal vein and its branches and tributaries; also in the small veins of the bladder, ureters, and inferior cava. They are frequent in Africa, especially Egypt, the Cape and Natal; also on the coast of Arabia. There is likewise evidence to show that they occur in the Ile de Bourbon, Mauritius, and Brazil.

Located within the visceral veins, the adult parasites, if present in any large numbers, will soon make their presence felt. If many worms exist, a violent hæmaturia may occur, without any warning. Experience has shown that, although hæmaturia invariably accompanies the disorder, the bleeding—in cases where but few worms exist—may be so slight as to escape, not only the eye of the victim, but even also that of the medical attendant. From this it follows that the presence of the disease can only be certainly diagnosed by microscopic examinations of the urine and fæces to detect the eggs. These eggs (fig. 12, Plate VI.) are bright and translucent oval bodies, with a smooth surface and thin non-operculated shell, possessing a spine situated ordinarily at one end, but sometimes laterally. They have a length of 0·16 mm., and a breadth of 0·06 mm. The embryo is ciliated, and if left in urine soon dies; in water, however, its vitality is both marked and sustained. According to Sonsino, the intermediary host of *Bilharzia* is a small fresh-water crustacean (amphypoda), on encountering which, in water, the free embryo attacks at a vulnerable point, and, by means of the papilla at its head, bores and forces its way into the animal's body after having rid itself of its covering of cilia. Having effected an entrance, it proceeds to encyst itself. The encysted larva, being transferred with the crustacean in drinking water to the human stomach, is then set at liberty; afterwards, penetrating the intestinal walls, it arrives in the portal vein, where, presumably, it completes its development.

At one time it was suggested that the re-introduction of this parasite to man might be made through the skin, urethra, or anus whilst bathing, instead of by the digestive tract, but in the face of the precise observations of Sonsino, this hypothesis is as untenable as it is unnecessary.

BIBLIOGRAPHY AND REFERENCES.

Blanchard, "Note sur quelques vers parasites de l'homme," *Comp. rend. de la Societé de Biologie*, Paris, Séance du 18 Juillet 1891. Bollinger, "Die Actinomykose," *Centrl. f. d. Med. Wiss.*, 1877, No. 27. Braun, "Bericht. u. die Fortschritte in der thierischen Parasitenkunde," *Centr. f. Bakter. u. Parasiten*, x. p. 389; also *Die thierischen Parasiten des Menschen*, Wurzburg, 1894.

Cobbold, *Entozoa*, Lond., 1864, with a Supplement, 1869; also *Human Parasites*, Lond., 1882—this book gives an extensive literature up to that date. Crookshank, "On Certain Forms of Hæmatozoa," *Journ. Roy. Microscop. Soc.*, Nov. 10, 1886.

Davaine, *Traité des Entozoaires*, Paris, 1877.

Erni, "Report on Tricocephalus dispar and Beri-beri in Sumatra," as an Appendix to Kynsey's *Report on the Anæmia or Beri-beri of Ceylon*, Colombo, 1887.

Felkin, *On the Geographical Distribution of some Tropical Diseases*, Edin., 1889. Font, "De la Filariosis: exposicion del primer caso esporádico observado en Europa," *Rev. de cienc. méd. de Barcelona*, 1894, pp. 73 and 94. Friedberger and Fröhner, *Lehrbuch der speziellen Pathologie und Therapie der Hausthiere*, Stuttgart, 1889.

Galloway, "On the Parasitism of Protozoa in Carcinoma," Morton Lecture, *Brit. Med. Journ.*, Feb. 4, 1893. Giles, *Report of an Investigation into the Causes of* *the Disease known in Assam as Kála-ázar and Beri-beri*, Shillong, 1890. Grawitz, "On the Oidium Favus," Virchow's *Archiv.*, Bd. lxx. p. 560.

Israel, "Die Actinomykose," Virchow's *Archiv.*, Bd. lxxiv., 1878.

Johne, "Die Actinomykose," *Centr. f. d. Medic. Wissensch.*, 1881, No. 15.

Kanthack, "On the Fungus of Madura Foot," *Proceed. Patholog. Soc. Lond.*, Jan. 19, 1892; also *Journ. Path. and Bacteriol.*, vol. i. p. 140. Kartulis, "On the Amœba of Dysentery," Virchow's *Archiv.*, Bd. 118, 1889. Küchenmeister, *Parasiten*, Leipzig, 1855.

Laveran, *Du Paludisme et de son Hæmatozoaire*, Paris, 1891; also English translation published by New Syd. Soc., Lond., 1893. Leuckart, *The Parasites of Man*, English translation by Hoyle, Edin., 1886; also "Uber Tænia Madagascariensis," Separat Abdruck aus *Verhandlungen d. Deutsch. Zool. Gesellsch.*, 1891. Lewis, *Physiological and Pathological Researches*, Lond., 1888.

Manson, *The Filaria Sanguinis Hominis, and certain New Forms of Parasitic Disease in India, China, and Warm Countries*, London, 1883; also Article on "Filaria Disease," in Davidson's *Hygiene of Warm Climates*, Edin., 1893, p. 738; also on "Distomum Ringeri," *Ibid.*, p. 852; also on "Parasitic Skin Affections," *Ibid.*, 928—these articles give copious references to the collateral literature.

Neisser, "On Molluscum contagiosum," *Vierteljhr. f. Dermat. u. Syph.*, 1888, No. iv. Neumann, *Traité des Maladies parasitaires et microbiennes des Animaux domestiques*, Paris, 1888; also English translation of same by Fleming, Lond., 1892.

Pasquale, "Nota preventiva sulle febbri di Massanah," *Estratto dal Giornale medico del R. esercito e della R. marina*, Roma, 1889. Peiper, *Die Verbreitung der Echinokokken-krankheit in Vorpommern*, Stuttgart, 1894. Pfeiffer, *Die Protozoen als Krankheitserreger*, Jena, 1890. Ponfick, "Die Actinomykose," *Breslauer ärztl. Zeitsch.*, i. p. 117; also *Berlin. Klin. Wochensch.*, 1879; also Monograph., Berlin, 1881.

Rabe, "On Psorospermia Infection," Adam's *Wochenschrift*, xx. p. 67. Roberts, "On the Present Position of Vegetable Hair Parasites," *Brit. Med. Journ.*, 1894, No. 1761, p. 685. Ruffer and Walker, "On some Parasitic Protozoa found in Cancerous Tumours," *Journ. Path. and Bacteriol.*, vol. i. p. 198—this paper gives a copious bibliography in connection with this subject.

Sabouraud, "Etude des Tricophytes," *Ann. de l'Institut Pasteur*, June 1893, p. 497; also February 1894, p. 83. Sauvagean and Radais, "Sur les Genres Cladothrix, Streptothrix, Actinomyces," *Annales de l'Institut Pasteur*, April 1892, p. 242. Soltmann, "Die Actinomykose," *Breslauer ärztl. Zeitschrift*, 1885, No. 3. Sonsino, Article on "Intestinal, Hepatic, and Portal Entozoa," in Davidson's *Hygiene of Warm Climates*, Edin., 1893, p. 861—this contains many references to the collateral literature; also "Contribution to the Life History of Bilharzia," *Lancet*, Sept. 9, 1893.

Unverricht, "On Psorospermia Infection," *Münch. Med. Wochensch.*, 1887, No. 26.

Van Beneden, *Parasites*, Lond., 1876.

Woodhead and Hare, *Pathological Mycology*, Edin., 1885—this book contains a copious bibliography up to 1885.

CHAPTER XII.

THE INFECTIVE DISEASES.

In the last chapter, a brief review was given of the most important facts and features in connection with the various fungi, monadinæ, and other organisms, belonging to the animal kingdom, which, by virtue of a more or less marked parasitism, produce some well-defined disorders in man and animals. There remains, however, for consideration that large class of micro-organisms—the Schizomycetes or Bacteria—which, in the light of our present knowledge, are now regarded as the active causes of the infective diseases. That most of the infective diseases, hitherto analysed, owe their origin to one or another species of these microphytes is sufficiently well recognised as to need no special demonstration in this place. Further, the general characters of bacteria, their general morphology, size, shape, motility, powers, and mode of multiplication, are so well known, and constitute so large a portion of present pathological teaching, that detailed descriptions under these respective headings would be superfluous in a work of this kind upon Public Health.

Recognising that the Prevention of the Infective Diseases can only rightly result by a proper comprehension of their etiology and natural history, it is intended, in this chapter, only to enumerate very briefly, and without unnecessary discussion, the chief facts in regard to these aspects of some of the more important of the infective diseases. It is true, the term "infective" is open to some criticism, especially as applied to some individual diseases hereafter to be considered, but, as expressing the etiological sequence of events of the whole class, it presents advantages which are not to be ignored.

Origin of the Infective Diseases.—It may be assumed that the occurrence of an attack of one of the infective diseases implies the action of microbial life, or the products of microbic life, upon the affected person; further, that the microbe did not arise into being independently, but was the progeny of a similarly endowed parental microbe. These assumptions, while removing all misconception as to the idea of a possible spontaneous generation of disease germs, involve the acceptation of the belief that there is an unbroken continuity of disease descent from antecedent cases. This conception of the origin of the causes of disease, if interpreted literally, implies the belief that every single case of each infective disease is the offspring or result of an antecedent case of the same disease. A little reflection and experience soon indicate that this doctrine is too inelastic for general acceptation, because certain of these diseases affect the lower animals as well as man, and consequently the antecedent case of a given instance of such disease need not be a human case: while, as regards others, which are known to affect man only, the pre-existing case must be sought in man alone.

A fuller knowledge of the life history of some of the micro-organisms of disease has shown that some are capable of existing outside the body for considerable periods of time, thriving and multiplying either upon human or animal tissues: others again are capable of thriving and increasing upon dead organic matter: while some, though capable of existing outside the body for long periods, are apparently incapable of passing through their life cycle except in living human tissues—so that diseases due to them must arise by direct or indirect infection from a previous human case of the same disease. Hence, because one affirms the continuation of the life of the microbial causes of disease, from generation to generation, one does not necessarily allege that human diseases only descend in a continuous series from one human case to another. Every-day experience teaches us that such is not the case. In fact, many attacks in man are due to micro-organisms which, although not developed *de novo*, are really derived from particular species that have not for generations found a habitat in man or other animals. Practically, in such an instance, so far as man is concerned, the disease has a new beginning. "The question, therefore, whether diseases do or do not descend in a continuous series from antecedent cases is one which must be worked out separately, as regards each disease, by a study both of the epidemiological behaviour of different diseases and the life history of the particular microphytes upon which such diseases depend."

Another view of the matter presents itself, if we remember that neither a micro-organism nor any species need necessarily be pathogenic throughout each life cycle. It is a matter of common knowledge that variations of severity and type are observed between different epidemics, and between different periods of one and the same epidemic of a given disease. In the same way, individual cases in an epidemic vary both in type and severity. Allowing for possible differences in the persons attacked, and for possible differences of dose of the virus, there is always the possibility of differences due to variations of pathogenic power on the part of the species of micro-organism. This latter may result from a variety of causes, such as warmth, light, moisture, and the suitability or otherwise of the soil which they may happen to invade. In other words, it is often a question whether the influence of the host, or medium in which the micro-organism grows, may not be capable of originating new varieties of disease. From these considerations, it is but a step to the question whether the pathogenic properties of some microbes are not acquired, by a process of adaptation to environment, in the transition from a purely saprophytic life to that of parasitism. These ideas of evolutionary changes on the part of the causes of disease are suggestive of an explanation of some apparent instances of *de novo* origin of disease, without being inconsistent with the belief of the doctrine that there is "no life without antecedent life" as applied to the etiology of the infective diseases. In the present day, the question of the possible origin of these diseases is not one of spontaneous generation, but of evolution.

Infection, Contagion, and Inoculation.—According to the manner in which these diseases are transmissible from one person to another, so are they spoken of as being either infectious, contagious, or inoculable. As a certain laxity prevails in the use of these terms, their proper definition is of importance. By *infection* is meant the conveyance of the poison in some indirect way, through the medium of the air, water, soil, food, clothing, &c., and its entrance within the recipient's body through the skin, or mucous membranes, but without any breach of continuity of surface. *Contagion* means transference of the poison by actual contact, but without breach of surface in the recipient. *Inoculation*, on the other hand, implies the conveyance of the poison, either directly by actual contact with the diseased body, or indirectly by means of some instrument or other article from the affected to the unaffected person, an essential feature of the procedure being some breach of surface in the skin or mucous membrane. While some diseases are only capable of being transmitted by inoculation, others are both infectious and inoculable.

Incubation.—Assuming that infective matter is living matter in the form of a primitive plant cell capable of growing and multiplying within the bodies of men and animals, the course of an infective disease is truly the life history, so to speak, of a lower plant, and as such has a period of development, a period of its greatest vigour, and a period of decline or death. The time of development, or as it is usually called, the period of *incubation*, is a most important feature in all the infective diseases, and may be defined as that period which elapses between actual infection and the appearance of the first signs or symptoms of the disease. This period varies considerably as regards different infections, ranging from a few hours in the case of some of them to weeks in the case of others, and even years possibly in one or two others. The following table, therefore, may be regarded only as an approximate statement:—

Disease.	Period of Incubation.	Duration of Infectivity.
Chicken-pox,	10 to 14 days.	3 weeks.
Cholera,	1 to 5 ,,	3 ,,
Diphtheria,	1 to 8 ,,	6 ,,
Diarrhœa,	1 to 4 ,,	1 to 2 ,,
Enteric fever,	8 to 14 ,,	6 ,,
Erysipelas,	1 to 5 ,,	1 ,,
Influenza,	1 to 4 ,,	3 ,,
Measles,	8 to 20 ,,	4 ,,
German measles,	6 to 14 ,,	3 ,,
Mumps,	14 to 22 ,,	3 ,,
Scarlet fever,	1 to 6 ,,	6 to 8 ,,
Small-pox,	12 ,,	6 ,,
Tuberculosis,	unknown	During the whole disease.
Typhus fever,	6 to 14 ,,	4 ,,
Whooping-cough,	4 to 14 ,,	8 ,,

For each different infection, however, the period is comparatively constant; though variation, within certain limits, occurs in different individual cases of the same disease, the period being more constant in some than in others. The incubation period is an important fact to know in connection with all infectious diseases, inasmuch as it enables us to say, when a person has been exposed to infection, that after the lapse of a certain number of days, if not already attacked, that person is safe and may mix with other people without risk to them. At present we know very little about the changes which take place in the body during incubation, beyond that the poison is multiplying in some part of the system. The majority of these diseases have a short and limited course, ending either in death or recovery more or less complete. A few, like chicken-pox, mumps, and German measles, are remarkably mild in their symptoms; but, on the other hand, a few are liable to vary greatly in their intensity. This is particularly so with both scarlet fever and small-pox. A general rule seems to be that severity or mildness holds good for the majority of cases occurring in a given outbreak, but that the severer cases are more common in the earlier part of an outbreak than in the latter. Age, sex, race, and season also have an important influence upon the severity of infectious disease attacks. Many curious facts relating to the peculiar action of the causes of these diseases upon the human body could be related; how in some cases only people of a certain age or sex suffer, while in others the attacks and deaths are largely confined to those of certain descent or parentage. These and many other points connected with infectious diseases are still but imperfectly understood.

Manner and Periodicity of Prevalence of Infective Diseases.—It is not unusual to speak of the general manifestations of the infective diseases as being either epidemic or endemic. The term *epidemic* merely signifies a tendency on the part of the disease to spread over a large area of the earth's surface, or in a given community, regardless of local circumstances. The term *endemic* indicates that a disease tends to remain among the inhabitants of a particular locality, and is apparently largely influenced by local conditions. Going back to the first causes of these diseases, it would seem probable that epidemic diseases are due to micro-organisms which thrive best in living animal tissues, whereas endemic diseases are mainly due to microbes whose habitat is outside human and animal bodies, and therefore largely influenced by local circumstances.

The more recent inquiries of Ransome and Whitelegge indicate that the more common and fatal infective diseases "observe definite periodic times or cycles," which may be described as "a succession of waves, the periods covered by the waves differing for different diseases." These waves are of two essentially different kinds—the accidental and the fundamental. The former is a wave of mere prevalence, and, as Whitelegge puts it, "probably but a reflex of changes in the environment." The true or fundamental cycle or wave is characterised by an increase of both prevalence and severity, and often extends over a considerable number of years. Though possibly not altogether independent of changes in environment, the true wave of periodicity of the infective diseases is more probably associated with microphytic evolutionary processes (Whitelegge).

Immunity and Protection.—One of the most important facts in connection with the infective diseases is that one attack usually protects the sufferer from a second attack of the same affection. Of course this is not always the case; neither is the duration of the protective action at all constant. In some diseases, such as diphtheria, for instance, its duration is apparently only just sufficiently long to prevent the sick person reinfecting himself. In others it seems to last during the whole of life; in fact, in some cases may be transmitted from parent to child. Various explanations have been offered to account for the protection conferred by one attack against a second onset of these diseases; and also to account for the termination of actual attacks. It is difficult to explain the occurrence of most of these affections only once in the lifetime of one person, except on the supposition that in the course of each disease the blood or tissues undergo such a change that they no longer afford, and never will afford afterwards, the conditions necessary for the development of the particular microbe. Whether this change is a removal of some chemical substance necessary for their growth, or the production and leaving behind of some direct or indirect product which prevents any further multiplication, or whether the cells and tissues are in some way modified during an attack as to be able to resist future attacks of the same microbe, is by no means clear. Probably other explanations may be given, but it is at least possible that in cases in which any one of the infectious diseases rages with marked violence when introduced into a community that has been long free from it, this may be because the victims come of a stock which has not for some generations been exposed to the contagion.

What may be termed the original liability to attack by these diseases varies in different individuals, "some appearing by nature almost immune, while others exhibit a marked degree of susceptibility." These differences are partly hereditary, and partly acquired. As an instance of the former, we have the marked tendency to phthisis observable in certain families; while the familiar predisposing influences of overcrowding and other defective conditions of life are examples of a possibly acquired liability to certain infections.

This subject of immunity is of not only scientific interest, but also of great practical importance to the student of hygiene. The problem is further a complex one, and can only be solved by a careful consideration of all the facts concerning the diseases due to the invasion of the body by bacteria.

"The first point to consider is the way in which bacteria act. It may be stated that all pathogenic bacteria produce their ill effects by means of the poisons they elaborate; these poisons are called toxins." Some bacteria, such as the diphtheria and tetanus bacilli, produce very active toxins; others, like the pneumococcus, produce very feeble toxins.

Now certain bacteria, notably the bacilli of diphtheria and tetanus, when inoculated under the skin, do not invade the circulatory system nor the internal organs; they only multiply at the spot of inoculation, elaborating toxins which, after absorption, produce the characteristic symptoms of those diseases. Diphtheria and tetanus, therefore, may be regarded as types of *toxic* diseases. Tetanus is somewhat peculiar, for tetanus spores, when freed from toxins by washing, produce no symptoms when injected under the skin; but do so at once if the tissue be injured, or other bacteria, themselves harmless, be simultaneously injected. "This association of bacteria is an important factor in many diseases, and must not be lost sight of in the consideration of their pathology."

"In contradistinction to *toxic* diseases there are others which may be called *septic*." Examples of these are anthrax in rabbits, relapsing fever in man, and the disease caused by the pneumococcus in the rabbit. In these cases, the micro-organisms rapidly invade the whole body, and the blood and organs are found crowded with them after death. The toxins produced are apparently relatively feeble. Between the typically *toxic* and *septic* diseases there are all degrees of types.

These considerations suggest that in the study of immunity we must bear in mind two points. "The one is the power of the body to destroy bacteria, or to inhibit their growth; the other is the power of the body to resist the effects of the toxins. In the case of septic diseases the former factor, and in the case of toxic diseases the latter factor, is the more important. Immunity may depend, therefore, upon either factor, or upon a combination of them both." Immunity may further be either natural or acquired.

Before considering, however, the nature and causes of these two kinds of immunity, it is necessary to discuss briefly certain properties possessed by the cells and humours of the body in relation to bacteria. The most important of these, perhaps, is that of *phagocytosis*, or the power of ingesting bacteria and other foreign substances possessed by amœboid cells; upon this phenomenon is based one of the most seductive theories of immunity, and for most of our knowledge upon this interesting subject we are indebted to Metchnikoff and his school. He has studied the process throughout the animal kingdom, and demonstrated how widely it is spread. Metchnikoff gives a large number of examples of phagocytosis among the invertebrata, and there is good evidence to believe that it is an important means of defence among these lower animals against the attacks of parasites. In the higher forms of the invertebrata the phagocytes become differentiated from the other cells of the body, but still retain their power of englobing foreign bodies. Thus, the introduction of a splinter of wood into the gelatinous bell of the medusa leads to an accumulation of phagocytes, and if the wood has been previously soaked in carmine, the particles of carmine are englobed by the phagocytes.

Among the vertebrata, a very similar condition of affairs exists. The most important cells which are phagocytic are certain kinds of leucocytes, but not all. Various classifications of leucocytes are given. Metchnikoff divides them into four varieties:—(1) The *lymphocyte*, which is a small cell with a large round nucleus surrounded by a small amount of protoplasm. (2) The *mononuclear leucocyte* is a large cell with an oval or kidney-shaped nucleus, closely resembling certain endothelial cells. (3) The *eosinophile cell*, possessing a lobed nucleus, and containing in its protoplasm coarse granules which stain deeply with eosine. (4) The *neutrophile leucocyte*, containing a lobed nucleus, of which the individual portions are united by delicate nuclear filaments, giving the appearance of a multinucleated cell. The protoplasm contains granules which can only be obtained by a mixture of the acid and basic dyes. Hence the name *neutrophile*.

"Of these leucocytes, the eosinophile cells and the lymphocytes do not possess phagocytic properties, while the mononuclear and the neutrophile cells are phagocytes, and even when removed from the body are capable of englobing foreign bodies." The other important class of phagocytes in the vertebrata are the endothelial cells of the vessel walls and of the lymphatics.

That these varieties of phagocytes are capable of englobing not only foreign particles, but also dead and living bacilli, has been repeatedly demonstrated. "If anthrax bacilli are injected under the skin of a pigeon, a local inflammation occurs, and if the exudation is examined it will be found to contain a number of leucocytes, many filled with anthrax bacilli. If tubercle bacilli are injected into a rabbit's vein, the bacilli quickly disappear from the blood of the general circulation, and are then found in the endothelial cells of the vessels, especially in the liver" (Washbourn). This emigration of phagocytes through the vessel walls, and their accumulation around the spots of inoculation or irritation is due to what is called chemiotaxis, or the power possessed by various substances of attracting or repelling amœboid cells. When an attraction is exerted, we speak of positive chemiotaxis, and when repulsion, of negative chemiotaxis. It is a phenomenon which can be observed in the lowest forms of life.

"In the vertebrata, chemiotaxis can be studied by inserting capillary tubes filled with various substances into the subcutaneous tissue, or into the peritoneal cavity. If the substances introduced exert a positive chemiotaxis, the tubes are filled with leucocytes, while if they exert a negative chemiotaxis, or are inert, no leucocytes are found in the tubes. The toxins produced by bacteria, especially those contained within their protoplasm, generally exert a positive chemiotaxis." Some are inert, and some are stated to possess a negative chemiotaxis. Chemiotaxis thus explains the accumulation of leucocytes around the spot of inoculation with certain bacteria, and the absence of any accumulation in other cases.

Another factor of great importance in connection with immunity is the power possessed by the blood and other body fluids of destroying bacteria.

This was first discovered by Nuttal, and has been carefully studied by Behring, Buchner, and Nissen. It was shown by Buchner that in the case of blood the power resided in the blood-serum. "The best method of demonstrating this property is to inoculate the serum with a cultivation, and to estimate the number of bacteria present at different intervals by means of plate cultivations. At first the serum destroys many of the bacteria; but this power of destruction is gradually lost, and then the bacteria are able to multiply without hindrance. It is supposed that the serum contains a substance called an *alexin*, which possesses bactericidal properties, while the bacilli secrete a substance called *lysin*, which neutralises the alexin, and thus enables the bacteria to grow. Both these substances are hypothetical, and have not been isolated. Whether they exist or not, there can be no doubt that the bacteria, if present in large numbers, can resist the bactericidal properties of serum. The bactericidal properties of serum are very readily destroyed by physical agents, such as exposure to a temperature of 60° C." (Washbourn). On the other hand, there is good evidence to show that the bactericidal substances are secretions formed by certain of the leucocytes. Hankin has suggested that the eosinophile cells were cells which secreted alexins, and this view has been supported by the observations of Kanthack and Hardy. Some others, notably Buchner, have shown that inflammatory exudations containing many leucocytes possess more powerful bactericidal properties than the blood itself.

The blood of animals which have been rendered immune by submitting the animal to a mild form of the disease by a process of vaccination, possesses properties which are quite distinct from the above mentioned bactericidal properties. These are the so-called anti-toxic properties of blood. Behring and Kitasato first proved that the blood-serum of animals, immunised to diphtheria and tetanus, possesses the power of annulling the toxins of these diseases when injected into other animals. The recognition and practical application of this fact has been the means of introducing well-known and efficient therapeutic methods in connection with these diseases. Ehrlich has shown that the blood-serum of animals which have been habituated to large doses of the two vegetable poisons, ricine and abrine, possesses anti-toxic properties with regard to these poisons. The same principle has been applied to a number of bacterial diseases, it being generally shown that the blood-serum of immunised animals will protect other animals against the disease; the potency of the protective serum depending upon the state of immunity of the animal furnishing the serum. "A serum which is anti-toxic is also anti-biotic." Thus a serum which will protect an animal against the toxins of diphtheria will also protect it against inoculation with the living bacilli. The converse does not hold, for it has been shown in several instances that a serum which will protect perfectly against inoculation with living bacilli is quite inefficacious against their toxins.

The bactericidal properties of a serum and its protective power are quite distinct properties, and must not be confused. While the former are very readily destroyed by heat, the latter are not so, and moreover, the protective substance can be precipitated in various ways without losing its efficacy. How and why the anti-toxic substance in the serum is formed is not very clear, but from the two facts that the potency of the serum is roughly proportional to the amount of toxin introduced into the body, and that the anti-toxic property is specific, that is to say, a diphtheria anti-toxin protects only against diphtheria, and a tetanus anti-toxin only against tetanus, we are led to the conclusion that the essential element in the anti-toxic serum is a derivative of the bacterial toxin.

Many animals are *naturally* immune to bacteria which are highly pathogenic to other animals, but no one theory will account for all cases of natural immunity. In some cases the explanation is a simple one, and in others very complex. Frogs are immune to inoculation with the tubercle bacillus, chiefly because the temperature of the frog is not suitable for the growth of the bacillus. Fowls are insusceptible to inoculation with the tetanus bacillus, because their tissues are not affected by the tetanus poison, just in the same way as they are not affected by morphine. These explanations are not enough: we must explain how it is that the tubercle bacilli and tetanus bacilli are destroyed after introduction into the bodies of the frog and fowl. This can only be by phagocytosis, or by means of the bactericidal properties of the fluids. Neither factor is sufficient to explain the destruction of the bacilli in every case of natural immunity. In some instances the bactericidal properties of the blood are quite sufficient explanation; in cases where the fluids of the body possess no bactericidal properties, phagocytosis must be the most important factor in immunity. Metchnikoff looks upon it as the most important factor in all cases, but this is probably an over-estimation, as some of the arguments which have been brought forward in favour of this theory are, in the light of our present knowledge, fallacious. The mere fact that the bacteria are taken up by the phagocytes is no proof of immunity, for in pigeons dying of swine erysipelas marked phagocytosis occurs. Again, when anthrax bacilli are injected into the circulation of susceptible rabbits, they are at once taken up by the phagocytes of the liver, and again set free to multiply freely in the blood. So again, the formation of an exudation rich in phagocytes at the point of inoculation is not sufficient evidence of the exclusive *rôle* of the phagocytes in the production of immunity, for such exudations contain many leucocytes which are not phagocytic, while the fluid portions of these exudations possess bactericidal properties.

In most cases of natural immunity it is probable that the bacteria, when introduced, are destroyed partly by the bactericidal substances in the blood, and partly by the phagocytes. Possibly, in some cases the bacteria are destroyed by the bactericidal substances alone, the phagocytes only playing the secondary *rôle* of digesting the already dead bacteria. In others it is possible that the phagocytes alone destroy the bacteria.

As regards *acquired* immunity, the problem is more complicated, because in addition to phagocytosis, and the action of the bactericidal properties of the blood, we must consider the protective power of the serum. It has already been indicated that the immunity acquired to toxic diseases by inoculations with attenuated cultivations, or by inoculations with very minute quantities of virulent cultures, is chiefly due to the anti-toxic properties of the blood which annuls the effect of the toxins upon the tissues. The bacteria are then destroyed by the phagocytes, for the blood-serum of animals immunised to toxic diseases like diphtheria and tetanus has no bactericidal properties. The phagocytic power of the cells was present in the animal before immunisation, but was apparently inhibited by the bacterial toxins. That this is the case is shown in the case of tetanus, when the spores of the disease, freed from toxins by washing, are readily destroyed by the phagocytes of susceptible animals.

It is easier to render an animal immune to fatal doses of living bacteria than to fatal doses of their toxins. The serum of immunised animals is protective against inoculation with living bacteria, but not against their toxins, that is, it is anti-biotic but not anti-toxic. This fact renders the explanation of the immunity acquired to septic diseases somewhat difficult.

In some cases the immunity appears to be due to an increased bactericidal property of the blood; in other cases, the blood-serum of immunised animals has no marked bactericidal properties, and yet will protect perfectly. Such a preventive serum probably acts as a stimulant to the phagocytic cells, which then destroy the bacteria by intra-cellular digestion.

The whole theory and explanation of immunity from infective diseases must be still regarded as being in a very incomplete state. It is too complex to be explained by any one theory. In each case we must consider several factors, and in the majority of cases several factors are concerned, sometimes one and sometimes another being the more essential.

ANTHRAX.

This is a fatal acute disease which fortunately affects cattle, horses, sheep, and goats more frequently than man. It is a widely spread form of disease, appearing with unusual frequency in certain districts, and rendering thereby these localities especially dangerous to herds of cattle.

The clinical aspects of the disease are different in different species of animals; in larger ones it is said to run a comparatively slow course, being accompanied with violent fever, and in most cases, but not always, ends in death. The smaller animals, such as mice and guinea-pigs, succumb to the disease almost without exception, but often without showing any striking symptoms up to the moment of death. On *post-mortem* examination, a conspicuous symptom is the dark, congested, and enlarged spleen. In sheep and cattle there occur hæmorrhagic exudations under the skin of various regions: the exudation forming tumours of a dark to black gelatinous nature.

Anthrax affects man in two forms, external and internal. External anthrax, or, as it is sometimes called, "malignant pustule," has its usual seat on the neck or face, being doubtless due to inoculation. The first local manifestation is the appearance of a papule or vesicle, which develops in the course of a few days into an inflamed indurated mass, with a central black slough. The surrounding tissues and the lymphatic glands are swollen and indurated. In rare instances the disease may remain local, and end in either resolution or suppuration. More commonly, however, constitutional symptoms appear, indicating general infection. Occasionally malignant pustule supervenes upon internal anthrax, which appears to be due to the inhalation or swallowing of the virus. Internal anthrax is only known as affecting wool-sorters, and as the result of the experimental infection of animals.

After a very variable incubation period, ranging perhaps from two to twelve days, the early symptoms of internal anthrax are weariness, depression, chills, restlessness, and a tight feeling across the chest. This stage may last only a few hours, but more usually three to seven days, when graver symptoms set in suddenly. Prostration becomes extreme: pulse and respiration are hurried: temperature rises, but always marked by sudden remissions, accompanied by perspiration. Even in serious cases recovery may follow, but more commonly death ensues from syncope, pneumonia, or the exhaustion of diarrhœa. In cases of recovery the protection derived from the attack is very slight, if any. This form of anthrax is called wool-sorters' disease, from its prevalence in the Bradford district among men employed in sorting certain foreign wools, particularly those of goats from Van, in Armenia. More or less successful attempts have been made to render the sorting of wools, which experience has shown to be dangerous, safer, by preliminary disinfection or washing, cleanliness and ventilation of the sorting rooms, with the use of fan-blasts to carry away the dust generated during the opening and sorting of the bales. To these precautions must be added washing of the hands before eating, and changing of clothes when the work is done.

A microscopic examination of the blood and spleen shows the pathogenic microbe or *Bacillus anthracis*. When examined fresh, these bacilli are non-motile rods, more or less truncated and homogeneous looking, varying a little in size, according to the animal from whence they have been derived. They are usually from 5 to 20 μ long and from 1 to 1·25 μ broad: within the body they do not form spores. The longer bacilli or their chains show, within a common sheath, cubical or rod-shaped cylindrical, square cut, stained masses of protoplasm: these are the real bacillary elements. These appearances are more pronounced and noticeable in specimens made from artificial cultures: in some anthrax-threads of cultures, all elements constituting a thread are separated one from another by a transverse septum. Anthrax bacilli readily admit of cultivation in feebly alkaline broth, or in gelatin, blood-serum, or on agar and potatoes. All the cultures have a more or less characteristic appearance: for instance, in a stab gelatin culture there is first a whitish line in the track of the needle, and from it fine filaments spread out in the gelatin. Occasionally a little isolated spot develops, from which rays extend in all directions, like the silky filaments of thistle-down. The gelatin slowly liquefies and the growth subsides as a flocculent mass. In stroke cultures on gelatin the streak of inoculation is marked after twenty-four to forty-eight hours by a whitish-grey line, from which a number of fine whitish threads shoot out horizontally. On agar a thick greyish film is noticeable after two days. In broth at 37° C. a slight turbidity is seen after thirty-six hours, which gradually forms into a flaky and flocculent mass at the bottom. On potato at 37° C. a thick cohesive paste-like layer is formed; this is of a brownish colour.

Anthrax bacilli, cultivated on the surface of a solid medium, or with free access to air, readily form spores which preserve their vitality for years. The bacilli themselves are readily destroyed by heat or other disinfecting agencies, but the spores are extremely resistant. Animals can be infected by inhaling or swallowing the spores, but not by the bacilli unless there is some abrasion, such as to allow practically of inoculation. The bacilli are destroyed by the gastric juice, spores are not. Klein has shown a further difference between bacilli and spores by results of inoculation. The former cause a slight and localised malady, the latter a severe constitutional illness which is usually fatal.

The usual mode of infection, so far as man is concerned, is by inoculation, tanners, butchers, and others engaged in handling raw hides being very liable to malignant pustule: it has been suggested that the poison may be carried by flies and other insects. Man may be also infected by inhaling or swallowing spores in the form of dust, as in wool-sorters' disease. Although exact evidence is wanting, it may be assumed that anthrax can be acquired by eating the flesh of diseased animals.

Animals may contract anthrax by similar means as man: but probably their chief methods of infection are by inhalation and swallowing. A field may become infected with anthrax, and healthy animals grazing on it, after the lapse of months or even years, may acquire the disease. The infection is probably imparted to the superficial layers of the soil by the blood or secretions of affected animals. Pasteur's suggestion, that the spores from buried carcasses are brought to the surface by earth-worms, has been shown to be unlikely by Klein, for the simple reason that spores are not formed under such conditions, and that the rapid onset of putrefaction soon destroys all infectivity.

With varying degrees of success, various attempts have been made to attenuate the growths of anthrax bacilli, and by successive inoculations of them to render animals resistant to the disease. The success of these methods depends, however, to a large extent on the primary degree of virulence of the bacilli at starting and the absolute purity of the resulting vaccines. While sheep, cattle, and rabbits that have once passed through a mild form of anthrax are, as a rule, refractory against further inoculation with virulent anthrax, this is not the case with some other animals, for instance, guinea-pigs. Klein has shown that mouse's anthrax blood is attenuated anthrax, and can be used for the protective inoculation of sheep. Pigs are naturally difficult to infect, though they can be infected: adult rats, dogs, and cats are almost insusceptible: healthy fowls are quite so, though if their bodies be cooled down, they can be fatally infected.

Prevention resolves itself into the need of obvious precautions for avoiding direct inoculation of a cut or abrasion from the carcass of an anthrax-affected animal. The flesh of such animals must be condemned as food. As regards the trades affected, all dangerous wools should be disinfected by steam, or at least thoroughly wetted and sorted while damp, to avoid dust. Sorting rooms should be provided with an apparatus for extracting the dust, and be well ventilated. In regard to cattle, it must be borne in mind that diseased animals do not transmit the affection to others in the ordinary way by association: the carcass of an animal dead from anthrax is more dangerous than the diseased animal was during life. In slaughtering diseased animals, effusion of blood should be avoided as much as possible. Burial of uncut carcasses with a sufficient covering of quicklime is the most simple and effective method of disposing of them. The organisms soon die when access of air is prevented. If the carcasses are destroyed by burning or boiling, it is generally necessary to cut them in pieces first ; this is not only dangerous to the persons employed, but is calculated to spread the disease, unless the greatest care is observed to avoid spilling or effusing the body juices, and disinfectants freely used. As yet a satisfactory method or system of preventive inoculation has not been devised.

CEREBRO-SPINAL FEVER.

This is a disease which appears to be more prevalent abroad than in this country: and in reference to its epidemic prevalence in various countries during the present century, a very considerable historical literature has accumulated. As regards this country, the most recent outbreaks have been in Dublin in 1885–6 and at Oakley in Suffolk in 1890. Some doubt has arisen as to whether the Oakley cases were those of true cerebro-spinal fever, chiefly on account of their low fatality, and the frequency with which multiple cases occurred in the same families: on the other hand, the cases betrayed the existence, in the form of a small epidemic, of a disease which had for its main symptoms vertigo, headache, great drowsiness, marked retraction of the head, and in some instances opisthotonos and subsequent paralysis: in fact, constituting a malady clinically indistinguishable from cerebro-spinal fever.

Mortality.—In well-marked epidemics, this has usually been very great, varying from 60 to 90 per cent. In non-epidemic periods, it is difficult to accurately determine what the mortality from this disease really is, as it is not unlikely that true cerebro-spinal fever is of more frequent occurrence than is generally supposed, owing to errors of diagnosis between this and tubercular meningitis or indeterminate "fevers." The deaths recorded annually in England and Wales as due to this disease, during the twenty years 1874–1893, have ranged from 13 in 1893 to 58 in 1878.

Influence of Sex, Age, and Race.—It is difficult to find any difference in regard to the incidence of the disease upon the two sexes. As regards age, it usually attacks those approaching puberty, or in early adult life: it has been known, however, to occur in persons of all ages, though certainly rare among those beyond middle life. The evidence in respect of race indicates it to make no distinctions.

Effects of Climate and Season.—Except for its occurrence in Fiji, in the unusually cool year 1885, we have no accounts of the prevalence of this disease in tropical climates. In all countries in which it has been observed as an epidemic, this has usually occurred in either winter or spring, that is, in the coldest seasons of the year.

Etiology.—Owing to the frequent manifestations of this disease in an epidemic form in public institutions, the earlier views regarding it indicated infection as a prominent factor in its diffusion. A close analysis of the more recent outbreaks indicates that cerebro-spinal fever varies considerably as regards infectiveness, and that, if directly communicable from person to person, it is communicable only in a very low degree (Simon). If not directly communicable, there are strong grounds for regarding it at least as being readily transported from place to place by infected persons and things.

Fagge, quoting the views of Ferguson, veterinary surgeon to the Privy Council in Ireland, suggests that "a contagious principle is given off by the sick, but that it has to undergo some transformation or intermediate stage of its development, possibly in another animal, before it can infect a human being," and that on each occasion "when the disease has prevailed in Ireland, it has co-existed with an epizootic of the same nature among pigs and dogs." Arguing from analogy with what we know to be the case in respect of other diseases, and bearing in mind that this affection has a tendency to prevail under conditions of overcrowding or defective ventilation, and to recur in districts which have suffered from previous epidemics, we are justified in believing that the cause of the disease is a micro-organism belonging to the class of facultative parasites, and as such capable of thriving and multiplying outside human or animal bodies. At present, this microbe has not been identified. Importance has been attributed by some observers to dampness of soil as an etiological factor in this disease, even so far as to allege that it is of malarial origin: as Hirsch has pointed out, the geographical distribution of the affection does not support this view.

Prevention.—In our present condition of defective knowledge in regard to the exact origin of this disease it is difficult to formulate prophylactic measures. Isolation does not seem to be required, and we do not know what to disinfect. Free ventilation, good food, and avoidance of fatigue appear most essential.

CHICKEN-POX.

It was only towards the end of the last century that this disease was clearly distinguished from small-pox: but beyond a certain superficial resemblance there is nothing in common between the two diseases. Chicken-pox occurs as an epidemic, which very often coincides with epidemics of small-pox, and adds to the difficulty of diagnosis of mild cases of the latter. Persons of all ages are liable to attack, but children more so than adults. The mortality is practically *nil*, though the Registrar-General annually records a few deaths from chicken-pox: how far these fatal cases may be set down to unrecorded deaths from small-pox is difficult to decide: possibly a large proportion may be so, without error.

The incubation period has been variously estimated from four to twenty-eight days: recent opinion sets it down at about fourteen days, for which reason the Association of Medical Officers of Schools insist upon a quarantine of eighteen days before re-admission to school, after exposure to infection.

The characteristic vesicular eruption appears without any previous sickness, or at most with only some twenty-four hours of fever or malaise. It begins on any part of the body, and is added to irregularly by fresh crops for four or five days, during which time the constitutional symptoms are most irregular. The vesicles are not usually umbilicated, but this is not a reliable point for diagnosis, as among them are often some which are so. The vesicles consist of a single cavity, with a very thin covering, and with little or no hardness at the base. About the third day, the clear watery contents of the vesicles become turbid; within the week a thin crust forms which eventually falls off and leaves no cicatrix unless sores have been caused by irritation. The infection of chicken-pox is active from the very first, and is readily imparted by contact or by means of fomites. As in small-pox, the length of infectivity will depend on the falling off of the crusts, which usually become detached in parts rather than entire.

Attempts have been made to inoculate from the vesicles, but without success. Chicken-pox and small-pox are not mutually protective.

CHOLERA.

It is usual to speak of cholera having its endemic area in certain parts of India, more particularly the delta of the Ganges, but it is possible that other parts of Asia are also its endemic home. Although Portuguese writers refer to an extensive and fatal outbreak of this disease in India in 1503, it is not until the beginning of the present century that we have any scientific or systematic accounts of cholera. The first well-recorded pandemic diffusion of the disease dates from 1817, when there was a widespread prevalence of cholera in Bengal, extending during the next two years throughout India and the greater part of Asia. Since then, at irregular intervals, it has spread in epidemic form over a greater or lesser part of the world. It has followed, almost invariably, the lines of traffic by land or water, but no reason has been found for the apparently capricious way with which it has selected some routes and omitted others. The invasion of each new country along its line of march has been, in most cases, traced to infection through some communication with a country already attacked. In temperate climates the outbreak frequently subsides in winter, but often reappears with the warmer weather, and in some instances has recurred in the third year, apparently without fresh introduction.

As an epidemic, cholera has appeared in England four times, namely, in 1831–2, 1848–9, 1853-4, and 1865–6; the disease having on these occasions slowly spread from India. On several other occasions the disease has invaded Europe, but failed to reach England. In July 1831 infection was carried to the Medway by ships from Riga; later in the same year it broke out at Sunderland and other northern ports, as a result of importation by ships from Hamburg. In the course of the next year it was extensively prevalent in Great Britain, extending later to Canada and the United States. In 1848 London was infected from Hamburg in September, and Hull and Sunderland in October from the same port: from these centres the disease at once spread. During the winter of 1848–9 cholera abated, but in the spring of 1849 it broke out again with increased vigour, finally disappearing in December, having caused 53,293 deaths, besides a heavy diarrhœal mortality, part of which was probably due to cholera. In 1854 it was again severely epidemic in Great Britain, having been once more imported from Germany. During this year cholera caused over 20,000 deaths in England and Wales.

The fourth epidemic invasion of Great Britain, in 1865, had a somewhat different history. Starting from the basin of the Ganges in 1863, cholera was carried by ships to South Arabia; it next broke out among the Mecca pilgrims, by whom it was carried to many places, among them Suez. From Egypt it spread along the Mediterranean littoral, extending through the whole of Southern and Central Europe. England was infected through Southampton from Alexandria during August, but only to a small extent. In the following spring the disease was again repeatedly imported from the Continent, and during that year something like 15,000 people died from cholera in the whole of England. Since then the disease has not prevailed as an epidemic in this country, though frequently imported and prevalent in various parts of Europe, more especially since 1884. During this year (1884) cases of cholera were three times brought in ships to England, but no spread of the disease occurred. The same thing occurred again in the two next following years. In 1890 a recrudescence of cholera advanced from Persia and Central Asia, culminating in the infection of Hamburg on August 23rd, 1892. The mortality in Europe during the gradual extension of the disease westward in 1892 was very great. Two days after Hamburg was declared infected, three cases of cholera from that city arrived in London, and by the middle of October quite thirty cases had been brought to this country; but in no instance, so far as is known, did the disease extend to any person other than those arriving from abroad.

Although at one time or another cholera has extended widely over the earth's surface, still it has, so far, never invaded Australia, the Pacific Islands, St Helena, Ascension, the east coast of Africa south of Delagoa Bay, Iceland, the Faröe Islands, the Hebrides, Orkney, and Lapland (Hirsch). Apart from the possible enjoyment of perhaps special sanitary advantages, more particularly pure and wholesome water-supplies, local exemptions from cholera are mainly due to the relatively little communication between the places in question and the continent of India, or other centres of endemic prevalence.

Mortality.—This is often enormous. Some figures, as regards cholera in this country, are shown in the following table:—

Date.	England and Wales.		London.	
	Total Cholera Deaths.	Cholera Deaths per million living.	Total Cholera Deaths.	Cholera Deaths per million living.
1831	30,924	2,225	11,240	6,784
1849	53,293	3,034	14,137	6,182
1854	20,097	1,094	10,738	4,288
1866	14,378	685	5,596	1,842

English experience shows the prevalence and mortality of the disease to be greater in the second than the first year of the epidemic. The fatality of cholera is also very high, ranging commonly from 30 to 50 per cent. of those attacked: it is said to be greater at the beginning than during the later stages of an outbreak.

Influence of Climate, Season, and Temperature.—Warmth is a predisposing condition of great importance, but it is not, in itself, sufficient to cause an outbreak of cholera, nor does cold necessarily arrest it. That a certain degree of heat favours the activity of the poison is sufficiently evidenced by the fact that in Europe the disease has generally attained its greatest prevalence from June to August, subsiding during the winter, often only to reappear in the following summer. There are, however, exceptions to this general rule: even in India the seasonal curve of cholera prevalence is not coincident always with that of temperature. In Bengal there is a chief maximum of cholera deaths in April, with a smaller one in November; in the Punjab the maximum prevalence is in August; in Bombay the maximum is in April; in the North-West Provinces and the Deccan in August; and in Madras there are two maxima, in February and September. In all these regions, except two, the highest mean temperature is reached in May or early June; in the Punjab and North-West Provinces it is in July. In Madras cholera mortality is at its minimum in June, when the mean temperature is at its highest.

As regards rainfall, there can be no doubt that it has a marked influence upon the prevalence of cholera, and supplies a clue to many of the discrepancies in respect of the connection between cholera and temperature. As a general rule, it may be asserted that not only is rain connected with the development and dissemination of cholera, but that in India no extensive epidemic can occur unless during or after rain. On the other hand, there can be no doubt that the reverse effect is not infrequent, particularly if the rainfall be excessive, prevalence of the disease being prevented by destruction of the micro-organisms of the affection, partly as the direct result of the amount of water in the soil, and partly from their being carried further from the surface where they are no longer among surroundings favourable to their existence.

Influence of Race, Sex, and Age.—There is a general consensus of opinion among authorities that the incidence and severity of cholera are greater among negroes than Europeans, but as to the relative susceptibility of other races little is known. The evidence as to influence of sex is imperfect: what there is, indicates that the general mortality is greater among males than females, but that the case fatality is in excess for females up to twenty-five years of age, after which it is greater for males. As regards age, apart from sex, the actual number of deaths is much greater during the extremes of life than during the middle periods. This is very much what might be expected.

Etiology.—General sanitary defects, no doubt, are conducive to cholera prevalence and mortality, as determining the points of attack, especially by inducing a lowered standard of health with diminished powers of resistance, and by specifically fouling the air, soil, and water. The words of Sir John Simon, written in 1866, are as true of to-day as they were of thirty years ago. He says, "The diffusion of cholera among us depends entirely upon the numberless filthy facilities which are allowed to exist, and specially in our larger towns, for the fouling of earth, air, and water, and thus secondarily for the infection of man, with whatever contagium may be contained in the miscellaneous outflowings of the population. Excrement-sodden earth, excrement-reeking air, excrement-tainted water, these are for us the causes of cholera." Hence the disease attacks more especially the poorest quarters of towns. The poison doubtless gains access to the system by swallowing, more rarely by inhalation, the incubation period being from a few hours to three days: though it may apparently reach as much as ten days. The infection is given off in the discharges from the bowels, and possibly in the vomit also. These may infect, as already explained, either water, milk, soil, or fomites.

Etiologically, cholera exhibits some connection with, and likeness to diarrhœa. Marked prevalence of the latter disease is often noticed as a precursor of the former: while both appear to be associated with filth, and to be influenced by heat and certain physical conditions of the soil, more particularly porosity, a low level of the subsoil water, and a subsoil temperature of 56° F. at 4 feet below the surface. Clinically, the two diseases are not unrelated, for such differences as there are between the two maladies are mainly differences in degree of malignancy. The curious and remarkable etiological and clinical resemblance between cholera and diarrhœa (epidemic) has been ably discussed by Thompson and others, with the surmise that "cholera may after all be but an Asiatic variety of a disease known elsewhere as 'diarrhœa' and cholera nostras." Further, in regard to cholera in India, the deduction is permissible that in localities in which it is endemic, the soil is so charged with the necessary micro-organism that the disease, although doubtless diffused, even there, most frequently by water, is also probably occasionally disseminated by direct emanations from the soil. As we shall see in a subsequent section, this proposition conforms closely with what are known to be the facts in connection with epidemic diarrhœa: and, put in other words, the diffusion of cholera in India and other endemic areas is practically identical with that of diarrhœa in England. Complementary to this, the further deduction is permissible that when the cholera micro-organism is imported into countries where the conditions are less favourable to its vitality and multiplication in the soil, its opportunities for passing to man are limited mainly to occasions of conveyance by water and fomites. Without absolutely accepting these views, it must be acknowledged they are not antagonistic with the accepted facts concerning cholera diffusion and prevalence, and at the same time afford a "basis for reconciliation between the Anglo-Indian and British schools with respect to the etiology of cholera."

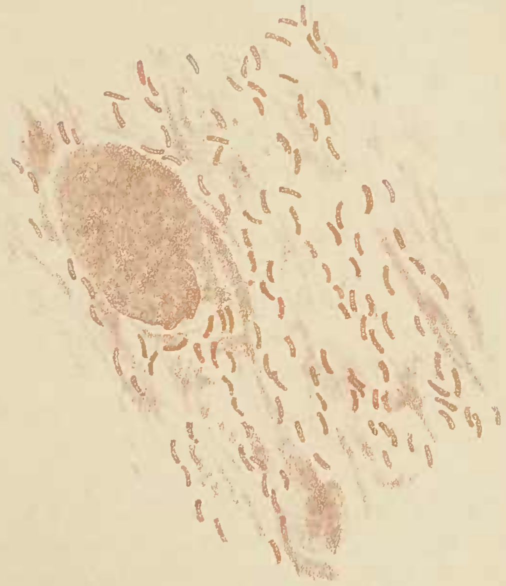
That cholera ultimately depends upon micro-organic life processes has been provisionally assumed in the preceding remarks. Since Koch discovered a comma bacillus in the evacuations and intestines of cholera patients, and adduced evidence in support of the view that this organism is the cause of the disease, the *comma bacillus* has become generally to be regarded as the real infective agent of cholera: though there have not been wanting competent critics who question the pathogenesis of this bacillus.

Cholera bacilli appear as rods curved in the direction of their long axis so as to resemble a comma in figure, hence the name "comma bacillus." They have a twist in addition to this curve, so that they represent a kind of spiral bacteria: when connected in chains they give rise to corkscrew forms. A flagellum can be demonstrated at one end, but no spore formation. These commas feebly resist chemical reagents, being destroyed by the acid of the gastric juice, and refusing to grow upon feebly acid gelatin. They also perish at temperatures above 50° C., while drying causes speedy loss of the power of development.

On gelatin plates, the individual colonies are round, and lie in a funnel-

Plate culture of Cholera spirilla
(×160)

Stab culture of Cholera spirilla
in gelatin.



West, Newman chr. lith.

Section of intestine from a case of Cholera
(× 1000).

Cholera.

shaped cavity, due to liquefaction of the medium: when viewed with transmitted light and magnified, they look like ground glass, the edge of the colony being finely notched. In thrust cultures also the gelatin liquefies slowly, the liquefaction being chiefly seen on the surface, so that a bubble of air appears in the upper part of the funnel-shaped excavation. From this bubble a thin prolongation runs down along the track of the needle. When liquefaction has gone still further the bacilli sink in the needle track, the bacilli falling to the bottom as a greyish-white sediment. These bacilli grow with a fair degree of luxuriance upon other media also, forming on beef bouillon a wrinkled membrane, while the broth itself remains tolerably clear. They grow also in sterilised milk, producing coagulation, but in unsterilised milk undergo speedy destruction owing to the occurrence of acid fermentation. On agar the bacilli grow in the form of a whitish-grey shining expansion. On potato they thrive even when the surface shows a slightly acid reaction, but only at from 30° C. to 40° C.: if the potato be saturated with a 2 per cent. solution of sodium carbonate, they will thrive both at 16° C. and at the higher temperature. Blood-serum is slowly liquefied by the growth of cholera bacilli (Plate VII.).

In all old cultures numerous involution forms are seen. Comma bacilli stain best with an aqueous solution of fuchsin, but are not coloured by Gram's method.

Besides the cholera commas of Koch, various species of comma bacilli are known which present some points of resemblance to it, notably those of Finkler and Dencke, the spirillum of noma, and various spirilla found in mucous secretions. The Finkler-Prior bacillus, or *Vibrio proteus*, is somewhat larger and thicker than Koch's bacillus, but the spirilla formed by it are never so long as the cholera forms. The culture on a gelatin plate liquefies so rapidly and extensively that the difference between it and a culture of cholera bacillus becomes at once apparent.

Dencke's comma bacillus is more difficult to distinguish from that of cholera. It was grown by Dencke from old cheese, and scarcely differs from Koch's bacillus in its morphological relations. It is, however, distinguished by its speedier liquefaction in gelatin, and the yellowish colour of the colonies.

The *Vibrio Metchnikovi*, which was found by Gamaleia in the intestinal contents in a Russian disease of poultry, is a curved bacterium forming screw-shaped spirilla of considerable length, but which is much shorter and thicker than the cholera bacillus. Its accurate differentiation from Koch's comma is often extremely difficult.

A peculiarly characteristic property of the cholera bacillus lies in the fact that cultures of the bacilli in media containing peptone give a reddish-violet colour in a short time when treated with pure hydrochloric or sulphuric acid. This coloration is sometimes spoken of as the indol reaction, since that substance gives a red colour with nitrous acid, the theory being that the cholera bacilli split off indol from the peptone of the nutrient medium, and at the same time develop nitrites which are decomposed by the addition of a strong acid. Of all the other morphologically and biologically similar micro-organisms, *Vibrio Metchnikovi* alone gives this cholera-red reaction.

It cannot be said that the final proof of the direct pathogenic relation of Koch's bacillus has yet been obtained by inoculation, although injections of cultivations into lower animals has been followed by death. On the other hand, it has been urged by Klein and others that these experiments are inconclusive, death in the cases quoted being not so much induced by the comma bacilli as by the other means adopted, and that other bacilli may be substituted without altering the result. There can be no question that the *Vibrio Metchnikovi* is very nearly related to the cholera bacillus of Koch: but that the various other forms of vibrio, which have been described, are identical remains unproven. From all the evidence at our command, therefore, it seems impossible to question the truth of Koch's original views regarding the existence of a specific bacillus in cases of Asiatic cholera, or to doubt that this specific bacillus is the particular spirillum known as the comma bacillus of cholera: particularly as this bacillus is invariably present, and intimately associated with definite changes in the intestine to be found in all cases of Asiatic cholera. Lastly, this bacillus is seldom, if ever, met with in the evacuations or in the intestines, either in health or disease, except Asiatic cholera.

The precise parts taken by air, milk, soil, and water in the diffusion of cholera have already been considered elsewhere. Of these, brief mention need only again be made in respect of the two latter. The whole course of not only the last great epidemic of cholera in Europe in 1892, but of all others, especially in England, shows that the disease is propagated mechanically, and that the influence of the soil as a mere influence of place and season is quite subsidiary. On the other hand, soil may, and doubtless does, serve as a medium in which the cholera virus can survive outside the human body. Confirmative of this view are the striking instances, from India, in which fresh sand, from the banks of rivers used as bathing places by the infected, placed in filters, has been the means apparently of giving rise to outbreaks of cholera to those partaking of the water filtered through it.

As regards water, the earlier objections to the possibility of cholera commas conveying the disease, because of their alleged inability to survive any length of time in water, are no longer tenable. Many observers have shown that cholera commas not only live but multiply in drinking waters. Although results on this point have been conflicting and difficult fully to reconcile, still the inference is undeniable that cholera can be and is, more frequently than by anything else, conveyed and diffused by drinking water.

Striking as are the historical facts in connection with the relation of cholera to water, we do not desire to suggest that water-carriage constitutes, even in Europe, the only means of the propagation of cholera. We wish specially to emphasise the fact that experience has proved that polluted water-supplies have played at all times a conspicuous part in the dissemination of the disease. At the same time, the behaviour of cholera, not only in India but in Europe, seems to require for its explanation a theory of the ability of the cholera organism or virus to maintain life, or even pass through some phase of its life outside the animal body, most probably in the soil. It is not unlikely that it is capable, under certain circumstances, of escaping from the soil and infecting human beings, either directly or by fastening on to food. European experience has shown, over and over again, that cholera attains its widest diffusion during the second year of its epidemic appearance: and as the later diffusions were apparently connected with the earlier manifestations, it is not improbable that, during the interval, the cholera organism, "although reduced to a relatively latent condition, as regards pathogenic manifestation, must have continued its existence—presumably in the soil."

In connection with this point, Sims Woodhead has pointed out that the generally accepted cholera organism, or comma bacillus, when grown anaërobically, gains increased virulence, but largely loses its power of resistance to germicidal agents. Conversely, when grown aërobically, it largely loses its virulence, but gains in resisting power. "Its cultivation in the bodies of human hosts, therefore, while augmenting its virulence, does not tend to preserve that section of a given crop which has taken to colonise in the human subject. On the other hand, its aërobic existence outside the human body, while diminishing its ability for immediate harm to human beings, increases its ability of maintaining itself, and of migrating from the soil to man when favourable conditions shall come round." These facts further may explain why cholera displays so little tendency to spread immediately from person to person, but yet readily disseminates itself by fomites, such as infected body-linen.

Prevention.—Our course of action and duties in this respect cannot be more tersely stated than in the following extract from a Memorandum, issued in 1892 to the Sanitary Authorities of England and Wales, by the Medical Officer of the Local Government Board.

"Cholera in England shows itself so little contagious, in the sense in which small-pox and scarlatina are commonly called contagious, that, if reasonable care be taken where it is present, there is almost no risk that the disease will spread to persons who nurse and otherwise closely attend upon the sick. But cholera has a certain peculiar infectiveness of its own, which, *where local conditions assist*, can operate with terrible force, and at considerable distances from the sick. It is characteristic of cholera (and as much so of the slight cases where diarrhœa is the only symptom as of the disease in its more developed and alarming forms) that *the matters which the patient discharges from his stomach and bowels are infective*. Probably, under ordinary circumstances, the patient has no power of infecting other persons except by means of these discharges; nor any power of infecting even by them except in so far as these matters are enabled to taint the food, water, or air which people consume. Thus, when a case of cholera is imported into any place, the disease is not likely to spread unless in proportion as it finds, locally open to it, certain facilities for spreading by *indirect infection*.

"In order rightly to appreciate what these facilities must be, the following considerations have to be borne in mind:—First, that any choleraic discharge, cast without previous thorough disinfection into any cesspool or drain, or other depository or conduit of filth, is able to infect the excremental matters with which it there mingles, and probably, more or less, the effluvia which those matters evolve; secondly, that the infective power of choleraic discharges attaches to whatever bedding, clothing, towels, and like things have been imbued with them, and renders these things, if not thoroughly disinfected, capable of spreading the disease in places to which they are sent for washing or other purposes; thirdly, that if, by leakage or soakage from cesspools or drains, or through reckless casting out of slops and waste water, any taint (however small) of the infective material gets access to wells or other sources of drinking water, it can impart to enormous volumes of water the power of propagating the disease. When due regard is had to these possibilities of indirect infection, there will be no difficulty in understanding that even a single case of cholera, perhaps of the slightest degree, and perhaps quite unsuspected in its neighbourhood, may, *if local circumstances co-operate*, exert a terribly infective power on considerable masses of population.

"The dangers which have to be guarded against as favouring the spread of cholera infection are particularly two. First, and above all, there is the danger of WATER-SUPPLIES, which are in any (even the slightest) degree tainted by house refuse or other like kind of filth; as where there is outflow, leakage, or filtration from sewers, house drains, privies, cesspools, foul ditches or the like into springs, streams, wells, or reservoirs, from which the supply of water is drawn, or into the soil in which the wells are situate—a danger which may exist on a small scale (but perhaps often repeated in the same district) at the pump or dip-well of a private house, or, on a large or even vast scale, in the case of public water-works. And secondly, there is the danger of breathing AIR which is foul with effluvia from the same sorts of impurity.

"Information as to the high degree in which those two dangers affect the public health in ordinary times, and as to the special importance which attaches to them at times when any diarrhœal infection is likely to be introduced, has now for so many years been before the public, that the improved systems of refuse removal and water-supply by which those dangers are permanently obviated for large populations, and also the minor structural improvements by which separate households are secured against them, ought long ago to have come into universal use.

"So far, however, as this wiser course has not been adopted in any sanitary district, security must, as far as practicable, be sought in measures of a temporary and palliative kind.

"(*a*) Immediate and searching examination of sources and conduits of water-supply should be made in all cases where drinking water is in any degree open to the suspicion of impurity; and the water both from private and public sources should be examined. Where pollution is discovered, everything practicable should be done to prevent the pollution from continuing, or, if this object cannot be obtained, to prevent the water from being drunk. Cisterns should be cleaned, and any connections of waste pipes with drains should be severed.

"(*b*) Simultaneously, there should be immediate thorough removal of every sort of house refuse and other filth which has accumulated in neglected places; future accumulations of the same sort should be prevented; attention should be given to all defects of house drains and sinks through which offensive smells can reach houses; thorough washing and lime-washing of uncleanly premises, especially of such as are densely occupied, should be practised again and again.

"It may fairly be believed that, in considerable parts of the country, conditions favourable to the spread of cholera are now less abundant than in former times; and in this connection, the gratifying fact deserves to be recorded that during recent years enteric fever, the disease which in its methods of extension bears the nearest resemblance to cholera, has continuously and notably declined in England. But it is certain that in many places such conditions are present as would, if cholera were introduced, assist in the spread of that disease. It is to be hoped that in all these cases the local sanitary authorities will at once do everything that can be done to put their districts into a wholesome state. Measures of cleanliness, taken beforehand, are of far more importance for the protection of a district against cholera than removal or disinfection of filth after the disease has actually made its appearance."

Preventive Inoculation.—Admitting the value and effectiveness of the principles above referred to, it is none the less certain that considerable communities are quite unable to command the conditions to be desired, and consequently the question has arisen as to the possibility of protecting the individual members of such communities from the danger of infection by the inoculation of minute doses of the poison which produces cholera. Although the idea of inoculation against cholera is not a new one, the first process established on a scientific basis was that of Haffkine. Recognising that the symptoms of cholera are due to the absorption of toxins generated by the specific bacillus in the intestinal tract, Haffkine's inoculation aims at acclimatising the system by the injection of an exalted virus much stronger than any which it is likely to encounter in the ordinary way of infection, so as to enable it to bear such quantities of cholera poison as may be absorbed from the intestine while an attack of the disease is running its course. The vaccine actually injected may contain the living bacilli, or be "phenolised" so as to kill them. Phenolised vaccines are less dangerous and less liable to contamination, and may be kept indefinitely in sealed tubes, but are not so powerful. The injection of cholera vaccine causes a rise of temperature accompanied by malaise and other slight general symptoms, which soon pass off: locally, however, severe inflammation follows, unless a preliminary injection has been made three to five days previously with a weak vaccine prepared from cultures attenuated by being grown in media kept continually aërated, and at 35° C. The only local symptoms are then slight pain and œdema. After the symptoms have passed off, the animal is found to be scarcely affected by many times larger intra-peritoneal injections than suffice to kill control animals not so protected.

The symptoms following injection into human beings, of whom some thousands have now been inoculated by Haffkine in India, are identical with those exhibited by animals; subsequent hypodermic injections with an exalted virus also producing the same results in both, so that, although, of course, human beings cannot be directly tested like animals, there seems reason to believe that they are similarly protected. The method is now being subjected to extensive practical tests in many parts of India, but as yet the facts do not permit of definite opinions being given as to either its efficacy or otherwise.

More recently, however, some doubt has been cast on the reality of the protection given by the process against the ordinary infection of cholera by Klein and Sobernheim, who find that precisely similar results can be obtained with *Vibrio proteus*, *B. prodigiosus*, *B. coli communis*, the enteric fever bacillus, *B. subtilis*, and Finkler's comma bacillus. Vaccination with an exalted virus prepared from any of these conferred immunity against the cholera bacillus or any of the others, when injected intra-peritoneally. They also found that guinea-pigs, protected by Haffkine's method, were killed by intra-peritoneal injection of a gelatin culture of the cholera bacillus liquefied by its growth. These investigations on infection and immunisation, without justifying the absolute denial of the significance of experiments on animals in relation to the bacteria of cholera, certainly suggest that the idea must in any case be set aside that the symptoms observed after intra-peritoneal injection of comma bacilli in guinea-pigs are referable to an entirely specific process.

DENGUE.

As a specific febrile disease peculiar to warm climates, characterised by severe articular and muscular pains, and often by a cutaneous eruption, our earliest knowledge of dengue does not go farther back than 1780, when it prevailed extensively in Egypt, Batavia, Spain, and Portuguese India. Its first recognition as a distinct disease was made during outbreaks in India in 1824, and subsequently in the West Indies and Southern States of America in 1827–8. Since then it has repeatedly been recognised and described in various tropical and sub-tropical countries, more particularly as endemic in Egypt, East Central Africa, Arabia, some parts of India, the Hawaiian Islands, Bermuda, and Honduras. In the intensity of its epidemic manifestations dengue closely resembles influenza: it spreads mainly by personal contact, adhering closely to lines of traffic, but sporadic cases are often observed to break out almost simultaneously in several parts over a wide area. As the *incubation* period is very short, extending often only over a few hours, its "simultaneous" appearance needs to be interpreted with discrimination.

Influence of Season, Soil, and Locality.—The relation of the disease to heat is clearly defined. Even in tropical countries epidemics of dengue usually attain their maximum during the hot season, but do not always decline or die out in the coldest months. Rain appears to have only an indirect influence by its relation to temperature.

The physical and geological characters of the soil appear to have no significance in respect to the sporadic or epidemic manifestations of the affection. As a rule, epidemics are limited to towns, especially to the low-lying, filthy, and overcrowded quarters, and the attack may be limited to such, or may involve the whole population. All ages and both sexes seem to be equally attacked: but its fatality is more marked in both the very young or very old. In some epidemics, a distinct tendency to abort has been noticeable among pregnant women attacked with dengue.

Infectivity and Etiology.—There seems to be little room for doubt that dengue is highly infectious, although some authorities question this. From analogy the infection may be assumed to be microbial, parasitic, and to be given off usually by the breath, and possibly by the secretions and cutaneous emanations. Several observers have found what they believe to be parasitic bodies in the blood of patients suffering from the disease, but the specific agent has not been satisfactorily demonstrated.

One attack usually confers a protection against a second infection, but in connection with this aspect of the disease, it is believed that if the eruption proper to the second stage of the affection fails to be clearly manifest, the patient is liable to relapses or recurrences. In some epidemics, epizootic disorders among horses and cattle are said to have synchronised with dengue in men. The precise value of this observation has not been made clear, nor has it been determined whether, in these instances, the animals suffered from dengue or not.

The mortality from this affection is small, fatal cases occurring usually only in debilitated persons, or in the very young or old.

DIARRHŒA.

Although, in the ordinary sense of the term, diarrhœa is simply a physiological process and merely symptomatic of either the normal reaction of a healthy bowel against irritating contents, or of some morbid internal condition, still considerable evidence exists to show that the diarrhœa which contributes so large a share to the mortality of young children, especially at certain seasons of the year, is of a distinct kind and merely the most prominent manifestation of an epidemic disease belonging to the zymotic group. As affecting large numbers of persons at the same time and place, and displaying a decided affinity for certain populous places during certain seasons, the diarrhœa now to be discussed may be designated as *Epidemic diarrhœa:* and, in the matter of its epidemiological features, its symptoms and pathology, constitutes a general disease, of which the diarrhœa is but one of its several symptoms. This view has for some years been recognised by the Registrar-General, who includes diarrhœa among his "Principal Zymotic Diseases"; while the official nomenclature of the Royal College of Physicians also classifies epidemic diarrhœa with the "Specific Febrile Diseases."

According to Ballard, "the leading phenomena of the disease are diarrhœa, vomiting, convulsive phenomena: a bodily temperature at certain periods above, at other periods below, what is normal; reduction in quantity or actual suppression of urine, embarrassed breathing, and, when looked for, commonly physical indications of pulmonary hyperæmia or inflammation, pallor of surface of the body, loss of bulk and flesh, and exhaustion, with its various well-known clinical features. I must add, that occasionally there is jaundice. Now and then a (fugitive) rash has been observed on the body." After giving detailed remarks upon the various symptoms, he goes on to say that "I may here state my strong suspicion, almost my belief, that the malady usually characterised by diarrhœa may run its course from first to last, and even to death, without any remarkable diarrhœa at all. In other cases, although diarrhœa occurs, it is by no means the prominent symptom of the disorder: it may be comparatively of trifling amount or of short duration."

Influence of Age, Sex, and Season.—This is by far the most fatal of the zymotics in infancy, causing a mortality of about 25 per 1000 births. From infancy the mortality diminishes until about the twentieth year, after which it again increases until the end of life. No age is exempt from attack, but the liability to attack seems to be slightly greater in the second year than the first, or at all events is far greater in the first two years than in the third or later years. It is comparatively small in the first three months, and probably increases up to the end of the first or beginning of the second year.

From a large experience in Leicester, Tomkins states that "infants and young children form only a small proportion of those attacked, although they furnish nearly the whole of the deaths."

As regards *sex*, the liability to attack is greater among males at all ages. The mortality is greater for males in infancy and old age, but usually somewhat greater for females from the second or third to about the forty-fifth year.

Fatal diarrhœa occurs at all *seasons*, but always increases greatly in summer. Whitelegge has shown that, in London, the mortality curve, based upon the records of many years, indicates a slight rise throughout June, rapidly increasing in July, and reaching its maximum in the first week of August, after which it again falls rapidly throughout September and October. During the rest of the year there is very little variation. The same facts apply closely for other large towns, where diarrhœa may be regarded as largely endemic. In both Leicester and Preston, which for some years past have enjoyed an unenviable notoriety in this respect, epidemic diarrhœa causes a heavy annual mortality.

Infectivity and Etiology.—The incubation period is apparently very short, varying from a few hours to a couple of days. In many instances diarrhœa has appeared to be somewhat infectious by means of the excreta, but this is not an invariable rule; neither has the micro-organism upon which it depends been identified with certainty. Tomkins has shown that the air is peculiarly rich in microbial life during diarrhœa epidemics: and among these prevalent micro-organisms are certain small bacilli, cultivations of which cause diarrhœa when swallowed. The same bacilli were isolated from samples of polluted soil by Tomkins, but he failed to establish its specific character as the real cause of the epidemic manifestation of this affection.

The chief facts concerning the prevalence of this form of disease may be summarised in the terms of the results of Ballard's inquiry into its causation, as explained in his Report to the Local Government Board in 1887.

Elevation of site influences diarrhœal mortality only in so far as it affects infant mortality from all causes.

Soil.—Loose porous soil is most conducive to mortality from diarrhœa; particularly if coupled with organic fouling of the earth, no matter whether vegetable or excremental. Diarrhœa is prevalent upon sites such as "made soils," or on ground polluted by drain or cesspool leakage. Both excessive wetness and excessive dryness of soil seem to lessen diarrhœal mortality, but a moderate dampness of soil favours it.

Temperature.—The mortality from diarrhœa is usually high when the air temperature is high, but this is only indirectly so, because the highest mortality coincides less with the highest readings of the air-thermometer than it does with the thermometers in the soil. The summer rise in the diarrhœa death-rate does not commence until the mean temperature of the 4-foot soil-thermometer has reached 56° F.; no matter what heat may have been recorded by the air and 1-foot soil-thermometers. The maximum mortality and decline in the diarrhœa rate coincide with the mean weekly maximum and decline of the temperature recorded by the 4-foot earth-thermometer.

Rainfall exerts little influence, except by its effects upon soil-temperature. The diarrhœa death-rate is greater in dry seasons and less in wet ones.

Wind lessens the mortality, but calm, stagnant days promote it.

Social Position.—The diarrhœa prevalence and death-rate are notoriously greatest amongst the very poor.

Want of cleanliness has a similar influence, and is, too, usually associated with poverty.

Foul air from sewers and cesspools, and accumulations of filth, favour diarrhœa mortality, while smoke and chemical effluvia are inoperative.

Undefined foulness of drinking water is not responsible for ordinary epidemics of summer diarrhœa, though it may occasionally produce a few cases.

Want of ventilation and light are particularly conducive to diarrhœal mortality; especially associated as it is with overcrowding, back-to-back houses, dark courts, alleys, and streets.

Density of buildings upon an area, irrespective of density of population, materially increases the tendency to diarrhœa.

Food is closely concerned with the epidemic prevalence of diarrhœa, not by causing ordinary indigestion, but owing to its being contaminated with some substance, "which substance is by itself an efficient cause of the malady." The mortality is very high among the artificially or bottle-fed children; the breast-fed infants being remarkably exempt.

Maternal neglect conduces to much infant mortality; this is specially seen in the greater mortality among illegitimate children as compared with the legitimate.

The occupation of females from home, by conducing to neglect and artificial feeding of infants, promotes diarrhœal mortality.

Upon these and other observations Ballard makes the inference "that the essential cause of epidemic diarrhœa resides ordinarily in the superficial layers of the earth, where it is intimately associated with the life processes of some micro-organism not yet isolated."

"That the vital manifestations of such organism are dependent, among other things, perhaps principally upon conditions of season, and on the presence of dead organic matter, which is its pabulum."

"That occasionally such organism is capable of getting abroad from its primary habitat, the earth, and having become air-borne, obtains opportunity for fastening on non-living organic material (especially food, whether inside or outside the body), which serves as a nidus and pabulum."

"That from food and from organic matter in certain soils it can manufacture a virulent chemical poison which is the material cause of epidemic diarrhœa."

A distinction must be made between the epidemic diarrhœa indicated in the foregoing and certain epidemic outbreaks of diarrhœa which occasionally occur in public institutions. These latter can usually, upon investigation, be traced to articles of food or drink, especially water, when containing excess of mineral salts, sewage, or vegetable matter. Similarly, milk and butter, or cheese, may give rise to diarrhœa, owing either to fermentative changes in themselves or to fouling by some specific gas; especially when stored in cellars or ill-ventilated places. Tinned meats, pork pies, ham and game, or even fish, have on several occasions been traced as the ultimate cause of extensive diarrhœal outbreaks. In these cases the poison partakes of the nature of a chemical body, the product of putrefactive changes in the food, and is altogether unassociated with the seasonal and telluric conditions hitherto considered.

Prevention resolves itself into the avoidance of organic pollution of the soil, the absolute avoidance of "made soils" as sites for dwellings, the exclusion of soil-air from the house, the careful storage of all food in suitably arranged and well-ventilated larders, and the disinfection of all excretal evacuations.

DIPHTHERIA.

Under the name of angina maligna, epidemics of this disease have been known since very early times: but as applied to epidemics of malignant sore throat destroying life by suffocation, attacking children rather than adults, and sometimes leaving paralytic sequelæ, the name diphtheria dates only from about 1826. The history of this affection indicates a tendency to cyclical epidemicity, though the cycles "have extended over periods of various length, many of them only a few years, and others lasting several decades." This is particularly well shown in the experience of England, where localised outbreaks occurred from 1815 to 1825, after which the country was almost free from the disease until 1857, when, as part of a general prevalence over the whole of Europe, it appeared again. Since then the disease has practically never been absent from this country, and at the present time shows distinct indications of a tendency to increase in prevalence.

Influence of Climate and Season.—Although no climate can be said to give immunity, the tropics suffer less than cold and temperate climates.

The curves of both seasonal prevalence and mortality show a marked relation to cold, both being greater during the autumn and winter than during the warmer months; the maximum mortality being reached in November and December, and the minimum in the summer. The same general relation of diphtheria prevalence to the seasons of the year appears to hold good as regards other countries. In Great Britain, atmospheric humidity is considered most favourable to the general prevalence of diphtheria, but American experience indicates that it can prevail with severity in very dry weather. How far the influence of season upon diphtheria prevalence is direct, by stimulating the activity of the microbial cause of the disease, and how far it is indirect, by increasing individual susceptibility, is uncertain; but probably it acts in both ways. As Longstaff has insisted, there is little doubt but that anything which tends to damage the mucous lining of the throat, such as ordinary catarrhs, predisposes to attack by diphtheria, and increases the general susceptibility of the body to infection, given the presence of the efficient cause of the disease.

Influence of Age, Sex, and Race.—Of the whole number of deaths ascribed to diphtheria, 55 per cent. occur at ages under five years, and about 80 per cent. under ten years. As regards liability to attack, both Power and Thorne-Thorne have shown that the attack incidence of the disease, even apart from the influence of school attendance, is greatest upon children between the ages of three and twelve years. The mortality is greater among females than among males at all ages between three and forty-five years; after that period the male mortality seems to be slightly in excess of the female, just as it is during the first two years of life. The excess of female mortality at certain ages increases precisely as the age advances which fits the female more and more to take some share in the care of home, and of relations during periods of sickness (Thorne-Thorne).

As regards race, the balance of our present evidence seems to be in favour of the view that there is no racial immunity to this disease.

Influence of Locality.—Until the last few years, diphtheria, according to all authorities, was especially a disease of sparsely populated localities; but now, one of its most striking characteristics is its tendency to prevail in towns, and in the more densely peopled areas. During the period 1861–70, while the diphtheria mortality rate per million living was, for England and Wales, 187, it was for London only 179. In 1871–80 the rates were 121 and 122 respectively, and in 1881–90 they were 163 for England and Wales and 259 for London. Thus, although there has been a decided increase in diphtheria mortality in the country generally, this increase has been relatively greater in the metropolis. But this urban invasion has been by no means limited to the metropolis, as Longstaff has clearly shown that in each successive decennium the diphtheria mortality of the towns generally has become relatively greater to that of the rural districts. This is well indicated in the following table of death-rates from diphtheria per million of population, according to density, as worked out by Longstaff:—

Districts according to density of Population.	1855–60.	1861–70.	1871–80.
Dense districts, or those with less than 1 acre per person, . .	123	163	114
Medium districts, or those with from 1 to 2 acres per person, . .	182	164	125
Sparse districts, or those with over 2 acres per person,	248	223	132

It has elsewhere been pointed out that soil dampness appears to be closely associated with the prevalence of diphtheria; but admitting the material influence which this condition must have in impairing the general health of communities, and in establishing conditions of negative resistance in individuals against diphtheria, still, in the absence of any definite knowledge that the special virus of diphtheria is a normal inhabitant of the soil, it is difficult to regard the influence of soil states as etiological factors in this disease other than as an indirect one. This view is submitted, however, without prejudice to the belief (in justification of which we have experimental facts) that the diphtheria micro-organisms may exist, for an indefinite period, dormant in soil, where, protected from light and excess of oxygen and supplied with a necessary amount of heat, they can regain their full energy as soon as the environment becomes more favourable.

Mortality.—That the annual death-rates from diphtheria have been rising slightly in England and Wales, more markedly in the large towns, and most markedly in London, is perhaps better indicated in the following table, which shows the annual mortality from diphtheria, *per million living*, for the last twenty years.

The rate for England and Wales in 1893 was 82 per cent. in excess of the average rate in the ten-year period 1883–92, which had been 175 per million, and higher than in any previous year on record with the exception of 1858 and 1859, in which years the rates had been 339 and 517 respectively. All the county rates from diphtheria, except the rates for Huntingdon, Dorset, Notts, Northumberland, and North Wales, exceeded in 1893 their decennial averages. In thirty-four counties the rates were lower than the general rate in England and Wales, the excessive diphtheria mortality being limited to comparatively few counties, especially to London (758), Essex (557), Surrey (542), Sussex (473), Kent (433), Wilts (429), Suffolk (425), Oxford (422), Middlesex (413), and Bucks (367), all per million. These counties, omitting Wilts, form a continuous area closely corresponding with what is known as the South-Eastern diphtheritic region. The mortality from diphtheria in the ten counties above enumerated was 612 per million living, while in the remaining thirty-five counties of England and Wales the mean rate did not exceed 197 per million. The case mortality varies greatly in different epidemics, and there is little constancy even in the same epidemic. Hitherto, in well-marked cases it has been frequently 35 per cent. or more, but probably by "anti-toxin" treatment this rate may be considerably reduced.

Year.	England and Wales.	London.	Thirty-three other Large Towns.
1874	150	120	...
1875	142	170	...
1876	130	110	...
1877	110	88	...
1878	140	150	...
1879	120	155	...
1880	110	144	...
1881	120	170	...
1882	152	220	160
1883	160	244	160
1884	186	240	170
1885	160	227	170
1886	150	210	160
1887	160	230	180
1888	170	300	210
1889	189	390	260
1890	180	331	240
1891	173	340	290
1892	222	440	270
1893	318	758	430
1894	...	610	380

Infectivity and Etiology.—It is now well established that diphtheria is a highly contagious disease, transmissible from person to person, and having a contagium belonging to the group called fixed contagia. The *incubation* period is short, and has been between three and five days in most cases in which exact determination was possible, but the range has been stated to be from a few hours to as much as eight or fourteen days. The early symptoms are often insidious, but in most cases the membrane is visible within a few days of the onset, if not at first. In non-fatal cases the disease usually runs its course in two or three weeks.

As regards the actual diffusion of the disease, direct infection from the case plays the chief part. In this process the virus is, probably, given off by the breath from the throat of the patient, but actual contact, as in kissing, and the attachment of the virus to drinking vessels and spoons is in many cases responsible for infection.

Klebs was the first to draw attention to the presence of bacilli in diphtheria, an observation confirmed and elaborated by Löffler. The bacilli are immotile, straight or slightly curved rods of about 6 μ by 1 μ. They grow well upon blood-serum, or upon glycerin-agar, and broth containing sugar. Generally speaking, they require a temperature for development of between 19° to 37° C. They retain their vitality even when completely dried, and Löffler found them still capable of developing after 101 days. If diphtheritic membranes are protected from the action of light and kept dry, cultures retaining their virulence can be prepared from them even after three months.

Upon gelatin, the bacilli form small, round, white colonies, with a coarsely granular texture and irregular edges: they do not liquefy the medium. In stab cultures, little white dots may be observed. The growth upon ordinary agar is scanty, although luxuriant upon glycerin-agar. A greyish-white deposit is visible in forty-eight hours upon potatoes which have been rendered feebly alkaline. On white of egg a rapid glistening yellowish-grey growth is obtainable at 37° C. in eighteen or twenty hours. Often in diphtheritic membranes there occur two species of bacilli, identical in morphological respects and in the mode of growth on various nutrient media; but one species is not constant, and is probably the pseudo-diphtheria bacillus of some writers, while the other is constant in large numbers in all diphtheritic membranes: this second species is the one which is pathogenic, and is the diphtheria bacillus of Löffler, while the first is not pathogenic. They can be usually differentiated by the fact that the true diphtheria bacillus grows well in and on gelatin at 19° to 21° C.; the other does not grow on this medium below 22° C. Numerous cocci are often found in the false membrane of diphtheria, and these were formerly looked upon as the cause of the disease: some, however, are streptococci, the rest are saprophytes (Plate VIII.).

Various animals exhibit a high degree of sensibility to infection by inoculation subcutaneously with pure cultures of the diphtheria bacillus. These bacilli can be detected at the point of injection, but all the remaining organs and the blood are free. This fact, taken in conjunction with the observation of Roux and Yersin, that, after removal of the microbes by filtration, injection of a pure culture is still pathogenic, has suggested the belief that in diphtheria we have to deal with a chemical poisoning, the chemical poison being produced by the living bacilli in the diphtheritic membrane of the human disease, and in the case of experimental animals at the seat of inoculation, and, absorbed by the system, produces the whole general disease symptoms associated with, and characteristic of diphtheria. Martin has shown these same poisonous principles to be of the nature of a ferment, organic acid, and albumoses, and that, with some of these, diphtheritic paralysis can be produced.

It is usually said that diphtheria confers no immunity against subsequent attack; this may be so, in respect of man, but undoubtedly some animals, such as the horse, are, if not actually immune against the toxic effects of the products of the diphtheria bacillus, certainly highly refractive. The practical recognition of this fact is, of course, the essence of the well-known procedure of treating the disease by injections of "anti-toxin" obtained from the serum of an immunised animal.

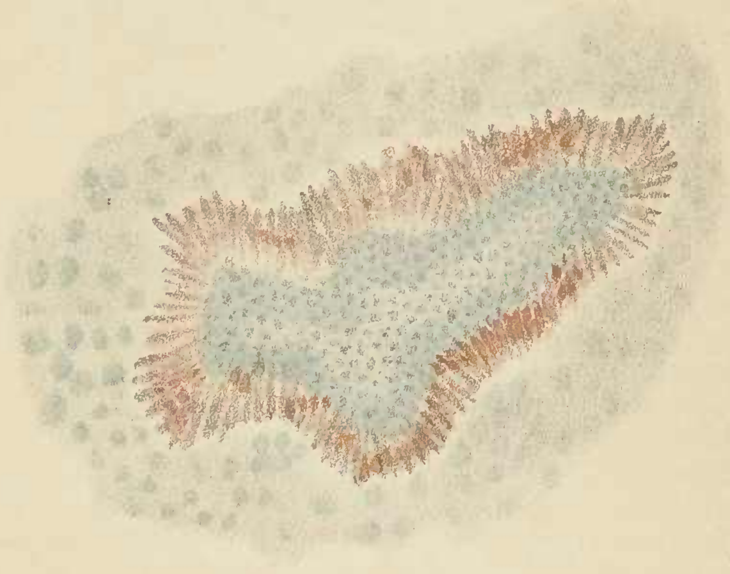
The *period of infectiveness* has been variously stated by different observers as being from fourteen days to eight weeks: this, however, is probably an under-estimate, as Schäfer has reported the persistence of Löffler's bacillus in the tonsillar mucus seven and a half months after recovery from an attack of diphtheria. Moreover, in this connection, Gresswell has observed that in certain individuals diphtheria may, so to speak, "become chronic, and subject from time to time, especially upon exposure to cold and damp, to recrudescence." It is needless to remark, perhaps, these considerations are of the utmost importance, and, if confirmed, will necessitate material modifications as to our estimate of the period of infectivity in cases of this disease.

Owing to the statements of various authors, it was long a current belief

Plate VIII.

Plate culture of Diphtheria Bacillus.
(× 10).

Cover-glass specimen from surface of
a Diphtheritic membrane (× 700).



Section through an actinomyces nodule in tongue of an ox,
(after Klein ×500).

Diphtheria and Actinomyces.

West, Newman chr. lith.

that a chronic infective process, observed in the mucous membrane of the mouth and pharynx of fowls and pigeons, was intimately connected with human diphtheria. This is now known not to be the case, as these necrotic processes are quite different diseases, both as to pathology and micro-organism. Cats, however, unquestionably suffer from a disease which bears a close affinity to human diphtheria. Klein has shown that the cat is the only animal in which, either with diphtheritic membrane or with cultures of the bacillus, it is possible to produce a definite and striking result on the cornea and conjunctiva or on the fauces and palate. Further, cats suffer naturally from, and, by inoculation with human diphtheritic membrane, can be made to suffer from a form of broncho-pneumonia which, as evidenced by subsequent paresis and inflammation of the kidney, is evidently a disease equivalent to human diphtheria. Therefore, the cat must be considered as susceptible to human diphtheria, and capable of communicating the disease to other cats and also to human beings.

Klein has further shown that pure cultivations of the bacillus of diphtheria produce by inoculation a severe constitutional disease in cows. A swelling appears at the point of inoculation, increases for a week, and then subsides. Broncho-pneumonia sets in, crops of vesicles appear upon the teats and udders, and the kidneys undergo fatty degeneration. The fluid from the vesicles, and also the milk taken from healthy teats, with every precaution contain the same bacilli. Cats fed upon this milk develop in a few days a severe and often fatal illness apparently identical with that just described as occurring naturally in these animals and equivalent to human diphtheria. In the cat, as in the cow, the lung seems to be the chief seat of the disease. As Klein says, it need hardly be added that these results lead in great measure to a right understanding of certain epidemics of milk diphtheria, and clearly show that, apart from human infection of the liquid, milk may be a medium of infection from the cow, as in the cases at Camberley and Yorktown, Enfield, Barking and Croydon.

Water has been suspected of conveying infection, but no complete demonstration has been made that diphtheria is ever transmitted by this agency. In a similar way, air has been credited with being the medium for disseminating this affection, but on very imperfect evidence. It is probable that cases of true wind-convection for any distance are of the utmost rarity.

Thorne-Thorne has called attention to the special incidence of diphtheria attending schools, and concludes "that, apart from age and susceptibility, 'school influence' so-called tends to foster, diffuse, and enhance the potency of diphtheria, and this, in part at least, by the aggregation of children suffering from that 'sore throat' which commonly is prevalent antecedent to, and concurrently with, true diphtheria." The period of life at which there is most susceptibility to acquire diphtheria is from three to twelve years of age, and school attendance increases the risks of personal infection by the aggregation and prolonged association of children together. So often have outbreaks of true and typical diphtheria, following minor throat illness, occurred in particularly isolated places, and under conditions which exclude the likelihood of their having resulted from any importation of the infection from elsewhere, that an idea has grown that possibly ordinary sore throats may be able to acquire a progressive degree of the property of infectiveness. At present there is no precise knowledge as to the fact of this actually taking place; but it is suggestive of the need to correct any faulty sanitary conditions of schools and other buildings which may in any way tend to ill-health.

For many years it was thought that accumulations of filth and drainage defects were the direct cause of the origin and spread of diphtheria. In the light of more recently acquired knowledge, there is reason to think that this older belief must be modified, and that the true part which insanitary states play is by way of predisposing to infection by lowering the standard of health rather than by being the actual origin of the disease.

Prevention.—Of the first importance are isolation and disinfection. All insanitary conditions in and around the dwelling should be sought for and remedied. No children from infected households should be allowed to attend school; and if diphtheria is at all prevalent in the district the schools should be closed. Failing this, the children attending should be medically examined daily, and all cases of sore throat segregated and forbidden to attend school until quite recovered. Milk-supplies should be inquired into, and any doubtful ones stopped at once. Milk should in all cases be boiled, especially that given to children. Isolation should be prolonged for about three weeks after disappearance of local symptoms; and bacterial cultivations from the throat secretions systematically made during convalescence, and so long as the bacilli are found isolation to be maintained. All expectoration and throat discharges should be either received into vessels containing a disinfectant, or preferably wiped off with rags which should be burnt. Disinfection of clothing, bedding, furniture, and rooms must be carried out in detail. There are some indications that injections of serum anti-toxin may be both preventive as well as curative.

Relation to other Diseases.—Diphtheria outbreaks are noticeable for being associated frequently with cases of so-called "croup," and with a series of antecedent cases of scarlet fever. Some doubt has long existed as to the precise meaning of these associated cases: the true explanation probably is, that what is called croup is oftener than not unrecognised diphtheria, or, at least, a form of laryngitis. In the other association, it is probable that scarlet fever leads to more or less temporary damage to the mucous membrane of the throat, and in this manner predisposes to the reception of the diphtheria poison, causing a series of diphtheria cases to follow after a series of scarlet fever cases. Both diseases appear to be more prevalent during the autumn and winter than during the spring and summer.

DYSENTERY.

Formerly this disease was very prevalent in this country, but, in the present day, is practically confined to hot climates. Clinically, it may be described as an affection marked by frequent, bloody, mucous, serous or ichorous stools, accompanied with tormina and tenesmus, and often with some febrile disturbance. Pathologically, it may be regarded as a specific inflammation of the inner coats of the large intestine, having a tendency to terminate in ulceration, suppuration, or even gangrene of the affected tissues. The disease may be either acute or chronic, sporadic, endemic, or epidemic in its manifestations.

Influence of Climate, Season, and Locality.—Dysentery being an ubiquitous disease, we find it prevailing at one time or another in all climates, but a close examination of its present-day distribution indicates its increased frequency, as an endemic disease, as we approach the equator. Accurate statistical facts in this connection are, however, difficult to obtain, as we have no data for satisfactorily determining the mortality which it causes as distinguished from other "bowel complaints" among the native populations.

Dysentery in all its forms is undoubtedly a seasonal disease. In Europe, as an endemic malady, dysentery has always attained its maximum in summer and early autumn. In the United States, summer is also the season when it is most prevalent. Within the tropics, dysentery is usually most fatal in the third and fourth quarters, when the temperature has begun to fall and the season to become dry. In India, as a whole, dysentery is a disease of the colder seasons: and among both Europeans and natives is most fatal in late autumn or early winter. While a high temperature is essential to the development of dysentery, as evidenced by its being a disease of warm seasons in Europe, its prevalence, in tropical countries, is only markedly manifest after the temperature has begun to fall, or even when it has reached its minimum. Few facts in connection with the possible relation between dysentery and climate or season are more clear than those which indicate the influence of vicissitudes of temperature and exposure to cold in determining attacks. The whole medical history of both our own and other armies, either in the pre-sanitary or present age, bristles with instances illustrative of the importance of these agencies in the predisposition to this affection.

While perhaps it cannot be maintained that the physical condition of the soil is altogether immaterial in respect to endemic dysentery, it is still certain that it is met with in both very dry and very marshy places. The disease is by no means rare on the bare rocks and burning sands of Aden, while at the same time it is common in many of the jungly districts of Burmah and India. Speaking generally, the disease has a preference for damp and water-logged soils: and has often been associated with the drying up of marshes and ponds. There is, however, no evidence to show that the geological constitution of the soil has any appreciable influence on the disease. On the other hand, soil contaminated with excremental matters is undoubtedly one of the most important causes of dysentery. Clouston described an outbreak of the affection in the Cumberland Asylum, traceable to the emanations of sewage applied to land adjacent to the buildings. Millbank prison was another case in point, the repeated outbreaks of dysentery being due, as pointed out by Baly, to emanations from a moist subsoil loaded with the products of organic decomposition. More recently, Norman has given details of a similar outbreak at the Richmond Asylum, near Dublin, where, owing to the antiquity of the buildings, the primitive nature of the original arrangements for disposal of excreta, and the unscientific and frequent alterations which these had undergone, the soil under and around the Asylum had everywhere become saturated with sewage. The terrible outbreaks of dysentery in the armies of earlier times were doubtless largely attributable to the pollution of the localities on which large bodies of men and animals remained encamped for often many months, resulting in fouling of both soil and water.

Influence of Diet.—Faulty dietary, especially coarseness of food, the prolonged and exclusive use of salt meat, indulgence in either alcohol or unripe or overripe fruits, are all indirect causes of dysentery by predisposing the system to infection. Of still greater importance is deficient nourishment, especially when manifested in the appearance of scurvy. The scorbutic condition modifies in a marked way the symptoms and course of dysentery, being, in fact, one of the most terrible phases of the malady.

The instances in which outbreaks of dysentery have been traced to the use of foul water, particularly water polluted with fæcal impurities, are very numerous. In fact, in the greater number of cases, the various contributing factors to the prevalence of dysentery are quite secondary to the influence of impure water. Of course, in some instances the water merely serves as a vehicle by means of which the specific cause of dysentery is introduced into the system: in others, it may act only as a predisposing cause of the infection, by virtue of an irritative action on the bowel.

Influence of Malaria and **Personal conditions.**—All cachectic states of the constitution powerfully predispose to dysentery; and malaria is no exception to the rule, as this cachexia gives rise to a particular form of dysentery which is not always amenable to treatment. Formerly much stress was laid upon a fancied connection between the two affections: it is now generally recognised that they both may run their course simultaneously without the one affecting the course of the other, or both may become aggravated by association. In the same manner, the geographical distribution of dysentery does not correspond with that of malaria. Although it is quite common to find malaria and dysentery endemic in the same region, and even in the same place, this is by no means always the case; indeed, in some instances it would almost appear as if there were an antagonism, as regards locality, between the two diseases. On the other hand, nothing is more common than an outbreak of dysentery in bodies of men who have been reduced by repeated attacks of malaria, subjected to fatigue, and exposed to the sun by day and chills by night.

Personal conditions, such as age, sex, race, and length of residence in the tropics, appear to be without material influence in the causation of dysentery. It is true, coloured races suffer more than the white, but this is largely dependent on their coarse food, the impure water they often drink, and their more frequent exposure to wet, cold, and other unfavourable conditions. It is rare to find dysentery in towns; it is specially a disease of rural districts and small villages.

Infectivity and Etiology.—At this period in the history of medicine it scarcely needs to be argued that dysentery is a specific disease and probably dependent upon a specific poison. Duncan, citing Roth, gives the following striking instance how dysentery is, in some instances, transportable, and spreads from the sick to the healthy. "A patient suffering from dysentery came to the Hotel Dieu from Madagascar. At the time of his admission there were no cases of dysentery in hospital. The man went out uncured. After eight days from his admission, cases broke out in the Hotel Dieu. The man from the hospital went to an inn; the waiter thereof was shortly seized with the disease. After leaving the inn, the man went to a village in Aube; in this village, again, cases broke out after his arrival. Finally, he went to a family at Brienne, and of that family several members were then seized with dysentery." Trousseau, Maclean, and Fayrer all insist strongly upon the infectious nature of the disease, and upon the risk attending the retention of dysenteric stools in the wards of an hospital, and we ourselves have seen dysentery propagated to those treated in the same ward with dysenteric patients by the effluvia of their discharges.

Besides the presence of undoubted infection in primary dysentery, there is also a probable acquired infection developed from primary diarrhœa, just as there is the probable occurrence of a progressive development of the property of infectiveness in simple "sore throat" up to a condition of diphtheria. The gradually developed infection of dysentery engrafted on diarrhœa is nowhere better seen than in the experiences of military campaigns. Although true dysentery is a disease *per se*, still on service the causes predisposing to the ordinary forms of simple diarrhœa will, if persistent, also predispose to the true spreading epidemic of dysentery. Although as yet the relation of micro-organisms to true sporadic and epidemic dysentery has not been fully worked out, yet in the aggravation of the lesion causing the primary diarrhœa, we may suppose the soil and environment to be gradually rendered fitting for the "contagium," and thus infected powers will be acquired. The infectivity of dysentery lies in the stools; and the doctrine that the dejecta of apparently simple diarrhœa cases can assume an infective character, especially when many patients are accumulated together in camps or barracks, should never be lost sight of.

The etiology of dysentery, however, is by no means a simple question, as there can be no doubt that what is clinically called dysentery is not in etiological respects one single disease, since, judging by the literature and diverse statements of observers, some dysenteries are caused by one form of organism, and others by another: also some are contagious, while in others the discharges only become infective after they have undergone some changes outside the body. It is highly probable that the specific cause of dysentery is often introduced into the system without giving rise to the disease. The healthy bowel does not afford a favourable soil for its growth; it is only when the intestinal mucous membrane is impaired, as by excessive or extreme vicissitudes of temperature, by exposure to cold, bad or deficient food, impure water, or by cachectic conditions such as scurvy or malaria, that it becomes vulnerable to the attacks of the lower organisms. The etiological importance of these diverse factors is limited entirely to their influence in disturbing the nutrition of the large intestine.

As the specific cause of dysentery, Chantemesse and Widal have described short rods with rounded ends, but with scanty power of movement, in the contents and walls of the intestines, as well as in the spleen and abdominal glands in cases of dysentery. These bacilli stain badly and do not liquefy gelatin. On plate cultures they develop first as small white specks, which assume a yellow colour; but in some days the yellow colour vanishes, causing the colonies to become white and granular.

Many cases of dysentery are, however, believed to be due to the action of a protozoon, named by Lösch the *Amœba coli*, and by Councilman and Lafleur *Amœba dysenteriæ*. Kartulis has found these amœbæ in cases of tropical dysentery, and also in twenty cases of abscess of the liver complicating dysentery. All these observers give good reasons for considering these amœbæ the cause of dysentery, though others, like Massiatin, who has met with similar bodies in intestinal diseases in Russia and elsewhere, do not think so. For some further information regarding these amœbæ, reference may be made to page 562. Recently Ogata has found in the stools of patients suffering from an epidemic form of dysentery in Japan a short bacillus, about a quarter the length of the tubercle bacillus, which in pure cultures appears to have given rise to dysenteric symptoms when introduced under the skin or absorbed by the buccal or intestinal mucous surfaces. Which of these various observations will be confirmed remains to be seen, but in any case we may accept it as settled that, in epidemic and endemic dysentery, we have to do with a parasitic disease.

Prevention.—This will necessarily be based upon the etiology of the disease. Inasmuch as dysentery occasionally spreads in hospitals where large numbers suffering from the complaint are under treatment, the necessity of free ventilation, cubic space, the prompt and thorough disinfection of the stools, bed-pans, commodes and enema tubes are matters of the first importance. In camps, prophylaxis demands that the contents of latrines be disinfected and buried deeply, well away from human habitations, or better still, that they be burnt. All drinking water should be protected from contamination, and when open to the slightest suspicion, should be boiled.

Finally, exposure to extremes of heat and cold, dampness, or to deficient and imperfect diet, are important predisposing causes to dysentery to be carefully guarded against, whether for individuals or bodies of men.

ENTERIC FEVER.

This disease is clearly traceable in the earlier records of medicine, but it was not until 1850 that Jenner was able to demonstrate its differentiation from typhus fever. Enteric fever is distinctly influenced by season, by far the greater number of cases in Europe and America occurring in the late summer and autumn; the least number of cases occur in April or May. This seasonal prevalence is equally well marked in the tropics. Hirsch has aptly called enteric fever the ubiquitous disease, for it is of practically world-wide distribution: for many years it was deemed to be less common in tropical than in temperate climates, but making allowance that certain forms of malarial fever have been frequently mistaken for enteric fever, it is probable that the idea was erroneous. It is beyond dispute that remittent fever in the tropics frequently simulates enteric fever in a remarkable degree, though the autopsy shows the characteristic lesion of the latter disease to be absent. Many cases of the so-called typho-malarial fever are doubtless of the same kind.

Weather has no clear relation to enteric prevalence, except in so far that meteorological conditions may act by modifying the moisture and temperature of the soil, and that rain may either increase or diminish the chances of an outbreak according to the previous condition of the ground.

Influence of Race, Sex, and Age.—Although negroes and other native races are apparently less liable to suffer in their native countries than non-acclimatised persons, there is no evidence to show that *race* of itself exercises any influence over liability to attack by this disease. Very much the same conclusion may be drawn in regard to *sex* at all ages, though, if anything, males are apparently rather more susceptible than females. According to some figures published by the Registrar-General in his Fifty-first Annual Report, and based upon the returns of the London Fever and Metropolitan Asylums Board's Hospitals, it would appear that, between five and twenty years of age, although more males are attacked, there is a greater fatality among females between those ages. It is possible there may be some fallacy underlying this statement, as the number of cases upon which the conclusions were based was not large. The influence of *age* is very marked in this disease: of 5911 cases recorded by Murchison, 26·86 per cent. were between the ages of fifteen and twenty, and 66·42 per cent. were between the ages of ten and twenty-five. After thirty years of age the cases became fewer and fewer. Judging by the death-rate from enteric fever in this country, per million of living population, as furnished by the Registrar-General, the mortality is at its minimum in the first year of life for both sexes. It rises from the second to the fifth year, and then falls till the fifteenth, when it gradually rises until a maximum is attained in the age-period 20–25, after which it falls permanently. It is probable that true enteric fever is rare among infants and young children, and that many of the cases returned at those ages are due to faulty diagnosis. As in the case of some other diseases, the risk of a fatal termination steadily increases with age.

Influence of Place.—European experience indicates that enteric fever is often more prevalent in towns than in the country, and often fixes persistently upon one district. As a rule, in such districts where the disease is endemic, it will be found that insanitary conditions abound, notably impure water-supply, defective methods and arrangements for disposal of excreta, combined with want of care for preventive measures. In these areas, new-comers are especially liable to attack.

In connection with the endemic or epidemic prevalence of enteric fever, considerable importance has been attached to the *rôle* which pollution of the earth by excrementitious matter and movements of the ground water play. Pettenkofer and Buhl traced a connection, at Munich, between the occurrence of enteric fever sickness and mortality and variations in level of the subsoil water which has been confirmed by further observations in Berlin, various parts of Germany, and elsewhere. According to these observations, the prevalence of and mortality from enteric fever fall with the rise of the ground water, and rise with its fall: the level, however, reached by the disease being not in proportion to the then level of the subsoil water, but only to the range of fluctuation of it on each occasion. While doubtless true for Munich and the localities in question, this relation does not appear to hold good universally. In many places where enteric fever occurs the subsoil water is so deep, or its movements so trifling, that there is little probability of its producing any material effect. In the places where the relation has been observed, the soil is porous, the ground water high, and leaking cesspools not only numerous, but in general proximity to wells and other sources of water-supply. Given these conditions, there is no difficulty in appreciating how the purity of water in wells may be affected by changes in the level of the ground water, and, further, bearing in mind the readiness with which enteric fever is spread by means of specifically polluted water, the true value of the above mentioned observations as to a causal relation between the prevalence of the disease and the range of fluctuation of the subsoil water are manifest.

Mortality.—The following table, from the Registrar-General's returns, will give some idea of the remarkable diminution in the number of deaths from enteric fever in England and Wales during the last twenty years.

Year.	Total Deaths.	Death-rate per million living.	Year.	Total Deaths.	Death-rate per million living.
1874	8861	374	1884	6380	236
1875	8913	371	1885	4765	178
1876	7550	309	1886	5061	184
1877	6879	279	1887	5155	185
1878	7652	306	1888	4848	172
1879	5860	231	1889	5011	176
1880	6710	261	1890	5146	179
1881	5529	212	1891	4875	168
1882	6036	229	1892	4037	137
1883	6078	228	1893	6801	229

Though the mortality in 1892, when the rate did not exceed 137 per million persons living, was the lowest on record, the returns for 1893 show a large increase, being higher than in any previous year since 1884. The increase in mortality from this disease, during 1893, appears to have been general throughout almost the whole of England and Wales: Berkshire, Bucks, Wilts, Devon, and Worcestershire being the only counties in which the rate in 1893 did not exceed that in 1892. The counties which showed, in 1893, the largest excess, as compared with their respective averages in the preceding ten years, were Rutland, Sussex, Durham, East Riding of Yorkshire, Dorset, Lincoln, Hereford, Bedford, Cornwall, Warwick, and Cheshire: the great increase in Sussex, which amounted to 282 per cent. of the mean rate, being mainly due to the epidemic at Worthing.

The case mortality from this disease varies from 12 to 16 per cent.

Incubation and Protection.—The latent period of enteric fever is liable to considerable variation. The most usual duration is about twelve to fourteen days, but it may range from a few days to thirty: it seems to be shorter when the poison is introduced by water, or by milk. The peculiarly insidious mode of onset renders any exact determination difficult. The actual illness commonly lasts three or four weeks, but is often protracted by relapses. How far the disease confers protection against a second attack is still doubtful, but the weight of opinion is undoubtedly in favour of the view that it does confer immunity, possibly for life.

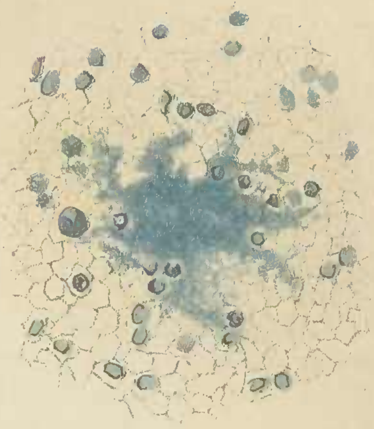
Infectivity and Etiology.—Though some doubt exists as to whether the breath of those suffering from enteric fever is infective, there is none as to the infective nature of the excreta. Experience shows that enteric patients can be treated in large general wards side by side with other cases without danger to the latter. With scrupulous cleanliness, especially as regards the nurse's hands, and clothing or bedding soiled by the patient's discharges, there seems little tendency for the infection to spread. The stools and urine are probably infective throughout the whole period of the disease, and apparently gain in infectivity for some few days after discharge from the sick person. This fact renders the disposal of the excreta a matter of great importance. They need to be disinfected with mercuric chloride or other reliable disinfectant, and disposed of at once either by burning or burial deeply and well away from houses or sources of water-supply: in towns, necessity often compels them to be dealt with like other excreta, in which case, effective disinfection is of even greater importance.

The remarkable ability of enteric fever to disseminate itself by means of water, milk, and other media, indicates the virus to be a living organism. Eberth first showed that in many cases of enteric fever there occur in the swollen mesenteric glands peculiar bacilli, rounded at their ends, motile, and occasionally including within a pale sheath one or more spore-like granules. Gaffky and numerous observers have confirmed these statements, and these bacilli are now, by many, if not most pathologists, considered as the microbial cause of enteric fever. These bacilli are three times as long as broad, their average length being from 2 to 4 μ, and sometimes uniting to form what are apparently threads of considerable length. Spore formation in them is doubtful. They thrive whether oxygen is excluded or has free access, although in the latter case the growth is more vigorous: they readily stain with the aniline dyes, but yield up their colour on application of bleaching fluids, so that their demonstration in tissues is difficult. On the surface of gelatin plates, the colonies have a translucent filmy appearance with irregular outline, thin at the margin, thick and less translucent at the centre. Those growing in the depth appear as dots, whitish in reflected, brownish in transmitted light. There is no liquefaction of the gelatin. Stab cultures show on the surface a thin growth, which also takes place along the needle track. A grey slimy layer, covering the whole surface, develops on agar and blood-serum. On potatoes their growth is not absolutely characteristic. Broth is made uniformly turbid after forty-eight hours, a greyish, powdery or flocculent precipitate, but no distinct pellicle, being formed (Plate IX.).

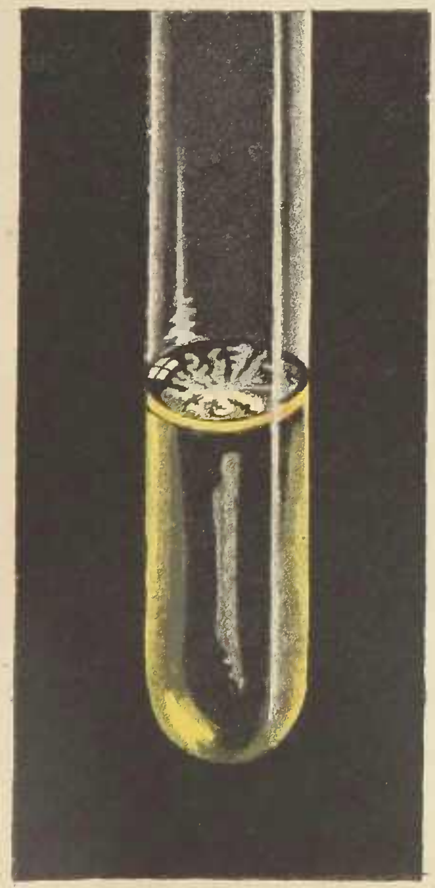
Rodet, Roux, and others have put forward the view that this bacillus,

Plate IX.

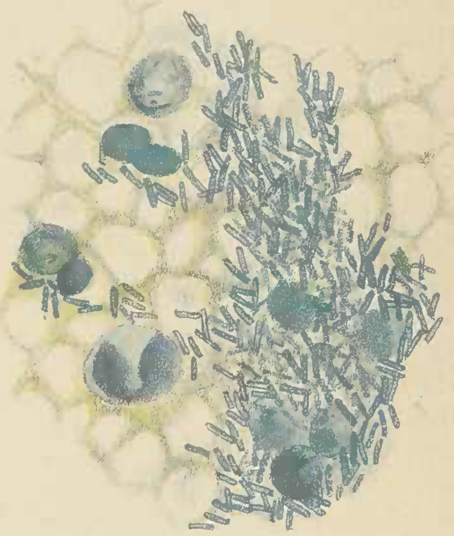
Plate culture of Enteric Bacillus (×100).



Section of an Enteric ulcer (×450).



Stab culture of Enteric Bacillus in gelatin.



Section of Spleen from a case of Enteric Fever (×1500).

West, Newman chr. lith.

Enteric Fever.

known as the Eberth-Gaffky bacillus of enteric fever, now admitted to be almost constantly present in the alimentary canal, in the mesenteric glands, and in the spleen of cases of this disease, is no other than the *Bacillus coli communis*, which is a constant and normal inhabitant of the bowels of man and animals under perfectly healthy conditions: and, further, they have contended that the *B. coli* passed with the normal dejecta is capable of acquiring in sewage specific and virulent properties, so that when reintroduced by water, milk, or other articles of food into a normal individual, it has become endowed with the power of setting up in him the specific and communicable disease—enteric fever.

In this view enteric fever may—in so far as it is referred not to a microbe directly derived from antecedent enteric fever or other disease, but to a saprophyte that has become altered in its physiological effect by sojourn for a while in sewage—arise, so to speak, *de novo*. This contention is the outcome solely of bacteriological study, not of epidemiological observation and experience, and based mainly on the fact that it is often difficult to distinguish the *B. coli* from the bacillus of enteric fever. Recent and closer observations, however, have shown that these two micro-organisms are quite distinct, and as judged by their cultural behaviour can be readily differentiated. In shape the *Bacillus coli* is an oval rod rounded at its ends, measuring about 0·5 μ broad and 2 μ long: comparatively few attain the length of cylindrical rods. They are less motile than the Eberth bacillus, and grow rapidly on gelatin, in the shape of translucent filmy patches, irregular in outline, thin in the marginal, thick in the central part, but without liquefaction of the gelatin. The three principal cultural characters, however, by which the two organisms can be distinguished best and easiest are: shake cultures in melted gelatin, which is afterwards allowed to solidify, milk cultures, and broth cultures. While the *B. coli* rapidly forms gas bubbles in gelatin shake cultures, the enteric bacillus does not do so; while the *B. coli* curdles milk on incubation for two days at 37° C., the enteric bacillus does not do so; and while the *B. coli* produces indol in broth, after three days' incubation at 37° C., as shown by a pink to red reaction on addition of nitrous acid, the enteric bacillus does not do so.

All authors who maintain the change of the *B. coli* into the *B. Eberth*, assume that this change is accomplished in sewage. As far as direct experiments can be made in this direction, they lend no support to this view, for it can be shown that the two microbes, while sojourning in sewage, maintain their biological characters unaltered. Moreover, direct observation proves that the two organisms, when planted in sewage, behave in a strikingly different manner. While the *Bacillus coli* retains its vitality there, and undergoes multiplication, the bacillus of enteric fever, on the contrary, shows less vitality and soon diminishes in numbers till ultimately it altogether disappears, in some cases within a fortnight, and long before the nutritive material is exhausted. But as long as the enteric bacillus is present in such sewage it retains the same cultural characters as mentioned above, and the same applies to the *Bacillus coli*. An important fact that has resulted from experiments with sewage in connection with these micro-organisms is that the enteric bacillus, when planted in sewage to which 1 per cent. of potassium nitrate is added, retains its vitality for considerable periods and also undergoes rapid and marked multiplication. This seems capable of explaining the observations often made that the enteric bacillus in sewage percolating through the soil into water is capable of preserving for long periods its vitality. Sewage percolating through the soil takes up nitrates from the soil, hence in such a medium the enteric bacillus is capable of growing and retaining its vitality.

Although septic, toxic, and septicæmic results have been produced in rodents by the injection of enteric fever stools and enteric bacilli, it cannot be said that this disease has been communicated by any experimenter to the lower animals. This apparent failure to furnish the crucial argument in support of the view that Eberth's bacillus is the cause of this disease, is due probably rather to the fact that domestic animals are not susceptible to enteric fever, than to the fact that this bacillus is not the specific micro-organism. As far, then, as bacteriological evidence goes, there is no valid reason why sanitarians should not continue to regard enteric fever as a specific disease derived from an antecedent case or cases of the same disease, and not, as has been suggested, on negative bacteriological and other evidence, as capable of originating *de novo*, that is to say, through the *Bacillus coli* or other intestinal microbes. While holding this view, our duty of preventing pollution with sewage of drinking water, milk, &c., is not less incumbent. For, although without the enteric germ the *Bacillus coli* and other intestinal bacteria, we maintain, are not capable of causing enteric fever, the presence of the *B. coli*, or any other well-known normal inhabitant of the intestines, in water nevertheless indicates a probable pollution with excremental matters, and amongst them possibly with specific—that is, enteric—excremental matter.

In the actual dissemination of the disease, water has been repeatedly proved to play the most important part. Not only in this country, but abroad, various epidemics and groups of cases have been investigated, where a contamination of drinking water by sewage from drains or old cesspools, and, by inference, with enteric excreta, has been proved to be connected with the outbreak and spread of the disease. Complete and instructive evidences as to contamination of drinking water by enteric stools, and wholesale infection by such water, are afforded by the Caterham epidemic in 1877, the Middlesbrough and Tees Valley outbreak of 1890–1, the Worthing epidemic of 1891–2, and many others to be found in the various supplements to the Reports of the Medical Officer to the Local Government Board.

Further, Ballard has shown in his report on the Islington epidemic in 1870, that milk plays an important *rôle* in the dissemination of the enteric fever virus: such milk epidemics, where milk had directly, or by the vessels containing the milk, been brought into contact with sewage-polluted water, have been numerously recorded. Other outbreaks have been traced to infected milk-supplies, in which material evidence has been forthcoming to raise the question whether milk can obtain enteric fever infective qualities from an ailment of the cow, as in the case of diphtheria and scarlet fever. Such a sequence of events would explain many otherwise inexplicable epidemics, but the evidence in support of this view cannot yet be said to be convincing. Although it is true that, in the greater number of epidemics of enteric fever, the cases are due to specifically contaminated water or milk, it is not safe to say that the disease is never conveyed by direct infection, nor must we overlook other possible modes of the spread of this disease. In India and other countries where dry systems of conservancy are in force, a possible danger exists in the dislodgment of dried and imperfectly buried excreta from the soil, and their diffusion, as dust, by winds. If specifically infective, even in the absence of direct experimental evidence, few persons, who have knowledge of the circumstances of life of tropical countries, will be disposed to deny that such dried excretal matter possesses considerable potentialities for evil. Some are of opinion that the *B. Eberth* is essentially a micro-organism of the soil, and capable of leading an independent life, and of reproducing itself in the earth. Our own observations indicate that in certain soils, rich in nitrates, this organism may retain its vitality for six or more months: if this be so, there is no difficulty in understanding why the disease often appears in the most diverse localities, where previous cases of the disease are difficult to trace.

From time to time, a good deal of evidence has been forthcoming in favour of the view that the air and gases of sewers or drains which have become specifically contaminated may, if allowed to find its way into dwellings through defective house connections, cause enteric fever among the inhabitants of such dwellings. In the light of recent researches, which indicate that sewage is unable to give off micro-organisms to the air in contact with it, we find it difficult to accept this view as to the occasional origin of enteric fever cases; and are compelled to conclude that some more exact causation has been overlooked in those instances.

The question whether enteric fever and malaria stand in any special relation to each other has been extensively discussed. There is some evidence to show that, in some localities, there is a mutual antagonism between these two affections, and that where malaria is common, there enteric fever is rare, or absent. This, however, is by no means universal, nor does the converse always hold good. Our explanation of the phenomena as observed is that civilisation, by leading to cultivation and drainage of land, has tended to banish malaria, but at the same time possibly has disposed to the prevalence of enteric fever, by pollution of water, soil, and air, as the result of an aggregation of people under circumstances of defective sanitation. The question has been further complicated by the suggestion, that some of the later supposed cases of enteric fever in malarial districts are but an altered type of malaria. In regard to this point, we think that, while it is unwise to accept the term typho-malarial fever as indicating a third form of disease, which is neither enteric fever nor malarial fever, it cannot be denied that the two latter diseases may co-exist.

Prevention.—General measures will be to secure pure air, pure water, pure milk, and to maintain all drains and sewers in good order. If any suspicion attach to either water or milk it should be boiled. To guard against the spread of the disease from the sick to the healthy, all stools and urine should be received into a vessel containing some strong disinfectant and at once covered up. After this, the excreta may be at once passed into a drain, or buried deeply in the earth, but this must not be done until the stool has been exposed to the action of a strong disinfectant for at least five minutes. If possible, all excreta should be burnt. All soiled linen should be at once placed in a vessel containing carbolic acid solution 1 in 20, until they can be removed for proper disinfection by either boiling or exposure to moist heat in a disinfecting chamber. Isolation of the sick person is not necessary, but several patients ill with enteric fever should not be aggregated together in one ward.

ERYSIPELAS.

As a contagious and infectious disease, the chief evidence of which is a spreading inflammation of the skin, extending in some cases to the areolar tissue, and accompanied by fever, erysipelas has been known since very early times. It is met with all over the world, but less frequently in the tropics than in more temperate climates; it affects all races alike, and is especially fatal among the very young. It has been said that erysipelas is more common among women than men: this is probably true with respect to attack, but the deaths at all ages are greater among males. The total number of deaths returned from this disease in England and Wales in 1893 was 1921, of which 1025 were males and 896 were females; the mortality for all ages being at the rate of 64 per million persons living, as compared with a rate of 49 per million for the last five years. The deaths from erysipelas are usually above the average from the middle of September to March, and below the average for the rest of the year. The absolute maximum for the year is commonly attained in the third week of November: while the minimum period is from the middle of June to that of September. Longstaff has pointed out that erysipelas has a mortality in inverse ratio to the rainfall, in this respect resembling scarlet fever: there is a further general resemblance in the seasonal curve of prevalence of erysipelas to puerperal fever, pyæmia, and rheumatic fever.

Etiology.—Fehleisen was the first to clearly demonstrate that erysipelas is caused by a micro-organism which he named the *Streptococcus erysipelatosus*; it is found at the edge of the inflamed skin, occupying the lymphatic channels and spreading along them as the disease advances. The cocci are from 0·3 to 0·4 μ in diameter: they are readily cultivated outside the body, and from the cultures true erysipelas can be induced in rabbits by inoculation. Associated with this streptococcus in erysipelas is usually the *Streptococcus pyogenes*, and some observers go so far as to say that they really are the same organism, the former being merely an attenuated form of the latter. The facts that two species of streptococci can be originally obtained by culture from the erysipelatous skin, and their differences proved by inoculation into rabbits, seem definitely to contradict the above supposition as to their identity. The cocci of erysipelas never enter the blood.

Formerly it was usual to regard erysipelas as occurring either through a wound or without. To a large extent this distinction between traumatic and idiopathic forms of the disease has been replaced by the belief that every case is caused by the poison entering the system through a wound, though this in some instances may be so insignificant as to be overlooked. The disease is undoubtedly infectious, but possibly less uniformly so than many of the other infective diseases.

The incubation period of erysipelas is evidently short, ranging from one to eight days, or more often from one to three or four days. In Fehleisen's inoculation cases on human beings for the removal of sarcomatous growths, the period was very short, varying from fifteen to sixty-one hours. The disease at times runs riot in hospitals, especially in surgical wards, the most important favouring circumstances being defective ventilation, overcrowding, want of cleanliness, and defective drainage arrangements. Some people seem to be more predisposed to erysipelas than others; among such are the intemperate, the badly fed, and those who have had it before. Our knowledge at present is small as to what are the precise connections between erysipelas and the various forms of blood-poisoning, more particularly that peculiar kind of blood-poisoning associated with lying-in women or those recently confined. Evidence is strong that there is a relationship of some kind between erysipelas and child-bed fever, as shown by the familiar fact that women in labour attended by doctors or midwives who are suffering from erysipelas, or who even have been in contact with erysipelatous patients, commonly get blood-poisoning or puerperal fever. Similarly, nurses, midwives, and medical men who attend, or come into close contact with, women suffering from puerperal fever frequently themselves suffer from erysipelas; also that the new-born children of mothers, ill with child-bed fever, die in large numbers from erysipelas. To a less degree, erysipelas has some obscure relationship to diphtheria prevalence.

Prevention is synonymous with attention to the sanitation of hospitals and institutions, especially the maintenance of ventilation, and cleanliness of wards. Hospital floors should be of hard wood, polished and readily cleaned by dry rubbing or sweeping. Cases of erysipelas should be isolated, and the ward, if possible, evacuated, and the walls, floor, furniture, &c., carefully disinfected.

GLANDERS.

Fortunately, this is a comparatively rare disease in man, but not uncommon in horses, asses, mules, and other animals. It may be described as a sub-acute, infectious disease of the nasal mucous membrane, respiratory organs, and skin: when localised in the skin, the affection is termed *farcy*, but is identical with the more ordinary form. Whether affecting man or animals, glanders is remarkably fatal. In the human subject the disease is usually acute, consisting of nodular deposits in the mucous membrane of the nose, particularly on the septum. The young nodules are of about the size of a hemp seed, deep seated, and surrounded by congested mucous membrane. Microscopically they resemble young tubercles: they soon enlarge, suppurate, and form ulcers. The nasal septum rapidly becomes riddled with abscesses: the cervical glands become swollen and purulent, and the disease process extends to the pharynx, trachea, lungs, and larynx. In cases where the skin is involved, the process is very similar.

The chief source of infection is the horse. The virus does not appear to be capable of aërial transmission, except, perhaps, for very short ranges, and no evidence exists in support of infection by either water or milk. Inoculation is the chief mode of infection, so far as man is concerned, generally through a cutaneous wound; but it may occur without abrasion of skin or mucous membrane. The usual incubation period is from three to eight days, but in acute cases may be shorter.

The cause is a bacillus, usually present in the nodules, being more numerous before these latter have become purulent. The bacilli are slender rods with rounded ends, resembling both in size and appearance the tubercle bacillus. They are easily cultivated at 35° to 38° C., on blood-serum, agar, potatoes, and other media. On boiled potato at 35° C. they form a characteristic brownish-yellow amber-coloured film. Inoculations of these artificial cultures into horses and asses produce typical glanders. The bacilli appear to be killed by drying, and by ten minutes exposure to 55° C.: in this respect they are less resistant than many other non-spore-bearing bacilli. Corrosive sublimate (1 : 5000) kills them in two minutes, and 5 per cent. carbolic acid in five minutes.

The injection into horses, suffering from glanders, of chemical substances obtainable from cultures of the bacillus (mallein) produces a well marked rise of temperature; but no reaction follows in healthy horses. Mallein is prepared in the same way as tuberculin, and affords in doubtful cases a ready means of determining the diagnosis of glanders.

Prevention will be best secured by early isolation of the infected man or animal. All discharges from the nasal and respiratory mucous membranes should be disinfected and destroyed. Infected stalls and stables should be disinfected. Glandered horses should be destroyed, but this is not compulsory in the case of farcy. Though there is no evidence that the flesh of glandered animals used for food propagates the disease, still it is advisable that it should not be so consumed.

HYDROPHOBIA.

From very early times it has been known that dogs are liable to a fatal disease which they transmit by their bite; and this disease when occurring in man was called "hydrophobia" from the dread of water, which is one of its chief symptoms. In the lower animals, however, this very symptom is absent, hence in them it is more commonly spoken of as rabies.

Rabies may occur in many kinds of animals besides dogs. It is common in wolves, jackals, and foxes, and the bite of a rabid wolf is notoriously the most dangerous of all. Cats are sometimes affected by it, but far less frequently than dogs. Among herbivora, horses, oxen, sheep, goats, pigs, rabbits, and guinea-pigs are capable of being infected experimentally by inoculation, or if they are bitten by rabid dogs. Rabies broke out as a destructive epidemic among the fallow deer at Richmond in 1889, and soon afterwards in the Marquis of Bristol's park. More than 450 died out of a herd of between 600 and 700 in the course of three months.

There are two varieties of the disease in dogs; one characterised by maniacal excitement, the other by paralysis of the jaw, so that it hangs down and allows a frothy saliva to run out of the mouth. In each form the bark is somewhat altered. Towards the last, the hind legs and the loins become paralysed so that the animal staggers about and falls. Rabies is always fatal in dogs, usually in a week after the symptoms have appeared, occasionally after nine or ten days. In rabbits the symptoms of rabies (transmitted from dogs) are like those of dumb madness, in the absence of excitement and the development of paraplegia, which, as in dogs, takes the form of acute ascending paralysis. The study of the disease when reproduced by inoculation in animals shows a very similar series of symptoms to those which are characteristic in man. There is first a stage of excitement with visual delusions; then hyperæsthesia with reflex spasms; next the stage of mania and (particularly in rabbits) paraplegia, corresponding to the dumb rabies of dogs; and lastly, death, often by sudden failure of the heart.

At one time hydrophobia was supposed to occur chiefly in temperate climates, but this is not the case, as it is by no means uncommon in India and Central Asia. The only part of the world in which it is as yet unknown is Australia. Like other specific diseases it is often absent from a town or locality for several years together, until some accident introduces it and it becomes epidemic. In England the greatest number of cases of hydrophobia occur in London and the home counties, Lancashire, and the West Riding of Yorkshire.

For London, the Registrar-General's returns show twelve deaths from hydrophobia in 1838, and four in 1839. Then only one, three, four, two, three, two, in the successive years to 1845, none in 1847, '49, and '52, and only one in 1846, '48, '50, '51, and '53. Seven were returned in 1854, and two in 1855 and '57. None in 1856, '58, '59, '60, '61, and '62. Two in 1863, and none again in 1864, but nine in 1865, and six in 1866. There were three in 1867 and '69, none in 1868 and '70; one in 1871, '72, and '73. Then there were nine in 1874, six in 1875 and '76, and sixteen in 1877; five in 1878, two in 1879, three in 1880, five in 1881, four in 1882, eight in 1883, nine in 1884, and in 1885 no less than twenty-seven. In 1886 the number suddenly fell to nine, after muzzling was enforced, and in 1887, '88 there were only two and three deaths respectively. Seven occurred in 1889, two in 1890, two in 1891, none in 1892, one in 1893, and one in 1894.

According to the popular belief, the disease is more frequent in the hot season than during winter and spring. Of 132 cases throughout England and Wales, fifty-one occurred in July, August, and September. Hydrophobia causes most deaths at ages between five and fifteen years, more males being affected than females. Bites about the face, and especially those inflicted by rabid wolves, are more deadly than others; the danger is less when the part bitten is protected by clothing. Of cases of bites by animals proved beyond doubt to be rabid (the proof being the occurrence of a genuine case of rabies in some person or animal bitten by them or inoculated from them), hydrophobia manifests itself in 15 per cent. of the persons bitten. By means to be described subsequently, this mortality may be reduced to at least 1·5 per cent., and by other preventive measures the disease can be and has been stamped out completely.

Hydrophobia is doubtless caused in all cases by the transference to the patient of the specific virus of rabies, such transference being imparted to man and probably animals also by the bite of rabid dogs; or more rarely of rabid wolves, jackals, foxes, and cats. The *incubation period* is most frequently about six weeks. When the infecting wound is on the face, the incubation is probably shorter. In children, also, it is usually shorter than in adults. In 132 cases of hydrophobia, selected by the Registrar-General (1886) on account of the circumstances being accurately known, the shortest incubation was eleven days in a child bitten by a rabid cat. In 23 cases it was under a month, in 64 between one and two months, in 21 between two and three months, in 124 it was under five months, in 127 under ten months, and in 130 under two years. In one case it was between three and four years, and in one other above four years. Experimental inoculation in dogs, rabbits, and other animals shows, on the whole, shorter periods than when the disease dates from the infliction of a bite by a rabid dog; and when the virus is introduced, not subcutaneously but beneath the dura mater after trephining the skull, the period of incubation is measured by days, a week being a very frequent time.

There is no doubt that the virus resides in the saliva and salivary glands. Magendie long ago produced rabies in dogs by inoculating them with the saliva of hydrophobic patients. Pasteur demonstrated that the spinal cord is also the seat of the virus, and that inoculations from it, especially if introduced under the dura mater of a dog after trephining the skull, will reproduce the disease in dogs and rabbits. Pasteur further showed that the virus, when propagated through a series of rabbits, increases rapidly in its virulence; so that whereas subdural inoculation from the brain of a mad dog takes from fifteen to twenty days to produce the disease, in successive inoculations in a series of rabbits the incubation period is gradually reduced to seven days. The spinal cord of these rabbits contains the virus in great intensity, but, when kept in perfectly dry air, the virus gradually diminishes in intensity. If, now, dogs are inoculated with cords preserved for from twelve to fifteen days, and then with cords preserved for a shorter period, *i.e.*, with a progressively stronger virus, they gradually acquire immunity against the disease. A dog treated in this way will resist inoculation with material from a perfectly fresh cord from a rabid rabbit, which otherwise would inevitably have proved fatal. Relying upon these experiments, Pasteur began inoculations in the human subject, using, on successive days, material from cords in which the virus was of varying degrees of intensity. The method of preventive injections now employed for human subjects may be thus represented :—

Days of inoculation.	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th
Days' drying of the cords,	14, 13	12, 11	11, 10	10, 10	9, 9	9	8	8	8	7	7	7	6	6	5

"The material for injection is prepared by crushing portions of the dried spinal cord, and diffusing them in sterilised broth free from all risk of putrefaction, decomposition, or any change due to the presence of other micro-organisms; and the injection is made with syringes through fine tubular needles into the subcutaneous tissue. For transmission of rabies through rabbits, in order to obtain the spinal cords required for its prevention in other animals, injections of virus of highest intensity are made through minute holes in the skull into the space under the dura mater."

It is surmised that the protection obtained is due to a chemical substance, and not to any real attenuation of the microbe, which, so far, has not been isolated with any certainty; although both micrococci and bacilli have been found in the rabic cord. While the case mortality of hydrophobia is practically 100 per cent. if untreated by inoculation, after treatment at the Pasteur Institute in Paris it has fallen to 0·5 per cent. In 1894 there were seven deaths out of 1387 cases. Deaths occurring during treatment, or within fifteen days of last inoculation, are not included.

While, in the opinion of unprejudiced critics, it is generally admitted that Pasteur has discovered an efficient and strictly prophylactic treatment of hydrophobia, the serious question remains whether the intended protective inoculation may not, if unwittingly employed on persons who have not really been infected before, produce a fatal form of the very disease against which it is supposed to protect. The difficulties in the way of a sound decision on this point are serious, and have not yet been satisfactorily overcome.

Prevention.—Rabies can be stamped out by muzzling all known dogs for a sufficient length of time, and destroying all others. This was done in Sweden many years ago, and the country remains free from hydrophobia. The same is the case in Berlin. In England, several local attempts have been made in the same direction, notably in 1885 in London, in 1886 in Nottingham, and in 1890 throughout Lancashire, Cheshire, the West Riding of Yorkshire, and London. These muzzling orders have always been followed by a cessation of rabies, but have been invariably relaxed too soon. The only effectual way to stamp out rabies is to enforce muzzling strictly throughout the island for at least a year. Under the *Rabies Order of* 1892, issued by the Board of Agriculture, County Councils have power to make regulations for muzzling and other preventive measures.

INFLUENZA.

The recent series of epidemic visitations of this disease in this country have made its chief characteristics familiar to most people. Although the original home of this affection is not known, our knowledge is sufficient to convince us that it is a disease which has periodically prevailed in various parts of the world as an epidemic since very early times. An analysis of the chief epidemics of influenza during the present century shows that its progress and prevalence are quite independent of race, climate, or season: that man is the chief vehicle of its diffusion: and that its epidemic prevalence attains its height amongst crowded communities. Although there is some indication of its preference for lines of traffic, the actual progress of an epidemic is very irregular.

The interval between epidemics is variable: in England the chief outbreaks were in 1803, 1833, 1837–8, 1847–8, and some minor epidemics about every three years till 1860, when these practically ceased. Nothing was heard of the disease after 1860 until 1889, when a new series of epidemics began, each covering almost the whole country at intervals of about a year. Influenza epidemics differ in type from time to time, and there is also considerable variety in different centres during the progress of an epidemic as to the tendency to one or other group of local symptoms or complications. All epidemics, however, present the same general characters, such as "rapidity of dissemination, general independence of climatic, seasonal, age and sex influences, relative suddenness of onset as regards attack, and low case mortality" (Parsons).

When the 1889 epidemic appeared in England some doubt was expressed by a few as to whether it was influenza at all, mainly owing to the improper and traditional application of the term "influenza" during non-epidemic times to ordinary catarrh. Others were disposed to complicate the situation by the suggestion that the prevailing epidemic was one of dengue. This latter is, however, "essentially a disease of hot climates and seasons, seldom fatal, is unattended with pulmonary complications, almost always presents a rash, and is frequently followed by desquamation."

Mortality.—It is estimated by the Registrar-General that in England and Wales, in the four years 1890–1–2–3, the aggregate loss from influenza was not fewer than 46,615 lives. Although in most parts of the country there has been a great decrease in influenza mortality during the last year as compared with the preceding four years, nevertheless, in some parts of England and Wales, and notably in the metropolis, the disease may be considered to be still fatally prevalent. "The deaths in England and Wales specially referred to influenza during 1893 numbered 9669, as against 4523, 16,686, and 15,737 respectively in the years 1890–1–2." The heaviest incidence of influenza in 1893 was in the metropolitan area, where the deaths attributed to that disease were equal to a rate of 351 per million, as compared with 325 for the rest of the country. Experience shows that a rise in the mortality from influenza has generally been attended by a rise in the mortality from lung and sometimes heart disease. During the years 1890–1–2–3, this has been specially conspicuous, so that the mortality attributable to influenza must therefore not be measured solely by the deaths registered as due to that cause, but the indirect effect of the malady as expressed in the increased death-rate from certain other causes must also be taken into account. Accordingly, the Registrar-General estimates that, during the period 1890–1–2–3, the total number of deaths due directly or indirectly to influenza was not merely 46,615, but 125,000, or 1051 per million living. The case mortality is variable, but generally low, averaging about 1 to 1·6 per 1000.

The *protection* conferred by an attack is slight and evanescent, second and third attacks being common.

Etiology.—The period of incubation appears to be short, from one to three days. The breath is in all probability infectious from the first, continuing to be so as long as the eighth or tenth day, and perhaps longer.

Various hypotheses have been proposed to explain the cause of influenza, but in the light of what we know about other diseases, coupled with the general behaviour of influenza, the most probable one is that it depends upon a micro-organism. Though various species of bacteria have been described by different observers as present in this disease, those first described by Pfeiffer in 1892 as being constantly present in the bronchial sputum and pulmonary exudation in all cases of influenza are now generally regarded as the real microbial cause. The bacilli are very minute, about half the length but the same thickness as the bacilli of mouse septicæmia: in stained specimens they show a characteristic bipolar granule with intermediate clear part, hence closely resemble a diplococcus. They aggregate in clumps, occur in the leucocytes of the sputum, and also form chains; they disappear with the cessation of the disease. At 37° C. they grow in a characteristic manner in broth and agar. The broth remains clear, while a growth at the bottom of the fluid appears as whitish-grey granules and fluffy masses. On agar the growth forms minute translucent droplets, which have no tendency to coalesce; the bacilli do not grow on gelatin kept at 20° to 22° C. The presence of these bacilli in influenza and in no other disease has been confirmed by other observers.

The curious tendency of influenza to recur at intervals in the same locality is suggestive that the contagion may be able to live and thrive for considerable periods outside the human body; but whether this is in the soil or in the bodies of domestic animals is unknown. That these latter creatures, particularly dogs and cats, suffer during influenza epidemics from symptoms extremely like it is generally accepted. Horses, also, are liable to a severe and often fatal disease, known as "pink-eye," which has been regarded as a form of influenza. Certainly on several occasions, both in England and elsewhere, epidemics of influenza have been preceded by outbreaks of "pink-eye"; but, as explained by Klein, there are grave reasons for doubting the transmissibility of influenza to lower animals.

Prevention.—Isolation should be carried out from the earliest appearance of symptoms. During periods of epidemic prevalence, people should not congregate together, and public meetings should be avoided as much as possible. A regular life, plenty of open-air exercise short of fatigue, a proper number of hours in bed, and regular meals of good, simple food are among the best prophylactics.

LEPROSY.

This is a chronic infectious malady characterised by either the presence of tubercular nodules in the skin and mucous membranes or by degenerative changes in the nerves. At first these forms may be separate, but ultimately both are combined. Leprosy is one of the oldest of known diseases, and at present prevails widely, particularly in hot countries. In India it is estimated that there are some 300,000 lepers. In Europe, where it extensively prevailed in the Middle Ages, it has become almost unknown except in Norway. In America it exists in the Gulf States and in Mexico. In the Sandwich Islands leprosy has developed to an enormous extent; while in the West Indies the disease has been long endemic.

Cause and Etiology.—A microscopic section made through a leprous tubercle shows the tubercle to be a granuloma, each and all of the cells of which are filled with minute bacilli. Hansen was the first to observe this fact, and regarded these bacilli as the virus of the disease. These observations have since been repeatedly confirmed by others. The lepra bacilli are on the average 4 to 8 μ long, and about 0·8 μ thick; in well-stained and well-washed specimens they resemble somewhat the tubercle bacilli, by showing segregation of the protoplasm (deeply stained granules) in a faintly stained sheath. Cultivations of these bacilli have not been satisfactorily carried out; while all inoculation experiments on animals have yielded only negative results.

Leprosy attacks all classes and persons of all ages. It is probably communicated by contagion. Arning claims to have successfully inoculated in 1885 a Hawaiian convict, named Keanu, with leprosy; but subsequent criticism of this case suggests a possible mistake as to the inoculation having been successful, owing to the fact that the man Keanu is one of a family of lepers, and that the disease as it appeared in Keanu was too rapid to have been the result of the inoculation by Arning. Leprosy is, apparently, only contagious in the same sense as syphilis, and just as accidental contamination with this virus is extremely rare so it is with leprosy. The closest possible contact may take place for years, as between parent and child, without transmission; but it is difficult to explain the rapid spread of the disease in the Sandwich Islands on any other view than contagion, and yet it is strange that there is no evidence of a primary lesion or external sore comparable to that of syphilis. There is an increasing belief that in the majority of cases the disease is propagated by sexual congress, but the evidence is by no means definite. The disappearance of the disease in the Middle Ages was probably the result of the strict isolation of lepers enforced at that time. In more recent times, it is just possible that the affection may have been transmitted by vaccination, though there is no authentic case of such having happened. Hereditary transmission cannot be excluded, and there is no good reason why the disease should not be communicated, as is syphilis, from parent to child. Hutchinson believes that the disease is always associated with some special kind of food, particularly fish. He does not deny the specific nature of leprosy, or the possibility of contagion, but infers that it may be the fish diet which renders the patient susceptible, or even be the vehicle or medium with which the poison may be taken. So far, the general facts regarding the incidence of this disease do not lend much support to Hutchinson's views, but rather indicate the importance of keeping lepers as much isolated as possible, and otherwise treating it as being essentially a communicable disease.

Prevention probably depends upon the removal of children of leper parents from the leprous surroundings, and their education in asylums under favourable hygienic conditions; the voluntary isolation of lepers in colonies or farms, and the abstention of lepers from the occupations of barbers and washermen or washerwomen, and from the sale of food. The Leprosy Commission have reported that compulsory segregation is quite unnecessary.

MALARIA.

The malarial diseases may be conveniently considered as a single group, although they include many varieties that have received names suggestive of specific distinctions between them. They all have a characteristic tendency to periodicity, and in their general etiological conditions appear to be closely related. How far the malarial poison is the same in all cases is still undecided, but it is not unlikely that more accurate methods of research may ultimately establish specific distinctions between the varieties of microscopic bodies which appear to stand in causal relation to the various forms of malarial fever.

Geographical Distribution.—"Covering a broad zone on both sides of the equator, malarial diseases reach their maximum of frequency in tropical and subtropical regions. They continue to be endemic for some distance into the temperate zone, with diminishing severity and frequency towards the higher latitudes; in epidemic form they not infrequently appear in yet other regions, and in still wider diffusion with the character of a pandemic also beyond their indigenous latitudes" (Hirsch). The present distribution of malaria indicates it to be widely prevalent in a virulent form in tropical Africa, especially on the west coast. It also prevails in Algiers, and in the Nile Valley of Egypt. In Asia, it is notoriously prevalent in India, China, Ceylon, Arabia, Afghanistan, Persia, and Syria. In the western hemisphere, it is met with in the West Indies, Peru, Brazil, Panama, and the southern and central parts of the United States. Of European countries, Italy suffers the most, and perhaps Great Britain the least, though even now the disease still lingers in the fen districts of Lincolnshire, and the counties of Norfolk, Huntingdon, and Cambridge.

Although malaria is most prevalent and most malignant in tropical and subtropical countries, yet among such countries it appears to have a special affinity for certain parts. Thus, in India, the Presidency of Madras suffers much less than those of Bengal and Bombay. So also, on the West African coast, malaria "becomes less severe from Cape Lopez southwards, and this exemption becomes more and more marked the nearer we approach the Cape of Good Hope, which itself enjoys, along with St Helena, an almost complete immunity from the endemic fever." New Zealand and Tasmania are said to be completely, and Australia almost completely, exempt.

A point of some interest in connection with malaria is, that it, at times, has exhibited decided epidemic tendencies, extending to localities in which it is not commonly met with. This circumstance suggests the question whether there is any actual transport of the malarial organism beyond its ordinary endemic areas; or whether, in certain districts, organisms which are usually benign may not acquire pathogenicity as the result of some exceptional conditions of weather; or whether again these exceptional meteorological conditions may not operate indirectly by increasing the susceptibility of individuals, and thus render them "vulnerable to attack by organisms, indigenous to the neighbourhood, but not usually pathogenic." As to the possibility of the two latter hypotheses, we have no precise evidence, but the fact that some districts, which up to a certain time have enjoyed immunity from malarial disease, such as Réunion and Mauritius, have subsequently become endemic centres of that malady, is extremely suggestive of the possible transportation of the causative agent. Malaria may, without doubt, be conveyed by air currents, but for what distances is uncertain: in any case, its conveyance by air is, to a large extent, arrested by belts of trees and sheets of water, especially salt water. On the other hand, when favoured by ravines and heated currents of air, malaria can pass to a height which appears to differ in different climates, varying from 500 to 3000 feet.

As regards sex and age influence, males appear to suffer more frequently than females, but possibly this is due to increased exposure to infection. No age can be said to be exempt, but attacks are certainly less frequent among the very young and the very old.

Influence of Season and Locality.—Although in countries where malaria is endemic the disease occurs in any season of the year, its general prevalence, nevertheless, appears everywhere to be largely regulated by season, though the particular time of year in which it is most common varies in different countries. Even in the tropics, where malaria constantly prevails, there are minimum and maximum periods; the former corresponding to the summer and winter, the latter to the spring and autumn months. In temperate climates, there are only a few cases in the spring, but a large number of cases in September, October, and sometimes in November. In the most malarious districts in the tropics, the maximum prevalence is during and towards the close of the rainy season. In the temperate climates the relation between the rainfall and malaria is not so clear, the cases being often more numerous after a dry summer; but if either heat or moisture is excessive, the development of the virus is checked for a time. A tolerably high temperature appears to be one of the essential conditions for the development of the virus.

The importance of the state of the soil in the etiology of malaria is universally recognised, and has already been discussed in a previous chapter. The disease is particularly common in low, marshy regions which have an abundant vegetable growth. Estuaries, badly drained low-lying districts, the course of old river beds, tracts of land which are rich in vegetable matter, and particularly districts such as the Roman Campagna, which have been allowed to fall out of cultivation, are favourite localities for the development of the malarial poison. These conditions are most frequently found, of course, in tropical and subtropical regions, but it must not be overlooked that some of the most malarious districts of India are steep mountain slopes, and that many others both in India and elsewhere are equally free from moisture of the soil. Instances are common in which districts, previously healthy, have become temporarily or permanently malarious, without apparent change in their physical conditions. The proof of the close relation between malaria and the soil is completed by the fact that malarious soil conveyed in boxes to healthy districts has given rise to outbreaks of the disease.

The Malarial Parasite.—Malaria being a specific disease, the presence of a specific organism is necessary, and the conditions of climate, season, and soil above described are to be regarded merely as more or less favourable to its growth and dissemination. In 1880, Laveran, a French army surgeon, announced the discovery of a parasite in the blood of patients attacked by malarial fever. His observations have been since confirmed and extended by Marchiafava, Celli, Golgi, and many others. In fact, not a single observer who has had the necessary training and the material at his command has failed to demonstrate the existence of these parasites.

The bodies which have been found invariably associated with all forms of malarial fevers belong to the protozoa; in some respects they resemble the monads and in others the sporozoa. In the blood of patients with malarial fevers the following forms may be seen: (1) an unpigmented hyaline body within the red blood-corpuscles, which displays active movements; (2) a pigmented amœboid body within the red blood-corpuscles, which, under certain circumstances, may increase in size and form; (3) a segmenting body, in which the protoplasm divides into a variable number of definite small spheres; (4) crescentic bodies, the so-called crescents, which develop within the blood-corpuscles and form characteristic and distinctive structures; (5) flagellate organisms, which may be seen to develop from the intracellular pigmented forms, or from ovoid bodies which are altered crescents; (6) free flagella. To the amœboid forms within the red blood-corpuscles

Marchiafava and Celli gave the name *Plasmodium malariæ*, but this is probably an incorrect nomenclature, as the malarial parasite really belongs to the class sporozoa amongst the protozoa. On Plate X. are represented various forms of this organism, as observed in the blood by Manson and others.

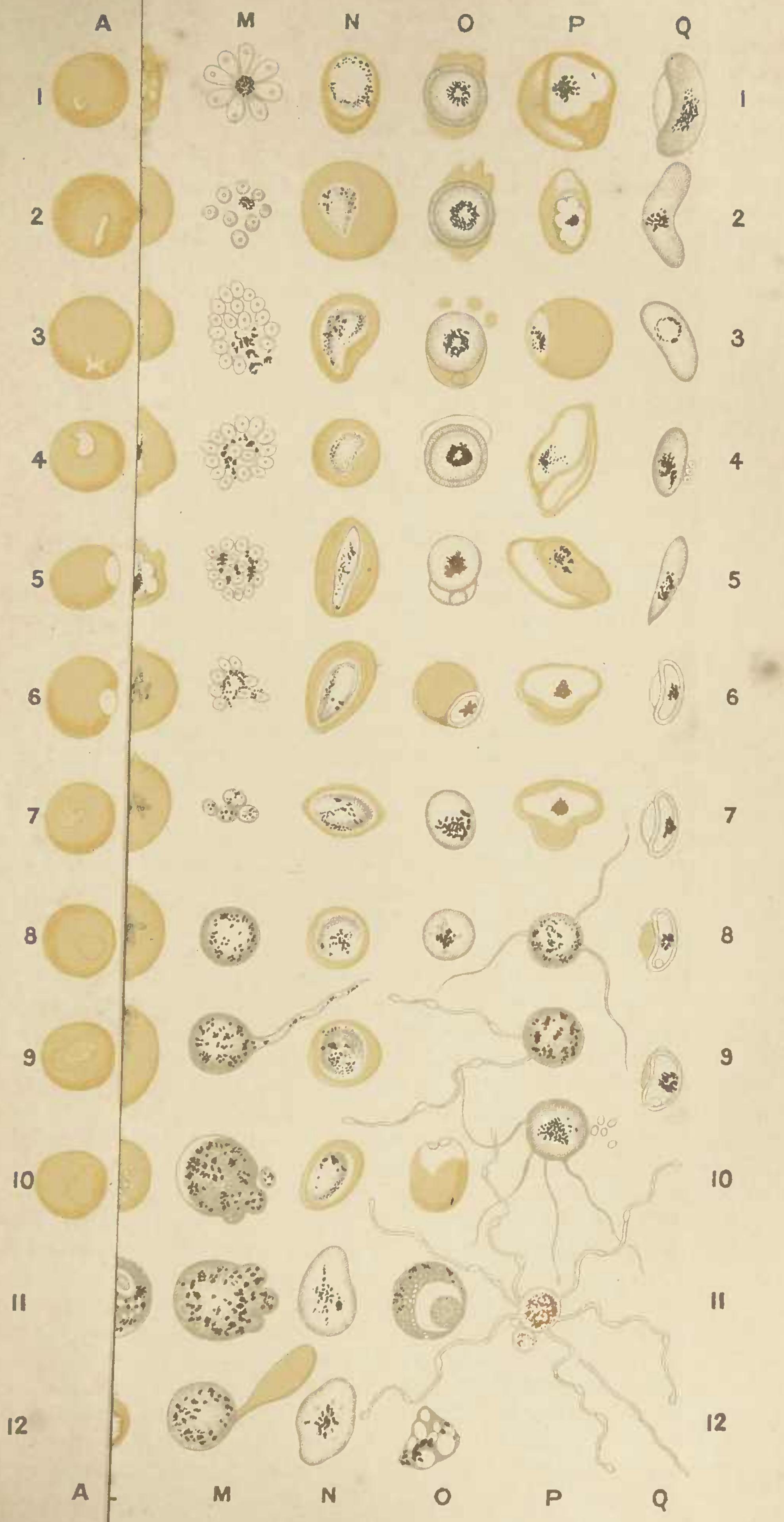
The relation of the parasites to the symptoms of the disease has been worked out, in part, by Golgi, who has shown that, corresponding to the paroxysm, there is a process of segmentation. But whether in these different forms we have really to deal with different species of the same group of parasites as Golgi and others incline to think, or rather with differences in the life history of the same species caused by unknown conditions, is not decided. Though the relation of the different forms or phases of growth of the parasite to the varieties of malarial fever has not yet been thoroughly established, the following points may be here referred to. The typical intermittents are associated with large forms of the parasites, of which several varieties have been described. Golgi has described two distinct forms which he considers the causes of tertian and quartan fevers, and makes all other types depend on combinations of these. This probably holds good for a large proportion of intermittents. With the remittents, Marchiafava and Celli have described a distinct species, and look upon the crescents as representing a phase in its development. The pernicious malarial fevers are also associated with this variety, which the Italian observers call the "small plasmodium." The crescents may occur also in acute cases, but are most constant in malarial cachexia. Both the crescents and the flagellate bodies may be regarded as atypical forms of the parasite.

All attempts to cultivate these organisms outside the human body have given negative results, and their complete life history is not known. The general belief is, that the parasites do not exist as saprophytes, but live as parasites in either animal or vegetable organisms; possibly the mosquito is the intermediate host.

Prevention.—The evidence with regard to the spread of malaria by water is conflicting, but the following case recorded by Boudin is highly suggestive of such being by no means uncommon. "In this case 120 soldiers embarked in the transport Argo' at Bona in Algeria for Marseilles. During the voyage 111 of them, thirteen of whom died, suffered from different forms of malarial fever. Two other vessels, carrying between them 680 soldiers, also from Bona, and arriving at Marseilles the same day as the Argo,' had no cases of illness at all, and the only ascertainable difference of circumstances between the troops in these ships and those in the 'Argo' was the difference of drinking water. The latter were exceptionally supplied with water, which was said to have an unpleasant smell and taste, from a marsh near Bona; those on the other ships were supplied with good water. Finally, the nine soldiers on the 'Argo' who escaped were said to have purchased wholesome water from the crew of that vessel."

If the ingestion is by water, a fresh source must be obtained. Well-water is generally safe, but not always. Rain-water may be unsafe, if the tanks are not clean. If a fresh source cannot be obtained, filtration and boiling, as well as infusion with tea or coffee, appear to be the best preventive measures.

If the introduction be by air, and if the locality cannot be left, the most approved plan is elevation to at least 500 feet above *the source of the poison* in temperate climates; and 1000 to 1500 feet in the tropics, or higher still, if possible. If this plan cannot be adopted, two points must be aimed at—viz., to obviate local, and to avoid drifting malaria. Thorough subsoil draining; filling up moist ground when practicable; paving or covering the ground with herbage kept closely cut, are the best plans for the first point.



Vincent Brooks, Day & Son lith.

Marchiafava and Celli gave the name *Plasmodium malariæ*, but this is probably an incorrect nomenclature, as the malarial parasite really belongs to the class sporozoa amongst the protozoa. On Plate X. are represented various forms of this organism, as observed in the blood by Manson and others.

The relation of the parasites to the symptoms of the disease has been worked out, in part, by Golgi, who has shown that, corresponding to the paroxysm, there is a process of segmentation. But whether in these different forms we have really to deal with different species of the same group of parasites as Golgi and others incline to think, or rather with differences in the life history of the same species caused by unknown conditions, is not decided. Though the relation of the different forms or phases of growth of the parasite to the varieties of malarial fever has not yet been thoroughly established, the following points may be here referred to. The typical intermittents are associated with large forms of the parasites, of which several varieties have been described. Golgi has described two distinct forms which he considers the causes of tertian and quartan fevers, and makes all other types depend on combinations of these. This probably holds good for a large proportion of intermittents. With the remittents, Marchiafava and Celli have described a distinct species, and look upon the crescents as representing a phase in its development. The pernicious malarial fevers are also associated with this variety, which the Italian observers call the "small plasmodium." The crescents may occur also in acute cases, but are most constant in malarial cachexia. Both the crescents and the flagellate bodies may be regarded as atypical forms of the parasite.

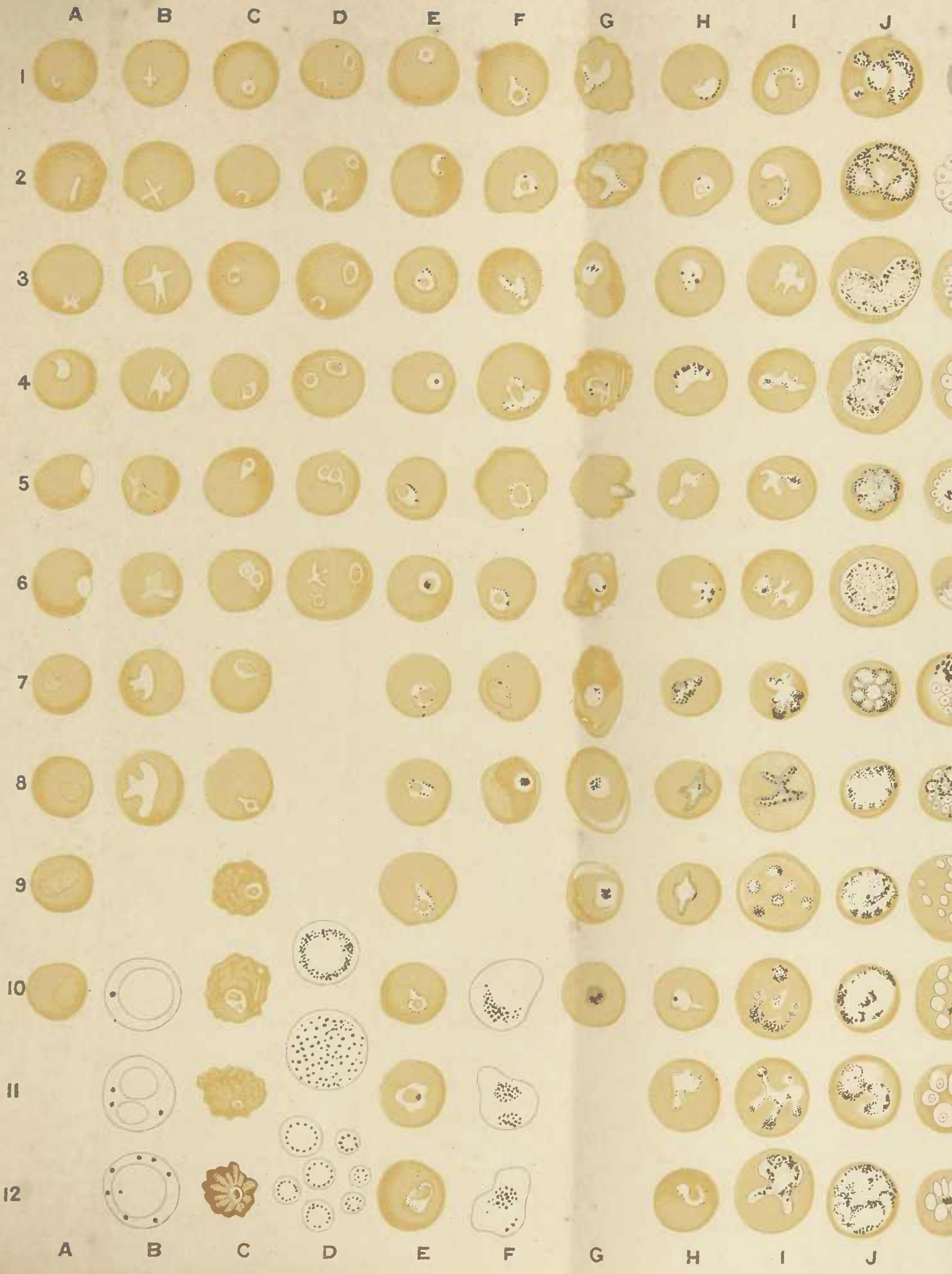
All attempts to cultivate these organisms outside the human body have given negative results, and their complete life history is not known. The general belief is, that the parasites do not exist as saprophytes, but live as parasites in either animal or vegetable organisms; possibly the mosquito is the intermediate host.

Prevention.—The evidence with regard to the spread of malaria by water is conflicting, but the following case recorded by Boudin is highly suggestive of such being by no means uncommon. "In this case 120 soldiers embarked in the transport 'Argo' at Bona in Algeria for Marseilles. During the voyage 111 of them, thirteen of whom died, suffered from different forms of malarial fever. Two other vessels, carrying between them 680 soldiers, also from Bona, and arriving at Marseilles the same day as the 'Argo,' had no cases of illness at all, and the only ascertainable difference of circumstances between the troops in these ships and those in the 'Argo' was the difference of drinking water. The latter were exceptionally supplied with water, which was said to have an unpleasant smell and taste, from a marsh near Bona; those on the other ships were supplied with good water. Finally, the nine soldiers on the Argo' who escaped were said to have purchased wholesome water from the crew of that vessel."

If the ingestion is by water, a fresh source must be obtained. Well-water is generally safe, but not always. Rain-water may be unsafe, if the tanks are not clean. If a fresh source cannot be obtained, filtration and boiling, as well as infusion with tea or coffee, appear to be the best preventive measures.

If the introduction be by air, and if the locality cannot be left, the most approved plan is elevation to at least 500 feet above *the source of the poison* in temperate climates; and 1000 to 1500 feet in the tropics, or higher still, if possible. If this plan cannot be adopted, two points must be aimed at—viz., to obviate local, and to avoid drifting malaria. Thorough subsoil draining; filling up moist ground when practicable; paving or covering the ground with herbage kept closely cut, are the best plans for the first point.

PLATE X.



MALARIA PARASITE.

For the second, belts of trees, even walls can be interposed; or houses can be so built as not to present openings towards the side of the malarious currents.

The houses themselves should be raised above the ground on arches; or, if wooden, on piles. Upper floors only should be occupied. The early morning air, for three hours after sunrise, should be avoided, and, next to this, night air.

MEASLES.

Although the original seat or native home of measles is unknown, there can be no doubt that it is a disease of very ancient origin, and in earlier times was often confounded with other maladies, more particularly small-pox and scarlatina. In the present day it is well established throughout Europe, Asia, America, and those parts of Africa of which we have any exact information: in all these parts it occurs in frequent epidemics. Attempts have been made to show that measles assumes an epidemic or even pandemic character with a certain amount of regularity, almost amounting to a definite periodicity. Without going so far as to accept this view entirely, it may be admitted that in large communities the disease does tend to occur epidemically at intervals of from two to four years, disappearing between these epidemic outbursts more completely than do some of the other exanthemata. In small communities, especially in rural districts, these intervals are not only less regular but longer.

Influence of Climate and Season.—The practically universal distribution of measles throughout the world indicates that its occurrence is independent of climatic influences: at the same time the influence of season is everywhere observed. In temperate climates, of 530 epidemics of measles in Europe and North America which Hirsch records, 339 occurred in the colder, against 191 in the warmer months. And the same thing has been observed in the tropics. In this country the effect of season upon urban measles has been studied by Buchan and Mitchell, and by the Registrar-General. The latter, from an analysis of the weekly deaths from measles in London for the fifty years 1841–90, points out that the weekly curve of deaths shows a double maximum and minimum, the larger maximum falling in November, December, and January, with an extreme excess of 50 per cent. in the fourth week of December, and the smaller in May and June, with an extreme excess of 25 per cent. in the first week of June. The larger minimum falls in August, September, and October, extreme deficit being 45 per cent. below the average in the last week of September; and the smaller minimum in February and March, the extreme deficit being 30 per cent. below the average in the third week of February. Buchan and Mitchell's analysis of the London death-rates for the thirty years, 1845 to 1874, gives very similar results. These facts accord with the conclusions arrived at by both Ballard and Moore that a mean atmospheric temperature above 60° F. was not favourable to the spread of this disease, and that a mean temperature below 42° F. was equally inimical to its prevalence.

Influence of Race, Sex, and Age.—Neither as to liability to attack nor to mortality does racial difference appear to have any effect. Similarly sex and age appear to be without direct influence upon liability to attack, but have some influence upon mortality. On the whole, the mortality is greater among males than females, especially among children under two years of age. About 98 per cent. of all deaths occur among children under ten years of age, 90 per cent. among those under five, 75 per cent. among those under three, and 60 per cent. among those under two (Squire),—the maximum mortality as well as the maximum rate of mortality being in the second year of life.

Mortality.—Of late years the mortality from this disease has undoubtedly shown a tendency to decrease. The following figures show the facts as given by the Registrar-General in his various reports for the last ten years :—

Year.	England and Wales.		Average Annual Death-rate per million living for each Five-Year Period.
	Total Deaths.	Death-rate per million living.	
1884	11,324	419	467
1885	14,495	533	
1886	12,013	436	
1887	16,765	602	
1888	9,784	347	
1889	14,732	518	445
1890	12,386	439	
1891	12,673	436	
1892	13,553	460	
1893	11,110	374	

The case mortality of measles is capable of varying within very wide limits, ranging from as little as 2 per cent. in some outbreaks to 40 or 50 per cent. in others. In this connection possibly there are two causes at work, namely, extra intensity of infection and unfavourable surroundings, such as overcrowding, poverty, and fatigue. In an epidemic in Fiji in 1874 all these conditions were operative, together with a probable maximum susceptibility, with the result that the mortality was enormous. The marked influence of insanitary and other unfavourable surroundings upon measles mortality is well shown in military experiences. "In Paris, during the siege (January 1871), out of 215 of the Garde Mobile who took measles, 86, or 40 per cent., died; and the mortality reached very nearly the same figure among the French troops who returned to Paris after the Italian War, 40 out of 125 cases dying in one hospital whose sanitary condition was bad." Even in this country the case mortality is higher always among the very poor, and in overcrowded districts.

Etiology and Infectiveness.—Arguing from analogy we may assume that the virus of measles is a specific micro-organism, and such has been recently demonstrated in the blood by Czajkowski. The infection is held to be given off by the breath and mucus, possibly also by desquamating cuticle, though this is less certain. The poison undoubtedly is capable of being air-borne and tends to cling to fomites and to hang about ill-ventilated rooms. There is no evidence of its being conveyed by either water, milk, or food. Infection is probably always acquired by inhalation.

The *incubation* period varies from eight to twenty days, the usual limit being about eleven days. The infective period, or that during which the patient is capable of infecting others, begins with the earliest symptoms. It is probably greatest during the pre-eruptive stage, and while the catarrh and rash are present; there is reason, however, to think that it extends throughout the illness, and even to some extent during convalescence. As a general rule, it may be laid down that infectivity is usually over by the end of the fourth week, provided all cough and desquamation have ceased. One attack of measles usually confers a lasting *protection* against future attacks; but second attacks sometimes do occur.

Prevention.—This involves isolation of the sick, and arrest of contagious matter by inunction with carbolised vaseline or glycerin; antiseptic inhalations, and use of rags for wiping the eyes and nose, these afterwards to be burnt. Clothing, bedding, and rooms should be disinfected.

MUMPS.

This affection has, at times, all the characters of an epidemic disease, but it is probably endemic in certain localities, especially in large centres of population. At certain seasons, particularly in the spring and autumn months, the number of cases increase rapidly. It is most common in children from ten to fifteen years of age, but the greatest registered mortality is among the very young. Males are, perhaps, more frequently attacked than females, though in institutions and schools the disease has been known to affect over 90 per cent. of all the children. Speaking generally, the mortality from mumps is insignificant, some eighty deaths only being registered annually as due to this disease among the entire population of England and Wales.

The infection of mumps is supposed to be given off by the breath, but as yet no specific organism has been isolated in respect of this infectivity. The period of *incubation* seems most usually to be from a fortnight to three weeks, and is probably seldom much less than twelve days. The period of infectivity seems to extend over at least three weeks. One attack of mumps usually confers immunity, but second attacks are not unknown. At times this disease occurs in close association with measles and diphtheria, and less often with scarlet fever; but whether this apparent relationship is anything more than an accidental one is doubtful. There is no evidence to suggest any connection between mumps and any particular conditions of soil.

Prevention depends upon ordinary measures of isolation and hygiene.

PLAGUE.

The recrudescence in 1894 of the bubonic plague of history in Canton, Hong-Kong, and other parts of China demands a brief reference to this disease. The first historical notice of the plague refers to an epidemic in Libya about 98 A.D.; but throughout the Middle Ages occur constant references to its epidemic prevalence not only in Persia, India, China, Syria, and Asia Minor, but also in Egypt, Arabia, North Africa, Italy, France, England, Germany, and Europe generally. Since 1841 the disease has been unknown in Europe. The whole history of the disease indicates its tendency to recur in places where it has been once prevalent, and to be carried by trade routes from these centres. A consideration of the events in connection with its previous manifestations enables one to trace its carriage in every case to the affected districts from one or two places where it is, or has been endemic; these endemic foci being mainly the Euphrates Valley and Southern China. It appears to be confined to the northern hemisphere, and only to flourish between 20° and 40° north of the equator, and never to have existed in the New World at all. The disease is a specific disease, caused by a specific portable organism, which has a variable length of life, according to the conditions in which it finds itself, and a varying virulence, also influenced by these conditions.

The disease is intensely contagious, selecting usually the poorest classes as its victims, or those living under circumstances of overcrowding and in the absence of adequate ventilation, or a proper food supply. It is inoculable on certain mammals, producing in them a disease similar to that seen in human beings, and possibly may be communicable by animals to man: it becomes epidemic at times, and is readily communicated by person to person, under insanitary and squalid surroundings, stimulated apparently by unfavourable meteorological conditions, such as prolonged drought, &c.

Kitasato and Yersin have demonstrated an organism in 25 out of 30 cases of the disease in the blood, spleen, and buboes of those affected. This organism is an ovoid capsulated bacillus, the poles of which are more readily stained than the middle. It is slightly motile, and grows best in blood-serum at 28° C. to 30° C. No spore formation has been observed. Mice, rats, and guinea-pigs inoculated with, or fed upon pure cultures of this bacillus present symptoms and pathological appearances identical with those of the human sufferer, the same bacilli being recoverable from the blood and viscera of the animals experimented upon. These bacilli have been detected in the dust and in earth from the floors of plague-stricken houses. Antecedent to epidemic outbreaks of plague, rats and mice appear to be affected with an epizootic disease, but the exact connection (if any) of which with plague is not known.

The plague bacillus is remarkable for its polymorphism, and when cultivated in the usual solid media it is seen to be accompanied by round figures like cocci, and elongated bacilli. In liquid culture media it forms little chains of several members placed end to end. Often at the extremity or in the middle of the chaplet is seen a large very deeply stained sphere. On gelatin the microbic colonies are white, at first transparent, but presenting later a more opaque and yellowish centre. In broth or peptones it forms tiny pulverulent clots, which settle to the bottom of the tube and along its sides. The broth remains clear.

Prevention depends upon isolation of the sick, thorough disinfection of the clothing, and avoidance of overcrowding.

PNEUMONIA.

Under this heading we refer to an infectious and not infrequently epidemic form of pneumonia, indifferently spoken of as "epidemic pneumonia," "croupous or fibrinous pneumonia," "pneumonic fever," and "acute lobar pneumonia," occurring as a so-called idiopathic affection. Epidemics of this malady have been described in considerable numbers in England and various other parts of Europe during the last two centuries; the most recent epidemics of importance being those recorded for India (Punjab) in 1875 and 1882, and for this country those occurring at Middlesbrough in 1888, and at Scotter in Lincolnshire in 1890. To these might be added many instances on record of outbreaks of pneumonia which, while remaining limited to a single household or small circle, presented facts strongly suggestive of specific infection.

Influence of Climate and Season.—Assuming that pneumonia, even in its narrowest acceptation of fibrinous or so-called croupous pneumonia, is an anatomical term that includes several inflammatory processes differing from one another in their etiology, the curious prevalence of the malady in both cold and hot countries indicates that climate alone has not much influence upon its prevalence. This, however, is not the case in respect of season. Statistics everywhere show that more persons are attacked in the winter and spring than in the summer and autumn. Seitz's large statistics of 5905 cases in Munich give 32 per cent. in winter, 36·8 per cent. in spring, 15·3 per cent. in summer, and 15·7 per cent. in autumn. So also Hirsch, in an analysis of a large number of cases in various places, states that 29 per cent. were attacked in winter, 34·7 per cent. in spring, 18 per cent. in summer, and 18·3 per cent. in autumn. The seasonal curve of epidemic prevalence coincides very closely with that of sporadic pneumonia mortality, which has its maximum in December, and is high from November to April. From these facts, it is evident that the prevalence of pneumonia—epidemic or otherwise—is associated with the colder months, and a closer analysis shows that in every climate the greatest prevalence of pneumonia occurs at the season of the most rapid and sudden changes of temperature, be it winter or spring, and in some measure varies with the intensity of changes of temperature. Nothing conclusive has been established as regards the influence of rainfall or soil conditions upon pneumonia, though it has been asserted that absence of rain and a low level of the ground water are favourable conditions.

Influence of Race, Sex, and Age.—No race can be said to be exempt, but many coloured races are especially susceptible to it. Longstaff, who has critically analysed the deaths from pneumonia, extending over some years, states that, as regards sex, the mortality is greater for males than females at all ages in the proportion of three to two. "The disparity is most marked at ages 35 to 65, when males suffer more than females, in the proportion of two to one." According to Wilson Fox and Huss's statistics, the fatality among the two sexes, given an equal number of attacks for each, is males ten, females fourteen, or in other words, that although the liability to attack is much greater in males, the liability to death if attacked is greater in females.

With respect to age, "the recorded mortality is highest at the extremes of life, being about three times as great in the first year of life as in old age." The minimum mortality is in the thirteenth year, after which it steadily rises throughout the remainder of life. The case mortality is actually greatest in advanced life. Of the general fatality of pneumonia at all ages together it is difficult to quote exact figures, as this varies in different times and places. A general average puts it at about 10 per cent., but it has been as low as 5 per cent. A widespread and fatal epidemic of pneumonia occurred at Middlesbrough in 1888, and was investigated by Ballard. Out of 1633 cases in a population of 97,000, 369 ended fatally, the case mortality being 21 per cent. The poorer classes suffered more than the wealthy, and cases were exceptionally severe and numerous in the workhouse, where grave sanitary defects existed. The workhouse children suffered six times, but adults only one and a half times as much as the corresponding classes outside. Exposure and fatigue seem to have acted as predisposing causes, and many apparent instances were recorded of direct infection from contact with a sick person.

Etiology.—Of all factors, cold or chill has been thought to be one of the most important, and for years was regarded as the efficient cause of this disease. Undoubtedly pneumonia does follow promptly, sometimes, a sudden chilling or wetting, but in a large majority of cases no such history can be obtained. Exposure to extreme cold or sudden changes of temperature may increase the activity of infection or the susceptibility of the individual, but nothing more. All depressing conditions, such as anxiety, fatigue, poverty and debility, predispose to pneumonia. Insanitary conditions, especially filth, overcrowding, and want of ventilation, act apparently as powerful, though not indispensable, predisposing causes. Effluvia from drains, sewers, and graveyards have also been held responsible for outbreaks. It is not unusual to find repeated outbreaks occurring in the same buildings, especially casemate barracks and prisons.

The *pneumococcus* of Fränkel is the most constant organism in lobar pneumonia, and is now generally regarded as being the specific agent of the disease. It is identical with the micrococcus which Pasteur and Sternberg found in the saliva of certain individuals, and which produces septicæmia in the rabbit. It occurs occasionally in the nose, the larynx, and the Eustachian tube. According to Netter's observations, it is present in the buccal secretion in 20 per cent. of healthy persons. It persists for months or even years in the saliva of persons who have had pneumonia. The researches of Fränkel, Weichselbaum, Gamaleia, and others show that it is by far the most constant organism in pneumonia, and that it occurs in the secondary processes of the disease, such as pleurisy, endocarditis, pericarditis, and meningitis. In the sputum it may be demonstrated by treating the ordinary cover-glass preparations with glacial acetic acid, and then, without washing off the acid, dropping on aniline oil and gentian-violet, which is to be poured off and renewed two or three times. The organism is seen to be a somewhat elliptical lance-shaped coccus occurring in pairs, hence the term diplococcus by which it is sometimes known. It is usually encapsulated.

According to the modern view, pneumonia is an infective disease caused by this diplococcus, which has its seat of election in, and produces its chief effects on, the lung, and which can, under favouring circumstances, invade other parts of the body. It is a widespread organism, at times present, as before stated, in the buccal secretions of healthy persons. It is not improbable that the various predisposing causes, such as cold, exhaustion, and debility, lower the vitality and render the individual susceptible, thus changing the character of the tissue-soil so that the virus can grow and produce its specific effects.

Several varieties of the pneumococcus have been described, differing from one another in the symptoms they produce in animals. These varieties differ from one another only in virulence, and by suitable means can be converted into one type. It is important, however, to bear in mind that the pneumococcus in the human subject varies enormously in virulence; this fact partially explains the degrees of severity of the symptoms in different cases.

Our knowledge of the toxins of the pneumococcus is still very defective. In artificial cultivations only feeble toxins are produced, and it is thus difficult to study their action carefully. There is, however, sufficient evidence to show that the toxins produce similar constitutional symptoms to those caused by infection with the pneumococcus.

The fact that the pneumococcus is found in many diverse conditions has been urged by some as an argument against the view that it is the cause of pneumonia. We are unable to accept this argument, as it is a general law in pathology that the same micro-organism may produce a different train of symptoms according to the part attacked. The tubercle bacillus causes a different type of disease when it attacks the joints, lungs, brain, or peritoneum. We are just as much justified in speaking of a pneumococcal otitis or a pneumococcal pleurisy as we are of speaking of a tuberculous otitis or a tuberculous pleurisy.

As Washbourn has pointed out, although the pneumococcus is the cause of croupous pneumonia, yet for the disease to develop there must be other factors than the mere presence of the micro-organism. "There must be some predisposing cause, for the pneumococcus is widely distributed, and is often present in the mouths of healthy persons without producing any ill effect. Under ordinary circumstances, the protective mechanism of the body prevents invasion; but should the cocci be introduced in very large numbers, or should the natural resistance of the body be lowered, invasion occurs and the disease develops. In many cases both these factors operate. The introduction of a large number of germs perhaps determines the seasonal prevalence of the disease."

"As to predisposing causes, influenza is the one best known. The other predisposing causes of pneumonia, such as cold and fatigue, are not capable of direct proof. Experimental evidence tells us that exposure to cold and fatigue renders animals susceptible to bacterial infections which in the normal condition they were able to resist. It is interesting to note in this connection that the growth of the pneumococcus outside the body is greatly influenced by very slight changes in the composition of the medium. By analogy we might suppose that slight changes in the composition of the body fluids would be favourable or unfavourable to the growth of the coccus; but this analogy must not be strained, for it would be incorrect to compare too closely the conditions within the body with those occurring in test-tube experiments."

In the Middlesbrough epidemic, above alluded to, and investigated by Ballard and Klein, the latter, while failing to find Fränkel's diplococcus in the morbid tissues, discovered large numbers of short bacilli, which he named *Bacillus pneumoniæ*. Inoculation of human lung-juice or of cultivations of this bacillus into mice caused an acute disease, the chief and constant lesion of which was pneumonia; further inoculations from such mice imparted the same disease to other mice. Samples of bacon were purchased in the infected districts, and it was found that of mice fed upon this bacon a large proportion became ill, with the same symptoms as those detailed. The *Bacillus pneumoniæ* was recoverable by cultivation from their tissues, and by inoculation the disease could be transferred to other mice. Whether the bacon had or had not become infected by human cases of pneumonia is not clear, but it may be suspected that the disease was capable of being spread by means of infected food. It may be added here that in two out of five cases of croupous pneumonia following after influenza Klein has found the same bacillus in large numbers, almost in pure culture, its cultural characters and its pathogenic action on mice being the same as in the Middlesbrough cases. It is probable that these Middlesbrough cases were exceptional forms of pneumonia, and possibly not unconnected with influenza, though how exactly so connected it is, at present, impossible to say.

The *incubation* period of pneumonia appears to be short, frequently being about from five to seven days. Both the breath and sputa may be assumed to be infective.

Prevention.—On the supposition that pneumonia is, or may be, infective, the sputa should be received into vessels containing some disinfectant. Soiled handkerchiefs should be well boiled before washing. Care should be taken to avoid chills and exposure to extremes of heat and cold. All dwelling-rooms should be scrupulously well ventilated, and care taken to see that sewer air does not gain access to the habitation.

PUERPERAL FEVER.

The deaths in England and Wales from this disease, as recorded by the Registrar-General, during the last ten years are given below. From the following table it will be seen that the mortality from puerperal fever, as registered, is showing a tendency to increase, the rate being calculated on the proportion of deaths from the disease to the annual number of births. Unless explicable by improved accuracy in certification, this increase in the puerperal fever mortality is remarkable, because the application of modern knowledge as indicated by the use of antiseptics and generally improved hygienic conditions in the management of lying-in hospitals has led to a very marked decline in the puerperal fever mortality in such institutions. The increased and sustained mortality from this disease suggest that the conditions under which women are confined outside hospitals, especially in the homes of the poor, have not in an equal degree shared in the improved sanitary conditions of hospitals and maternity institutions. This improvement can only be brought about by a full appreciation of the fact that puerperal fever is essentially a septic process, the virus gaining access to the body through the mucous surfaces of the uterogenital tract, to which it may be readily conveyed from case to case by the hands, instruments, sponges, clothing, bedding, and other articles.

Year.	Puerperal Fever Deaths.	Births.	Puerperal Fever Deaths to a Thousand Births.
1884	2,468	906,750	2·7
1885	2,420	894,270	2·7
1886	2,078	903,866	2·3
1887	2,450	886,331	2·8
1888	2,386	879,868	2·7
1889	1,852	885,944	2·1
1890	1,956	869,737	2·2
1891	1,973	914,157	2·2
1892	2,356	897,957	2·6
1893	3,023	914,542	3·3

There is evidence to show that the infection may come from various septic and decomposition sources other than those of the lying-in room; the chief sources of such infection being the handling of *post-mortem* materials, and the close attendance upon persons suffering from septic maladies. Allusion has already been made to the fact that erysipelas may have some causal connection with puerperal fever, while less definite evidence is forthcoming that possibly scarlet fever and other infectious diseases may operate in a similar manner. Besides these, various other causes play an indirect but none the less important part in the origin or at least the maintenance of puerperal fever. These are overcrowding, insufficient ventilation, drainage defects, accumulations of filth, and want of cleanliness generally. Nowhere have the influences of these conditions been more manifest than in the experiences of lying-in institutions and hospitals whose wards have been allowed to get overcrowded, imperfectly ventilated, and generally dirty. On the other hand, any marked improvement in these respects has always been followed by a marked diminution in puerperal mortality.

Puerperal fever shows similar annual curves to those of rheumatic fever and erysipelas, not only in this country but also on the Continent. This does not necessarily or probably mean identity of virus, but it is suggestive that the view that want of antiseptic care alone accounted for puerperal fever is not tenable unless it be imagined that in England and in Germany there was in years of excessive mortality from puerperal fever a conspiracy of carelessness. The years of excessive puerperal fever prevalence are generally years of small rainfall, and marked by low levels of the ground water; and the explanation of its epidemic prevalence probably lies in the favouring influence of a dry and warm subsoil on its specific contagium. From this point of view, puerperal fever is essentially a soil disease, having close relationships with erysipelas and other septicæmic diseases. Whether its contagium is alternately parasitic and saprophytic, or each case implies a fresh infection from the soil, is doubtful; but in any case, as based upon analogy with some other diseases, the belief is gaining ground that puerperal fever has wider etiological relations than has been hitherto generally recognised.

RELAPSING FEVER.

Under the names of "famine fever" or "bilious typhoid" this disease was first clearly recognised in 1739 in Ireland, where it still may be said to have its principal focus, at least so far as the United Kingdom is concerned. Epidemics of this affection have not been infrequent in Scotland, and have also occurred in England, Northern Europe, the Levant, India, and elsewhere.

Relapsing fever appears to be entirely independent of soil and largely so of season or climate. It occurs remarkably often in connection with typhus fever, and is apparently closely related to it in etiology, as the two diseases frequently coincide, or one follows the other closely, or isolated cases of the one are observed during the prevalence of the other. This frequent association of the two diseases is mainly to be explained by the fact that their predisposing causes are similar, the diseases themselves being specifically distinct. That the two diseases are distinct is believed mainly upon the following considerations: (1) that they present marked clinical differences; (2) that one disease does not protect against the other; (3) that the one disease does not give rise to the other; (4) that the peculiar spirillum, characteristic of the blood of relapsing fever, is not observed in the blood of typhus patients. It is, however, only just to state that there have not been wanting critics who have questioned the general accuracy of the second and third considerations. Even if both these considerations are found to be untrue, it may still be that the two diseases are mere evolutionary forms of a common stock, but "breeding true and consequently each producing only its own kind."

The mortality from relapsing fever in England and Wales during recent years has been insignificant: in 1891 there were eleven deaths from this cause, in 1892 there were seven, and in 1893 there were nine. The case mortality is low, varying from 2 to 4 per cent. More males appear to be attacked than females, but more females die than males when so attacked. The fatality of relapsing fever is very low during the early years of life, but increases as age advances. Murchison gives the following figures from the London Fever Hospital:—

Under 30 years, 1366 cases with 7 deaths, or 0·51 per cent.
Above 30 ,, 745 ,, 32 ,, 4·29 ,,
,, 50 ,, 191 ,, 18 ,, 9·42 ,,
,, 60 ,, 72 ,, 9 ,, 12·50 ,,

Etiology.—While the predisposing causes of relapsing fever appear to be identical with those of typhus, namely, overcrowding, filth, and starvation, the actual phenomena of the disease are regarded as being essentially dependent upon the presence in the blood of a particular spirillum, discovered by Obermeyer during the febrile stage, and which disappears from the blood immediately before the end of the febrile stage. The spirilla are very thin and about 20 μ to 40 μ long, their movement being that of rapidly progressing spirals. Immediately preceding the febrile stage of the disease they appear in the blood, grow more and more numerous during the fever, and disappear again completely from the circulation before the fever quite ceases. During the non-febrile stage they probably take refuge in the spleen and bone marrow, where, perhaps, they undergo germination and reproduction. These spirilla have not as yet been satisfactorily cultivated, but that they are the real microbial causative agents of relapsing fever is proved by the experiments of Vandyke Carter and others, who have produced typical relapsing fever in apes after injection of blood taken from a patient during the febrile stage and containing the spirilla.

Exact data as to the *incubation* period of relapsing fever are wanting, but from what facts are known, it would seem to be from fourteen to twenty-one days. When once established, the disease is highly infectious, the virus being apparently conveyed through the air, or by fomites, from the sick to the healthy. With free ventilation the disease almost ceases to be communicable. Relapsing fever appears to afford little or no protection against subsequent attack, as second attacks are by no means uncommon.

Prevention.—Recognising the fact that this disease is one of the most contagious of the infective diseases, preventive measures consist in prompt isolation of the sick, the freest ventilation, and the most thorough disinfection of clothing. Other prophylactic measures of the first importance are those which combat poverty and destitution.

RÖTHELN.

In this and other countries there occasionally occur both sporadic and epidemic cases of an ailment having some of the appearances of measles and some of those of scarlet fever, but still not conforming strictly to the clinical and epidemiological characters of either. This malady, seemingly different from measles and from scarlet fever, but having some of the characters of both, is commonly spoken of as "rubeola," "rötheln," or German measles. Many have regarded it as a hybrid of scarlet fever and measles, but the more generally accepted view is that it is an entirely distinct and specific disease.

The disease is undoubtedly infectious, but never very markedly so. The infection is given off probably by the breath and acquired by inhalation. The period of *incubation* is somewhere about fourteen days, while its period of infectiveness lasts from two to three weeks. The case mortality is low, and there are no very special features in respect of either the influence of age, sex, or race upon its incidence. This malady is of special interest to the public health officer, as the term "German measles" is very loosely employed, and too often is allowed to serve as a cloak to uncertainty in diagnosis. As Goodhart has pointed out, "a doubtful rash makes its appearance, and the medical man, instead of saying he is not certain of its nature, calls it German measles. 'Then it is not scarlatina?' say the parents. 'No,' says the doctor; and the parents, thinking nothing of measles, take no precautions." When we bear in mind that true rötheln is really a very rare disease, it needs little imagination to realise how many cases of either measles or scarlet fever are probably overlooked annually, and permitted to disseminate their specific infection involuntarily but none the less surely throughout the community.

SCARLET FEVER.

We owe the recognition of scarlet fever as a distinct disease to Sydenham, before whose time it was confounded with measles, and occasionally with diphtheria. It is most widely diffused in Northern and Western Europe and in North America, but has failed to establish itself firmly in Africa or any part of Asia, except Syria and some parts of Asia Minor. The disease occurs sporadically from time to time, and then under unknown conditions becomes widespread. Ransome, from a study of the Swedish scarlet fever mortality records, says that "not only a short cycle of four to six years may be traced, but also a long undulation of fifteen or twenty years or more; which may be likened to a vast wave of disease upon which the lesser epidemics show like ripples upon the surface of an ocean swell." Whitelegge, at Nottingham, found that scarlet fever shows a weekly cycle, the notified cases falling to a minimum on Wednesday. This he regards as probably due to the lessened chances of infection through school attendance upon the Sunday. In England scarlet fever is more prevalent in urban than in rural areas, mining and several of the large manufacturing towns being especially affected. In explanation of this it has been suggested that "probably the population in industrial and mining counties live in more than averagely close aggregation, and that the spread of infection is thus facilitated. If, however, this were the true and complete explanation, we should expect the geographical distribution of other infectious diseases to tally with that of scarlet fever." But this, the Registrar-General remarks, "is not true as regards diphtheria; nor does it seem altogether true as regards measles." Both Longstaff and Barnes have shown the marked difference between the distribution of diphtheria and scarlet fever; in fact, broadly speaking, it may be said that where the latter disease is most prevalent there a particularly low diphtheria rate prevails.

Influence of Climate and Season.—While climatic influences do not appear to play a very prominent part in determining the geographical distribution of this disease, there is evidence that season does influence its prevalence. In England the mortality is at its minimum in March and April, and rises to a maximum in October. In New York, however, the curve is almost reversed, the minimum being in September and the maximum in April (Whitelegge). From their analysis of the deaths from scarlet fever registered in London in the thirty years 1845 to 1874, Buchan and Mitchell conclude that this disease has its maximum from the beginning of September to the end of the year, and its minimum from February to July. The period of the highest death-rate is from the beginning of October to the end of November, being nearly 60 per cent. above the average, and the lowest in March, April, and May, when it is about 33 per cent. below its average. In each of the thirty years the deaths increased at the time of mean maximum, and in all except four of the years the increase was considerable. During ten of the years a high death-rate was continued on into the year immediately following, but in every year the deaths became fewer, and diminished steadily, if not rapidly. Whitelegge, by a table based on the notification returns of twelve large English and Scottish towns, has shown that—as was to be expected—the seasonal curve of notified attacks differs little in outline from the mortality curve; but the seasonal range of variation is greater in the attack curve,—in other words, the mortality rises and falls proportionately less than the cases do, indicating that at the season of the year in which the disease is most prevalent it is least fatal, and *vice versa*.

As to the meteorological conditions that are most favourable to the spread of scarlet fever and its mortality, there is a wide divergence of opinion. Upon the whole, there appears to be an inverse relationship between the mortality from scarlet fever and the rainfall; or, as Ballard puts it, "a temperature above the average for the season, and a dry state of the atmosphere with little rain, favour the prevalence of scarlet fever more than the reverse conditions."

Influence of Age and Sex.—The influence of age and sex upon liability to attack and death by scarlet fever were fully discussed by the Registrar-General in his 49th Annual Report, 1886, and the important conclusions at which he arrived are thus stated:—"1. The mortality from this disease is at its maximum in the third year of life, and after this diminishes with age, at first slowly, afterwards rapidly. 2. This diminution is due to three contributory causes: (*a*) the increased proportion in the population at each successive age-period of persons protected by a previous attack; (*b*) the diminution of liability to infection in successive age-periods of those who are, as yet, unprotected; (*c*) the diminishing risk in successive age-periods of an attack, should it occur, proving fatal. 3. The liability of the unprotected to infection is small in the first year of life, increases to a maximum in the fifth year or soon after, and then becomes rapidly smaller and smaller with advance of years. 4. The chance that an attack will terminate fatally is highest in infancy, and diminishes rapidly with years to the end of the twenty-fifth year, after which an attack is again somewhat more dangerous. 5. The female sex throughout life, the first year possibly excepted, is more liable to scarlet fever than is the male sex. 6. But the attacks in males, though fewer, are more likely to terminate fatally."

These conclusions of the Registrar-General have been largely confirmed by an independent inquiry made by Whitelegge, upon the basis of 6288 cases of scarlet fever notified in the three large towns of Nottingham, Salford, and Leicester. From his investigation, Whitelegge draws the following practical conclusion: "That in shielding a child against infection during the first few years of life there is a double gain; every year of escape from scarlet fever renders him less and less susceptible, until finally he becomes almost insusceptible; and, secondly, even if he should ultimately take the disease, every year that the attack is deferred reduces the danger to life which it brings."

Mortality.—The following table, compiled from the annual reports of the Registrar-General for England and Wales, shows the mortality from scarlet fever during the last twenty years.

Year.	Total Deaths.	Death-rate per million living.	Average Annual Death-rate per million living for each Five-Year Period.	Year.	Total Deaths.	Death-rate per million living.	Average Annual Death-rate per million living for each Five-Year Period.
1874	24,922	1,050	786	1884	10,863	402	272
1875	20,469	851		1885	6,355	233	
1876	16,893	691		1886	5,986	218	
1877	14,456	585		1887	7,859	282	
1878	18,842	753		1888	6,378	226	
1879	17,613	694	582	1889	6,698	235	214
1880	17,404	675		1890	6,974	212	
1881	14,275	548		1891	4,959	171	
1882	13,732	521		1892	5,618	190	
1883	12,649	475		1893	6,982	235	

Even after making allowance for the facts that not only do different outbreaks vary very greatly as regards mortality, but that epidemic prevalences tend to occur in cycles, it is justifiable to regard these figures of so long-continued and marked an abatement in scarlatinal mortality as an indication that some at least of the means conducing to the spread of this very fatal disease are being materially restricted. Even now the death-rate from scarlet fever is still unduly high in some counties. The 1893 returns show a death-rate of 308 per million in Lancashire, 316 in Monmouthshire, 329 in London, 355 in Nottinghamshire, 356 in Herefordshire, 375 in Leicestershire, 467 in Middlesex, and 521 in Cornwall.

The case mortality or fatality of scarlet fever varies largely in different epidemics and even at times during the different stages of the same epidemic. As a general average it may be said to be about 8 per cent., but may reach at times as high a figure as 30 per cent. The reports of the Metropolitan Asylums Board show that the mortality amongst cases treated in their hospitals was 6·18 per cent. in 1894, against an average of 8·35 per cent. in the six years 1887 to 1892.

The case mortality above given (6·18 per cent.) is somewhat high when compared with that of other towns. In Brighton the case mortality in 1894 for home-treated cases was 2·56 per cent., for hospital-treated cases 1·3 per cent. In Leicester in the same year it was 3·9 per cent. for home-treated cases, and 2·17 per cent. for the hospital-treated cases. Without an allowance being made for variations of age-distributions of patients comparisons between one locality and another are apt to be fallacious. But the relatively high rates in the Metropolitan Asylums Board hospitals suggest the idea of an increased virulence of scarlatinal infection caused by an aggregation of patients on too large a scale. The following table summarises the result of the treatment of 81,350 cases in the Metropolitan Asylums Board hospitals in the years 1871–94.

	Males.	Females.	Combined Mortality per cent. for both Sexes.
Under 5	18·1	17·0	17·6
5–10	5·6	5·1	5·3
10–15	2·3	2·4	2·4
15–20	3·0	2·3	2·6
20–25	2·3	2·8	2·6
25–30	3·8	2·8	3·3
30–35	5·2	4·3	4·7
35–40	8·1	4·4	6·2
40 and over	8·2	4·5	6·3

Etiology and Infectiveness.—The contagion of scarlet fever is probably not developed until the eruption appears, and is particularly to be dreaded during desquamation. No doubt the poison is spread largely by the fine scaly particles which are diffused with the dust throughout the room. Even late in the disease, after all desquamation has apparently ceased, a patient has conveyed the contagion; in these cases, however, there is usually to be detected some discharge from or dried purulent matter attaching to the auditory meatus, which possibly is equally infective as any purely cuticular particles. The poison clings with great persistence to clothing of all kinds and to articles of furniture. In no disease is a greater tenacity displayed. Bedding and clothing which have been put away for months or even for years may, unless thoroughly disinfected, convey contagion. The infection of scarlet fever seems to be given off by the breath, the secretions from the nose, mouth, pharynx, ears, and perhaps kidneys, as well as by the desquamating cuticle. It may apparently cause the disease either by being inhaled or swallowed. There is no evidence of its being conveyed by water, and inasmuch as the disease does not appear to spread in the neighbourhood of fever hospitals, it is doubtful whether the infection can be conveyed any great distance by air currents.

Although Boobbyer has recorded a series of cases of scarlet fever, the incidence of which appeared to be determined by disturbance of soil, there is at present little evidence to show that the disease has any definite relation to the soil. On the other hand, numerous epidemic outbreaks of scarlet fever are now known to have occurred in which milk was the vehicle of the contagium. Until 1882 all such milk epidemics were believed to be brought about by infection of the milk by the virus from a human case of scarlet fever; in fact, in a tabulated account of fifteen milk scarlatinas prepared by Ernest Hart, and published in vol. iv. of the *Transactions of the International Medical Congress for* 1881, several epidemics are detailed in which this mode of milk infection from a human source was clearly demonstrated. Later investigations by Power and Klein seem to show, however, that not only may milk be a medium of disseminating scarlet fever after its infection by virus from a human case, but that human scarlet fever may be produced by milk which owes its infective property to an ailment of the cow. The well-known "Hendon outbreak" constitutes so important and classical an instance of this class of epidemic that it demands some brief reference in detail. In December 1885 a sudden and extensive outbreak of scarlet fever occurred in Marylebone, and was found by Wynter-Blyth, the Medical Officer of Health, to be associated with a particular milk-supply obtained from a farm at Hendon. The milk was also distributed in St John's Wood, St Pancras, Hampstead, and Hendon; in each of these districts, except the first, scarlet fever became prevalent suddenly early in December. On the 15th the milk sent to Marylebone was returned to the farmer, and some of this was given away to poor people at Hendon on the following days; from the 20th onwards a number of cases of scarlet fever occurred among those who had drunk the milk. There was, therefore, strong presumptive evidence that the disease was conveyed by the milk. The whole outbreak was investigated by Power and Klein, on behalf of the Local Government Board, with the result that they found the cow itself was the source of infection. Their inquiries indicated that there had been no case of scarlet fever among either the employés or the neighbours of the dairyman that could reasonably be suspected of having infected the milk. On attention being next directed to the cows, many of them were found to be suffering, or to have recently suffered, from vesicles or ulcers upon the teats and udders. These were readily demonstrated to be infectious, and had been first seen upon a cow which was bought on November 15th. The dates of outbreak of scarlet fever in each district being known, it was found that each outbreak was preceded by a few days by the introduction of this affection into the cow-sheds from which the milk-supply of the district was drawn. The early exemption of St John's Wood was explained by the fact that the disease had not appeared in the small shed from which alone its supply was drawn; but during the inquiry this shed became affected at last, and an outbreak in St John's Wood immediately followed. All the cows showing any signs of the disease were then isolated, and no further cases of scarlet fever occurred among the consumers of the milk. The symptoms noticed in the cow were chiefly local, but there were bald patches of skin, especially about the tail and back, the epidermis in these patches being scaly and the cutis thickened. There was no pyrexia. The vesicles, which were small, were confined to the teats and udder. They extended, and in two days formed flat irregular ulcers covered with brown scabs. Inoculated upon calves, the matter from these ulcers caused local tenderness and swelling in three days, a scabbed ulcer with vesicular margin in six days, and a further extension during the next few days, followed by healing.

From these ulcers, and from the diseased portions of the viscera of these cows, Klein isolated and cultivated a streptococcus which was identical with that which he had obtained from the skin and blood of scarlatina patients. This streptococcus Klein designates as the *Streptococcus scarlatinæ*, and regards it as the microbe of scarlet fever. Among other cultural characteristics it solidifies milk if kept at 35° C. for two days, and is apparently distinct from the *Streptococcus pyogenes* and all other streptococci. Inoculation of calves with pure cultures of this Hendon micro-organism produced a constitutional disease that had many points of analogy with human scarlet fever, the condition of the kidneys, in particular, differing in no respect from acute scarlatinal nephritis. This theory of a bovine scarlet fever is rejected by the veterinary profession and by some medical authorities, but, apart from the facts connected with the Hendon outbreak, evidence is slowly accumulating, in association with other milk epidemics of scarlet fever, which indicate that there are sources of scarlatinal infection of milk other than those from cases of the human disease. Edington has also described a bacillus which he regards as the true specific microbe of scarlet fever, but his views in this respect are not generally accepted by competent critics.

The *incubation* period of scarlet fever varies from one to six days, and the period of infectiveness extends from the earliest symptoms to the end of convalescence, necessitating an extension of the period of isolation in most cases to some seven or nine weeks. One attack usually confers immunity throughout life, though second and third attacks occasionally occur. This disease is sometimes found closely associated with diphtheria, while its apparent relationship with a form of puerperal fever has already been referred to elsewhere.

Prevention.—Strict isolation is of the first importance, to which must be added the provision of infectious hospitals and the practice of notification of the disease. Arrest of contagious material from the skin may be secured by inunction with vaseline, oil, or glycerin combined with eucalyptus, carbolic acid, or some other disinfectant. Antiseptic inhalations for the throat and nose are of value. All clothing, bedding, furniture, and dwelling-rooms must be strictly disinfected. Milk should be boiled, especially for children. The convalescent person should not be permitted to mix with others until all desquamation has ceased, the process being aided by repeated bathing in warm water to which a little Condy's fluid has been added, and supplemented by thorough cleansing of all parts of the body with soap. The hair and scalp should be cleansed with a mixture of acetic acid, glycerin, and spirit.

SMALL-POX.

It is still a disputed point as to the country in which small-pox originated, though the earliest records of its existence are to be found in Hindustan and China, dating many centuries before the Christian era. The *pesta magna* described by Galen, and of which Marcus Aurelius died, is believed to have been small-pox. On the break up of the Abyssinian army at the siege of Mecca in 570 A.D., owing to the excessive prevalence of the disease among the soldiery, small-pox was gradually disseminated over northern Africa and into Asia Minor. Subsequently it spread to Europe, probably by the Moors through France and Spain, until by the eighth or ninth century it had reached Saxony, Switzerland, and England. The first accurate account of the affection was given by Rhazes, an Arabian physician, who died about 925 A.D., and whose description is available in Greenhill's translation for the Sydenham Society. It was introduced into the West Indies and America by the Spaniards early in the sixteenth century. In the seventeenth century a study of the disease was made by Sydenham, who still remains one of the most trustworthy of the earlier authorities on the disease.

In the present day, no part of the world can be said to be exempt from small-pox, or rather from epidemic outbreaks; while in India, the Soudan, and Central Africa it is so constantly prevalent that those countries may be regarded as endemic foci of the disease. From time to time so-called pandemic extensions occur, involving large areas and characterised by a particularly malignant form of the disease. The last of these was that of 1871–2, which overran Europe and America, and was the cause in these islands of something like 40,000 deaths during the two years.

Influence of Climate and Season.—As Hirsch says, "not many of the acute infective diseases show in their incidence and diffusion so complete an independence of the conditions of climate and soil." Season does seem to have some effect upon the spread of small-pox. In temperate climates, such as England, the mortality curve is above the mean from January to June, and below it from July to December. Taking India as a type of oriental countries, the maximum prevalence is in April and May, that is, in the hot season, but the onset of the rains invariably puts a check to the disease. In Europe and North America the maximum prevalence is usually during late winter and early spring.

Influence of Race, Sex, and Age.—Negroes and all coloured races appear to have a peculiar susceptibility to small-pox, and, moreover, suffer a heavy case mortality. Among aboriginal races the disease is terribly fatal. When it was first introduced into America the Mexicans died by thousands, and among the North American Indians the mortality has been appalling. In respect of *sex*, at most ages the mortality is greatest among males, but in the second and third years of life, and from ten to fifteen years of age, the reverse is, to a slight extent, the case. In relation to *age*, as we shall see presently, the prevalence and mortality of small-pox is essentially a question of vaccination. In pre-vaccination times, about 90 per cent. of the deaths were at ages below five years, the actual maximum being in the second year. In the present day, the deaths under five years, being practically limited to unvaccinated children, constitute about 30 per cent. of the total deaths from small-pox; and in this age-period the greatest mortality is in the first year. From this point it steadily diminishes until about the fifteenth year, rises to a second maximum about the twenty-fifth year, and then steadily falls again (M'Vail).

The following table from the Report of the Medical Officer to the Local Government Board, 1884, illustrates this point very clearly, by showing the contributions of various ages to 1000 small-pox deaths at all ages. These figures show that, "with the spread of vaccination, children as a whole, and especially vaccinated children, bear less and less of the total small-pox mortality, while among the unvaccinated the distribution approaches more nearly to that of pre-vaccination times."

Ages at Death.	Vaccination unknown.		Vaccination partial.	London, 1884, Vaccination general.		
	Geneva, 1580–1760.	Kilmarnock, 1728–1764.	London, 1848–1851.	Unvaccinated Community.	Vaccinated Community.	Total Inhabitants.
0–10 years,	961	988	815	612	86	343
10–20 ,,	26½	5	59	146	173	170
20–30 ,,	10	7	83	108	319	213
30–40 ,,	2½	...	32	72	221	142
Over 40 ,,		...	11	62	201	132
Total,	1000	1000	1000	1000	1000	1000

Mortality.—The introduction of vaccination has largely affected the epidemic character of small-pox. The "bills of mortality" for London, going back to 1629, show that upon an average some 70 to 90 per 1000 of the persons buried in London during the seventeenth and eighteenth centuries had died of small-pox, while in epidemic years the proportion often rose to 130, 150, or even 190 per 1000. The general small-pox death-rate per million living in England and Wales is shown in the following table compiled from the Registrar-General's returns for the last thirty years. It is noticeable that even in the epidemic years, 1871–2, the mortality approached nothing like the rate of pre-vaccination times.

Year.	Rate per million.	Year.	Rate per million.	Year.	Rate per million.	Year.	Rate per million.	Year.	Rate per million.
1864	367	1870	116	1876	103	1882	54	1888	36
1865	303	1871	1015	1877	178	1883	39	1889	1
1866	141	1872	824	1878	79	1884	87	1890	1
1867	116	1873	101	1879	25	1885	107	1891	2
1868	93	1874	91	1880	29	1886	13	1892	15
1869	70	1875	40	1881	124	1887	21	1893	49

Infectivity.—Although the pathogenic micro-organism of small-pox has not as yet been identified, it is a well-recognised fact that micrococci abound in the vesicles of the disease and in the adjacent lymphatics. The disease is disseminated from the sick to the healthy mainly by means of the air, and this power of aërial convection is one of the most striking characteristics of small-pox. It, moreover, can be carried by fomites, as by epithelial débris, pieces of clothing, &c.; similarly, the bodies of persons who have died of the disease, the beds on which they have lain, the furniture of sick-rooms, and all such ordinary means of infection have their share in the diffusion of small-pox. But, hitherto, neither water nor milk has been shown to convey the infection of the disease, though drinking vessels and other domestic utensils, if used by the infected, may serve as the vehicles of conveying the contagion to others.

The well-known investigations of Power regarding the influence of the Fulham Small-pox Hospital on the spread of the disease, conducted in 1884–5, have shown that the virus can sometimes retain its activity while passing through a quarter of a mile or more of London air. Power showed that, if the district were divided into zones, by means of circles drawn upon the map from the hospital as a centre, with radii of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ and 1 mile respectively, and an enumeration made of all the houses in each belt, and also of all houses invaded by small-pox, the proportion of invaded houses diminished as the distance from the hospital increased, and this relation held good in each quadrant of each zone. Taking the total results over a series of eight years, beginning in 1877, and including some half-dozen different periods of small-pox prevalence in London, it was found that the percentage of houses round the Fulham Hospital in which small-pox had appeared was as follows:—30·1 within a quarter of a mile, 14·5 between a quarter and a half mile, 9·5 between a half mile and three-quarters, and 4·6 between three-quarters of a mile and one mile. The position of the hospital was such that direct communication by traffic could practically be disregarded, as the incidence upon the quadrant which included the only approach to the hospital was actually less than upon any of the others. Power concluded that diffusion only occurred when *acute* cases were aggregated, and under foggy conditions of the atmosphere. Possibly only the air of towns or cities may possess the necessary carrying power, as, so far, no good evidence has been adduced of such occurring in connection with hospitals in rural districts; but the failure here may be as much owing to want of population as to atmospheric condition.

The practical outcome of this inquiry and of later ones made by others, leading to similar conclusions, has been that the Local Government Board have issued the following instructions:—That a local authority should not contemplate the erection of a small-pox hospital (1) on any site where it would have within a quarter of a mile of it as a centre either a hospital, whether for infectious diseases or not, or a workhouse, or any similar establishment, or a population of 150–200 persons; (2) on any site where it would have within half a mile of it as a centre a population of 500–600 persons, whether in one or more institutions or in dwelling-houses.

The *incubation* period of small-pox is practically twelve days, and its period of infectiveness at least six weeks in severe cases. Isolation should be maintained for at least three weeks in the mildest cases, and always until every scab has disappeared. After exposure to infection, a quarantine of seventeen days is usually sufficient, but should not be less than a fortnight. Second attacks are rare, except after some years' interval; third attacks are not unknown.

Occasionally one meets with persons who are entirely insusceptible to the contagion of small-pox,—what is the precise proportion of such insusceptible persons to the general population is very difficult to determine, but taking the mean of many observations, we may put the ratio down as 1 in 20 for adults and 1 in 60 among children.

Protection and Vaccination.—Individual protection against an attack of small-pox can be obtained in three ways: by natural small-pox, by inoculated small-pox, and by vaccination. In former years, protection once acquired was looked upon as permanent and absolute; but later experience shows that, from whatever cause obtained, the amount of protection varies according to the thoroughness of the protective procedure. Severe small-pox gives more lasting protection than mild small-pox; small-pox inoculation gives most protection when followed by an eruption; and a complete, thorough, and multiple vaccination gives more lasting protection than does a vaccination in which only a small single vesicle has been produced.

At the present time, a second attack of small-pox is less frequent than formerly, because, as a result of the practice of vaccination, a first attack of the disease usually comes later in life, so that the protection it affords does not wear off in time to readily allow of a second attack.

Protection from small-pox by deliberate inoculation of the disease, or variolation, as it was called, was very generally practised in this country during the last century, and until made illegal in 1840. The chief objections to it were the danger to life which attended it, the disfigurement which so generally followed, and the fact that the inoculated went about spreading the disease broadcast. The researches and obervations of Edward Jenner, between 1768 and 1798, led to the introduction of vaccination, or the inoculation of man with the small-pox of the cow, by which man contracted the affection called *vaccinia*. This vaccinia is, as Jenner always supposed it to be, small-pox of the cow; but owing to the remarkable change in the cow or calf of small-pox into vaccinia, the poison of human or ordinary small-pox is so weakened as to be unable to cause, except in rare cases, a general eruption, or to spread by atmospheric convection; in fact, to use the words of M'Vail, the change in the calf from small-pox to vaccinia has the effect of "removing the objectionable and retaining only the valuable part of the original disease." Which is the ancestor of the other still remains a moot point, but that small-pox and cow-pox are identical was Jenner's firm belief, and the most recent scientific investigations of the subject altogether go to strengthen this view.

Vaccination was introduced by Jenner in 1796, when he claimed for it that, "duly and efficiently performed, it will protect the constitution from subsequent attacks of small-pox as much as that disease itself will. I never expected it would do more, and it will not, I believe, do less." During the earlier part of the present century it gradually superseded inoculation. It was provided gratuitously by the first Vaccination Act of 1840, made compulsory in 1854, and systematically enforced by paid vaccination officers from the time of the pandemic in 1871. Following the introduction of vaccination, there has resulted a remarkable decline in the prevalence of small-pox, not only in England, but in various European countries. This decline, it has been urged, was due, not so much to the use of vaccination as to the decrease of inoculation and to increased attention to sanitation. That the mere decline in the practice of variolation was not the cause of a diminished small-pox prevalence is well shown by the experience of Sweden and Copenhagen, where it so happened inoculation for small-pox was never largely practised; yet the death-rate from small-pox per million of population was in Sweden, in the last century, no less than 2050, and now since the introduction of vaccination the death-rate is but 158 per million; the corresponding figures for Copenhagen are 3128 and 286. As bearing on the question of the influence of sanitation as a factor in the decline of small-pox, it has been pointed out by various writers, principally by M'Vail, that the statistics of all diseases teach that in reference to sanitation each disease has to be considered by itself. Though the removal of fæcal impurities has diminished enteric fever, it has not affected measles. The lessening of overcrowding and personal filth has much lowered the typhus fever rate, but without reducing the diarrhœa rate. Vaccination has diminished small-pox without similarly affecting whooping-cough, and while general cleanliness and purity of water and food are useful against all diseases, yet "the lessening of small-pox cannot be set down to improved drainage any more than can the lessening of enteric fever be set down to vaccination" (M'Vail).

The remarkable diminution in the small-pox death-rate, especially within the last fifty years, is shown in the following table with regard to the London death-rate:—

Years.	Average Annual Deaths per million from all Causes.	Average Annual Deaths per million from Small-pox.
1660–79	80,000	4,170
1728–57	52,000	4,260
1771–80	50,000	5,020
1801–10	29,200	2,040
1831–35	32,000	830
1838–53	24,900	513
1854–71	24,200	388
1872–82	22,100	262
1883–92	19,800	73

During 1855–64, when vaccination was optional in Scotland, the annual death-rate from small-pox was 340 per million of inhabitants; but when vaccination was made compulsory the death-rate dropped to 80 per million for the years 1865–90. Upon the same point Edwardes gives some interesting figures from Sweden, where the small-pox statistics go back to 1774. From that date to the beginning of this century the average annual death-rate was 2008 per million of people. From 1801 to 1815 vaccination was optional, and the death-rate fell to 631. In 1816 vaccination became compulsory in Sweden, and during the period 1816 to 1885 the death-rate has been 173 per million; while for the last eight years of that period it has been but 41 per million.

Perhaps the strongest argument in favour of the view that it is vaccination and not sanitation which has so reduced the prevalence and mortality of small-pox of late years, is the fact that in pre-vaccination times small-pox was very largely a disease of childhood, while now, owing to infantile vaccination, the main incidence of the disease has been transferred to later periods of life. The following table, which gives the mean annual deaths in England and Wales from small-pox at successive life periods per million living, indicates this fact very clearly.

Period.	All Ages.	0–5	5–10	10–15	15–25	25–45	45 and Upwards.
1. Vaccination optional, 1847–53, .	305	1617	337	94	109	66	22
2. Vaccination obligatory, but not efficiently enforced, 1854–71, . .	223	817	243	88	163	131	52
3. Vaccination obligatory, but more efficiently enforced by vaccination officers, 1872–91,	89	177	95	54	97	83	38

The figures show that, coincidently with the gradual extension of the practice of vaccination, there has been, in the first place, a gradual and notable decline in the mortality from small-pox at all ages; and, in the second place, that this decline has been exclusively among persons under ten years of age, and most of all among children under five; and thirdly, that after the age of ten years the mortality, so far from having declined, has actually increased—very slightly among persons of from ten to fifteen years of age, but very greatly for persons older than this; and lastly, that the increase has been the greater the more advanced the time of life. This changed incidence of small-pox is one of the most curious and convincing proofs of the efficacy of vaccination, and one which may profitably be studied by a close examination of the facts connected with each and all of the recent small-pox epidemics. No such change of age incidence is to be seen in any of the other zymotic diseases as is found to have taken place with respect to small-pox since the introduction of vaccination.

Confirmatory evidence, if any be needed, is afforded by Barry in his Report to the Local Government Board upon the Sheffield epidemic of 1887–88, in which he showed that, among each 1000 of the children under ten years of age, living under the common conditions of infection in the whole borough,

The attack-rate of the vaccinated was	5·00
The attack-rate of the unvaccinated was	101·00
The death-rate of the vaccinated was	0·09
The death-rate of the unvaccinated was	44·00

Among 1000 persons over ten years of age living under the common conditions of infection in the borough,

The attack-rate in persons twice vaccinated was	3·00
The attack-rate in persons once vaccinated was	19·00
The attack-rate in persons not vaccinated was	94·00
The death-rate among persons twice vaccinated was	0·08
The death-rate among persons once vaccinated was	1·00
The death-rate among persons not vaccinated was	51·00

Under the general circumstances of the Sheffield epidemic, therefore, the vaccinated children had, as compared with the unvaccinated children living in the town, a 20-fold immunity from attack by small-pox, and had a 488-fold security against death by small-pox. Among persons at ages above ten years there was a 5-fold immunity from attack, and a 51-fold security against death from small-pox. The twice vaccinated persons over ten years of age, as compared with the unvaccinated persons of the same age living in the town, had a 31-fold immunity against attack by small-pox, and had a 637-fold security against death from small-pox.

From Leicester very similar facts are forthcoming in respect of the epidemic of 1892–93. Quoting from the official report of the Medical Officer of Health, we get the following suggestive figures:—

Under Ten Years of Age.

Vaccinated cases, 2; death, 0, . = 0·00 per cent.
Unvaccinated cases, 105; deaths, 15, = 14·30 ,,

Over Ten Years of Age.

Cases once vaccinated, 176; death, 1, = 0·57 per cent.
Unvaccinated cases, 48; deaths, 4, = 8·30 ,,
Re-vaccinated cases, 14; death, 0, . . = 0·00 ,,
Doubtful as to vaccination—that is, no marks visible—cases, 2; death, 1, = 50·00 ,,

Whittington, in Derbyshire, suffered from a sharp outbreak of small-pox in 1893–94, there being 135 attacks and 13 deaths. The following table by the local Medical Officer of Health is sufficiently instructive to be worth quoting in its entirety.

Age-Period.	Number of Persons in Invaded Houses.	Attacks.	Vaccinated in Infancy.			Not Vaccinated.		
			Not Attacked.	Attacked.	Died.	Not Attacked.	Attacked.	Died.
Under 10 years,	177	25	148	11	0	4	14	5
10–20 years,	111	34	77	31	0	...	3	1
20–30 ,,	85	37	48	35	2	...	2	0
30 years and upwards,	109	39	70	39	5	...	...	...
Totals,	482	135	343	116	7	4	19	6

Therefore, of 459 persons vaccinated in infancy and living in houses invaded with small-pox, 25 per cent. were attacked and 1·5 per cent. died; whilst of 23 persons unvaccinated and in invaded houses, 82·7 per cent. were attacked and 26 per cent. died. No vaccinated person under twenty years of age died. Similar evidence is forthcoming from all other localities.

Much valuable evidence has been collected of late years in regard to the duration of the protection which vaccination gives against small-pox. This evidence indicates that although the susceptibility to the operation of vaccination returns comparatively soon after a primary vaccination, the susceptibility to small-pox returns but slowly; so slowly, in fact, that the power of infantile vaccination against attack by small-pox may be said to remain at least to one-half of its original extent at twenty years of age. On these points the evidence given by Gayton before the Vaccination Commission (Second Report, p. 245) is peculiarly interesting. He found that some 40 per cent. of vaccinated children could be re-vaccinated at the age of from six to ten years; but of vaccinated children of the same age exposed to the infection of small-pox by residence with cases of the disease, less than 10 per cent. were attacked, though under the same exposure no less than 92 per cent. of unvaccinated children of the same age contracted the disease. If we compare the attack rates under exposure with the fatality rates among attacked persons in successive age-periods from birth upwards, as shown by the statistics of the great small-pox hospitals, we find that resistance to death by small-pox among the vaccinated outlasts very considerably resistance to attack by small-pox, and also that the inclination to both attack and death by small-pox is much slower in course and much less in ultimate amount in the well vaccinated than in the badly vaccinated.

Ages.	Vaccinated. Good Marks.			Vaccinated. Imperfect Marks.			Said to be Vaccinated. No Marks.			Unvaccinated.		
	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.
0–5,	51	0	0·0	182	21	11·5	128	47	36·7	677	383	56·6
0–10,	267	2	0·7	714	48	6·7	325	87	26·8	1187	563	47·4
10–20,	1045	17	1·6	1976	98	5·0	419	81	19·3	521	160	30·7
20–40,	725	37	5·1	1898	258	13·6	420	140	33·5	382	181	47·4
Over 40,	48	6	12·5	266	51	19·2	131	44	33·8	79	34	43·0
All ages,	2085	62	3	4854	455	9	1295	352	27	2169	938	43

The quality of vaccination, that is, the number, area, and character of the cicatrices, has an important bearing upon the degree and permanence of the protection afforded, as well as upon the case mortality. The preceding analysis of 10,403 cases in the Metropolitan small-pox hospitals, by Gayton, makes this point very clear.

Marson gives the following case mortality in relation to the number of vaccine cicatrices:—

	Case Mortality (per cent.).
Unvaccinated,	35½
Stated to be vaccinated, but without cicatrices,	21¾
Having one cicatrix,	7½
Having two cicatrices,	4⅛
Having three cicatrices,	1¾
Having four or more cicatrices,	¾

Vaccination is protective against itself as well as against small-pox. Any number of insertions may be made at the time of vaccination; whether one vesicle is produced or a dozen, the protection is absolute for the time being, but all experience goes to show that the duration of the protection is limited, and is directly proportionate to the number and size of the vesicles produced. For this reason it is desirable to vaccinate in at least four places, and the total area of the cicatrices should not be less than half a square inch. As the protective influence of the primary vaccination fades, a time arrives when re-vaccination becomes possible. Very few persons are insusceptible to re-vaccination after the lapse of ten or twelve years; many are susceptible within five years, although the primary cicatrices may be good. The course of re-vaccination in the majority of persons is different from that of primary vaccination, being more rapid, and often failing to exhibit some of the typical stages. If, however, the former protection has entirely disappeared, the course of re-vaccination may be identical with that of a primary vaccination.

Re-vaccination renews in all respects the immunity given by primary vaccination. Barry showed that in the Sheffield epidemic the re-vaccinated had a great advantage over the rest. Of 8198 persons re-vaccinated prior to the epidemic, twenty-five were attacked and one died, the attack-rate being therefore 3 per 1000, and the death-rate 0·1. Among 56,233 persons re-vaccinated during 1887–88, two were doubtfully attacked, and none died.

The incubation of vaccinia being shorter than that of small-pox, it is possible to modify or even entirely prevent an attack of small-pox by vaccination performed some days after infection. This is especially the case with re-vaccination, the incubation of which is often shorter than in primary vaccination. Vaccination, if successfully performed within three days after exposure to infection of small-pox, will prevent the appearance of symptoms, and in all likelihood the attack will be arrested or modified by vaccination if performed as late as the fifth day. The proof of this statement rests upon the observation that attacks of small-pox may and do occur within six days of vaccination in persons who have been many days previously exposed to infection, but the few attacks that occur between six and nine days after successful vaccination are mild, and practically none commence later.

The Vaccination Acts require that every child shall be vaccinated within three months of its birth, unless (*a*) death occurs within this period, or (*b*) the state of health renders postponement necessary, or (*c*) the child is attacked by small-pox, or (*d*) three or more unsuccessful attempts at vaccination have been made, in which case insusceptibility is inferred. Certificates signed by a qualified medical practitioner must be produced in proof of any such exceptions. A certain number of children are lost sight of by the vaccination officers, chiefly owing to migration. At the same time, it cannot be denied that wholesale evasion of the law is countenanced by the authorities responsible for the administration of the Vaccination Acts, and that as a result the "proportion remaining unaccounted for" is annually increasing. In 1891 the percentage of children not finally accounted for as regards vaccination, that is, including cases postponed, was 13·4 of the total births throughout the whole of the country; the proportion of cases not finally accounted for in the metropolitan returns for 1891 was 16·4 per cent.; in the provincial returns 12·9. Of the registered births of the twenty years 1872–91, the corresponding proportion not finally accounted for in regard to vaccination in each year respectively has been as follows:—

Year.	England and Wales.	Metropolis.	Provinces.	Year.	England and Wales.	Metropolis.	Provinces.
1872	4·6	8·8	4·5	1882	4·8	6·6	4·5
1873	4·8	8·7	4·2	1883	5·1	6·5	4·9
1874	4·8	8·8	4·1	1884	5·5	6·8	5·3
1875	4·7	9·3	3·8	1885	5·8	7·0	5·5
1876	4·3	6·5	4·0	1886	6·4	7·8	6·1
1877	4·5	7·1	4·1	1887	7·1	9·0	6·7
1878	4·7	7·1	4·3	1888	8·5	10·3	8·2
1879	5·0	7·8	4·5	1889	9·9	11·6	9·6
1880	4·9	7·0	4·5	1890	11·3	13·9	10·9
1881	4·5	5·7	4·3	1891	13·4	16·4	12·9

The administration of the Vaccination Acts is not in the hands of the sanitary authorities, but, subject to the control of the Local Government Board, is entrusted to the Poor Law Guardians. Vaccination may be performed, and the certificate signed by any qualified medical practitioner, but the Guardians must provide for the gratuitous vaccination of all children. For this purpose Public Vaccinators are appointed, and attend at certain convenient vaccination stations at fixed days and hours. The most scrupulous care is necessary in the selection of "vaccinifers," or infants from whom lymph is taken, and in the cleanliness of instruments. The Local Government Board Instructions prescribe at least four insertions, and the total area of cicatrix should not be less than half a square inch. The vaccination of children who are not in good health should be postponed, unless there is some immediate risk of infection by small-pox. Re-vaccination is entirely optional, but persons over twelve years of age are re-vaccinated gratuitously at the public stations, and if there is immediate danger of small-pox the age-limit is reduced to ten years.

Some people profess to be much opposed to the practice of vaccination, and, in support of this view, allege that (1) vaccination neither prevents nor modifies small-pox; (2) that it gives rise to other diseases; (3) that it is unnecessary, as small-pox is only slightly infectious, and can be prevented by isolation in hospitals. No one who has studied the statistics, nor any one who has read the few facts explained above as to the real nature of the case, can for one moment honestly believe or think that vaccination neither prevents nor modifies small-pox. The truth is, vaccination does both. With regard to the second contention, that vaccination gives rise to other diseases, much untruth has been both written and spoken by prejudiced persons. The facts appear to be that, in a very small percentage of cases, certain diseased conditions have resulted either from or in consequence of vaccination having been performed. But when these cases have been closely inquired into, it has been found that grave errors had been committed in the performance of the operation, and that due precautions had not been taken in the choice of the source of the vaccine lymph. Considering the enormous number of vaccinations that have been performed during the past fifty years, it is remarkable how few genuine cases have occurred in which disease has in any way resulted from the procedure. It is probable that with an increased use of vaccine direct from the calf, and the exercise of greater care even than has hitherto been exercised, the alleged risks of vaccination in this direction will quite disappear. Coming now to the third objection to vaccination, or the statement that it is needless because isolation is a better preventive than it, we find that on this particular allegation there is practically no evidence at all. What evidence there is is based upon the experience of Leicester, in which town isolation of the small-pox sick has been very rigidly carried out. But this town is not an instance where isolation has been employed as a *substitute* for vaccination, because the great bulk of the inhabitants of Leicester have been vaccinated at some time or another, with the result that the experience of Leicester really only amounts to an experiment as to the efficacy of isolation, *plus* a certain amount of vaccination. Moreover, the doctors, nurses, and attendants of these isolated small-pox sick are all more or less vaccinated or otherwise protected individuals, which means simply that the patient has around him a cordon of protected or insusceptible people. Surrounded in this manner with persons protected from the disease, it is not remarkable that diffusion or communication of the affection has been small; but where the immediate attendants are not thus protected by either vaccination or re-vaccination, experience shows that isolation alone, as so understood, rapidly results in an overwhelming increase in the numbers of those attacked with the disease, accompanied by an increased severity of the disease type.

There is yet another interesting feature in the Leicester "experiment," and that is the system of "quarantining" for small-pox. In his report upon the outbreak of 1892–93, the Medical Officer of Health explains that by "quarantines" are meant practically persons in small-pox infected houses, for it is clear that such inmates must, more or less, have been exposed to the contagion. He goes on further to say that "such persons may be quarantined (1) in separate hospital wards and reception houses specially provided, a method, by the way, I do not recommend, whether from the point of view of economy or practicability; or (2) at their own homes, a method I have found satisfactory, both financially and otherwise. The value of quarantining has been well shown during the Leicester epidemic, and I have been able, with comparative ease, by means of my inspectors to quarantine hundreds of persons at their own homes and with a success that has been gratifying both financially and otherwise. 1261 persons were quarantined, and of these 123 sickened (that is, 9·7 per cent.). Each infected house was visited daily by one or other of the inspectors for fourteen to sixteen days. Other persons who had come into contact with small-pox were also watched in the same way. These 'quarantines' were strongly urged—practically compelled—not to go to work for the whole or part of their quarantine period of fourteen to sixteen days, and during that time have been made such monetary allowances as the Committee have thought fit, the sum advanced in each case being no more than sufficient to cover rent and maintenance."

It is clear this is a kind of compulsion which would not be tolerated to any great extent, if it be seriously thought that the system might be made general. In comparison with it, the compulsion of infantile vaccination is a trifling interference with individual liberty.

Prevention.—The most important measures are: (1) Vaccination, (2) Isolation. To these may be added fixation of contagious matter by smearing the skin with olive oil, vaseline, or carbolised glycerin, to prevent its diffusion into the air. All discharges from the nose, mouth, and elsewhere should be received into vessels containing some disinfectant. Rags should be used for wiping the nose, &c., and afterwards burnt. All clothing, bedding, furniture, and dwelling-rooms need to be most scrupulously disinfected. No persons should be allowed near the sick, unless vaccinated; vaccination should be performed upon all individuals occupying the same house in which a case of small-pox has occurred.

TETANUS.

Carle and Rattone were the first to produce typical tetanus in animals, and to show it to be a communicable disease. This they succeeded in doing by inoculating rabbits with pus taken from the ulceration of a human being in whom tetanus had set in; infection of a second animal with the sciatic nerve of the first produced the same result, but inoculations of the blood were negative. Nicolaier made the important discovery that garden earth is often capable of producing, when inoculated into the subcutaneous tissue of the mouse or rabbit, a local suppuration and hæmorrhagic effusion about the seat of inoculation, rapidly followed by typical tetanus and death. At the seat of inoculation fine bristle-shaped bacilli were found; these were often swollen at one end. If the garden earth was previously sterilised by heating it to 110° C., then no effect followed. Rosenbach was the first to demonstrate that the same bacilli exist in the exudation at the place of infection in human tetanus, and that tetanus was produced and propagated through a series of animals by inoculation of matters taken from near the inoculated place. Hochsinger, Beumer, Peiper, and many others confirmed the existence of these bacilli in tetanus, and even succeeded in producing the disease in animals with them by the aid of foreign bodies, yet these cultures were always in an impure state. The first pure cultivations of the tetanus bacilli were obtained by Kitasato.

The tetanus bacilli are slender bristle-like rods, having circular spores at one end, and possessing but little power of automatic movement. They are strictly anaerobic, and withstand a tolerably high temperature—about 80° C.—without losing their pathogenic power, but growth takes place best at 37° C. The fact that the spores can be subjected to a high temperature without losing their vitality enabled Kitasato to obtain pure cultures of the tetanus bacillus, since the other bacilli cultivated or growing along with them are destroyed at a temperature of 80° C. A trace of pus or exudation from a patient suffering from tetanus is smeared upon serum solidified in a slanting position, or upon agar, and the cultures so made incubated for a few days at 37° C. They are next transferred, for from half an hour to an hour, to a water-bath heated to 80° C., in order to kill the micro-organisms which have grown along with the bacilli, after which secondary cultivations must be made in the absence of air by substituting for it an atmosphere of hydrogen gas, or by planting the bacilli in the depth of the gelatin. One or two per cent. of grape-sugar may be added to the medium with advantage. The colonies have usually a halo radiating in all directions, and liquefaction sets in slowly, being combined with the formation of a certain amount of gas. If an infection is made with a pure culture, the bacilli are found only on the site of inoculation and in its immediate neighbourhood.

The more exact researches of recent years indicate that the introduction of tetanus bacilli under the skin is followed by the production by them of a chemical virus, which, as it is being produced at the seat of inoculation, is absorbed into the system and sets up the disease; but the bacilli themselves remain limited to the seat of inoculation, and do not enter the blood or any other tissue, and therefore only the seat of inoculation contains the infective principle, that is, the bacilli.

Brieger has isolated from the exudation at the seat of infection in human tetanus a toxic principle, *tetanin*, the injection of which produces tetanus. Kitasato has separated a similar chemical body from the cultures of the tetanus bacillus. According to Vaillard and Vincent, tetanin is neither an alkaloid nor an albumose, but is related in its chemical characters to snake poison.

Behring and Kitasato have shown that the blood of a rabbit (previously made insusceptible to tetanus), injected into a mouse, otherwise susceptible to tetanus, neutralises in this latter the action of the tetanus bacillus. Tizzoni and Cattoni have gone further than this by showing that the blood-serum of animals, made previously insusceptible, when injected into animals, possesses a decided anti-toxic action. From such blood-serum a tetanus anti-toxin can be prepared, which is effective in neutralising the virus of the tetanus bacilli.

Several cases are on record in which tetanus seems to have been conveyed by the hands or instruments of the surgeon, especially veterinary surgeons. One of the most striking of these is related by Langer, in which the horses castrated by the same *écraseur* died of tetanus, but after boiling the instrument in oil no others died or were affected from its use. Numerous cases are on record of the occurrence of this affection following wounds and injuries in man, the common feature of which has been contamination by dirt, dust, or soil. In view of this fact, that tetanus is produced by a micro-organism to be found in dust, dirt, and adhering to foreign substances, the surgeon will naturally take the greatest care to keep wounds and other injuries free from such contaminating influences. Save in the way of disseminating information on these points among the public at large, tetanus is a malady against which the sanitary officer can do but little. He may, however, point out that the discharges from such wounds should be collected on clean rags or similar materials, which can be either disinfected or burned.

From the frequency with which tetanus is met with among grooms and others much in association with horses, some writers have endeavoured to establish an etiological connection between horses and man in respect of this disease. The doctrine of an equine origin of tetanus has as few facts to support it as has the view that chills, exposure to extremes of heat or cold, and other climatic or meteorological conditions are the cause of the disease. That tetanus is frequent amongst those injured by, or in intimate association with horses, mules, and other quadrupeds, is probably to be explained by the simple fact that such injuries and associations commonly involve contamination by earth or soil, a medium which we know to be particularly favourable to the specific bacillus.

Prevention.—Extreme cleanliness in regard to all wounds, cuts, or lacerations, especially with a view to avoiding access of soil or any kind of dirt thereto.

TUBERCULOSIS.

This is a diseased condition which occurs in man in a variety of different forms, the most familiar being phthisis, scrofula, lupus, tabes mesenterica, and meningitis. Tuberculosis is not limited to the human race; it is very common among oxen and cows as a disease known as "grapes"; it also affects pigs as well as fowls, rabbits, and guinea-pigs. Though there is every reason to believe that tubercular disease, especially phthisis, has occurred in all ages, there are no data on which to form any estimate as to its relative prevalence in the past in respect of either time or place. In the present day, tuberculosis is certainly more common in some countries than in others; but this geographical limitation does not mean that the infecting virus is not widespread, but rather that the susceptibility to it is happily far less common. For this reason, the predisposing causes are much more important in this than in any other infective disease.

Influence of Climate and Season.—Speaking generally, tuberculosis is more prevalent in temperate climates, especially in the more populous parts of such countries. Neither hot nor cold climates are exempt, but humidity, especially if the daily range of temperature is high, is frequently associated with the prevalence of pulmonary tuberculosis or phthisis. Cold, and especially Arctic, countries suffer comparatively little as a rule, and the exceptions are mostly explicable by social conditions involving overcrowding and want of ventilation. Other things being equal, elevated and mountainous regions are less affected than lowlands, owing, probably, to the greater dryness and purity of the air and soil, and the deeper and fuller respiratory movements.

As regards the influence of season, in this country deaths from tuberculosis, as evidenced by the phthisis mortality, are most frequent in March and April, and least so in September and October. The seasonal curve of mortality is therefore later than in the ordinary respiratory diseases, and serves really to indicate seasonal conditions accelerating death rather than primarily inducing what is generally a disease of long and uncertain course.

Influence of Race, Sex, and Age.—Jews are said to enjoy a relative immunity from tubercular disease, but, speaking generally, no race is exempt. The coloured races seem to suffer much from phthisis, particularly if they change their natural and primitive habits of life for the conditions associated with a higher civilisation; this is all the more marked if such changed mode of life is synchronous with migration to a colder and more temperate climate.

The influence of sex is very marked. In proportion to their numbers, males suffer a higher phthisis mortality than females at all ages, except between 5 and 25 years. As regards age, deaths registered as due to phthisis fall from the first to the fifth year: after the age-period 5–10, they increase up to the age-period 25–35, subsequently to which they steadily decrease. Tubercular meningitis is most common between the third and eighth years of life, but tabes mesenterica is commonest at an earlier age, namely from one to three years.

Mortality.—It is a matter of common knowledge that tubercular disease occasions an enormous mortality. Owing, however, to the uncertainty which attaches to the actual cause of many of the deaths, especially among children, ascribed to tuberculosis, it is very difficult to ascertain accurately the extent of this mortality. It is generally estimated that, among civilised communities, at least one-seventh of the total mortality is due to tuberculosis in some form or another. As regards England and Wales, the following table, compiled from the Registrar-General's returns, shows the number of deaths recorded during the last twenty years as due to phthisis, and the corresponding death-rates per million of the population.

Year.	Total Deaths.	Death-rate per million living.	Year.	Total Deaths.	Death-rate per million living.
1874	49,379	2081	1884	49,325	1827
1875	52,943	2202	1885	48,175	1770
1876	51,775	2119	1886	47,872	1739
1877	51,353	2079	1887	44,935	1615
1878	52,856	2111	1888	44,248	1568
1879	51,272	2021	1889	44,735	1573
1880	48,201	1869	1890	48,366	1682
1881	47,541	1825	1891	46,615	1599
1882	48,715	1850	1892	43,323	1473
1883	50,053	1880	1893	43,632	1433

From this table it is gratifying to be able to note both a relative and absolute diminution in the deaths recorded.

Etiology.—Even by the older physicians, tuberculosis was regarded as an infectious disease, but it was not until Koch discovered the tubercle bacillus that this conception of its nature was very generally recognised. The tubercle bacilli in human tubercle are delicate cylindrical rods, measuring from $1{\cdot}5\ \mu$ to $4\ \mu$; many are straight, with rounded ends, but others are slightly curved. When stained, the protoplasm of the bacilli appears segregated into deeply stained, cubical, spherical, or rod-shaped granules; between the granules the sheath is empty, but these empty places are not to be taken for bright spores, nor is it proved that the bright granules are spores. That the tubercle bacilli contain spores is proved by their behaviour under conditions of drying and heating, but what the character of these spores is, or how they appear in the bacilli, has not been satisfactorily shown. In bovine tubercular matter the bacilli are, as a rule, shorter and thinner, but are in every respect identical with the human species, these minute differences being really differences due to the different soils on which the bacilli were reared.

Tubercle bacilli show definite characters in cultivation. On blood-serum, after ten to fourteen days, these bacilli show themselves in the form of whitish points and patches, resembling dry scales. On agar broth, and also in broth, the growth is very limited; but by the addition of 6 per cent. of glycerin to meat broth the tubercle bacilli can be brought into rapid and extensive multiplication. These bacilli will not grow below 30° C. or above 42° C.

Koch has shown that by subcutaneous or intra-vascular injection, by inhalation, and by inoculation into the peritoneum or the anterior chamber of the eye, &c., of artificial subcultures removed by many generations from the original source, typical tuberculosis is produced in all animals susceptible to tubercle (guinea-pigs, rabbits, dogs, rats, and mice), and that the tubercular deposits in these experimental animals again contain abundantly the tubercle bacilli; thus, the final and exact proof that the tubercle bacilli are the true cause of the tubercular process is definitely established.

The discovery of the tubercle bacillus, although a matter of the highest importance and of the greatest scientific value, by no means exhausts the etiology of tuberculosis. Admitting, however, the constant presence of the bacillus, we have, as in other specific diseases, to determine the power of resistance of the tissues to its invasion, and to note various other conditions as being also requisite for the production of the phenomena which we recognise as tubercular disease. In the case of tuberculosis this is pre-eminently true, and these other conditions or so-called predisposing causes must be regarded as having an importance hardly second to the micro-organism itself.

Of these predisposing causes, the most effectual is the fact of parents having suffered from the same disease, which we state abstractly as *hereditary* disposition or diathesis. As regards *direct contagion*, it must be confessed that clinical observation is altogether opposed to the idea that direct infection from another patient is at all common in the etiology of tubercular diseases. Some very striking evidence on this point has been collected from the experiences and after histories of the resident staff and personnel of the Brompton Hospital, which distinctly indicates that phthisis does not commonly spread from a patient to those in intimate contact with him. At the same time, there can be no doubt that phthisis can spread, and actually does spread at times by infection from case to case. In Italy consumption has always been regarded as a contagious disease. That it is not readily communicated is certain, but it does seem to be so under certain favourable conditions, as in the case of husband and wife and other persons living in close and habitual contact. The dried sputum of phthisical persons preserves the bacillus for a long time, and in crowded towns there must be abundant opportunities of infection from so common a disease.

Among other conditions influencing tuberculosis, elevation and *dampness of soil* play an important part; reference to this aspect of the subject has already been made on page 472. To these predisposing factors must be added *want of sufficient food*, especially want of the fatty elements, and the *breathing of impure air*.

The habitual breathing of air rendered impure by overcrowding or by defective ventilation may and probably does act in two ways: first, indirectly by weakening the resistance of the tissues, and secondly, directly by increasing the chance of infection. Strictly speaking, overcrowding and defective ventilation are not convertible terms; but in practice we scarcely ever meet one of them apart from the other. The proof that impure air is a cause of phthisis rests mainly upon the evidence of statistics as to the frequency of the disease among soldiers, artisans, and inmates of prisons.

As regards soldiers, a Royal Commission upon the Sanitary Condition of the Army, which reported in 1858, brought to light the fact that the death-rate from consumption in all branches of the service was in excess of that of the civil population of large towns, and that overcrowding had extensively prevailed in the barrack rooms. The overcrowding had been greatest among the Foot Guards, and in that branch of the service the phthisis mortality had been highest. During the ten years 1837–46 it was 11·9 per 1000 of strength. For the seven years 1864–70 it had been reduced to 2·3. The mean of the phthisis mortality in the army at home for the years 1837–46 was 7·89 per 1000 of strength; since the adequate provision of cubic space and ventilation, this death-rate in the home army has lessened enormously; for the year 1893 the mortality from phthisis in the British Army at home was as little as 0·76 per 1000 of strength. Similar experience is afforded by the health history of the Navy, and by that of the occupants of prisons.

As to workmen we have abundant evidence, the general tenor of which, in the words of Sir John Simon, indicates that "in proportion as the male and female populations are severally attracted to indoor branches of industry, in such proportion, other things being equal, their respective death-rates by tuberculosis and lung-disease are increased." But the pernicious effects of defective ventilation, as favouring phthisis, are not only due to the accumulation in the air of the products of respiration (including tubercle bacilli), exhalations from the body, and products of imperfect combustion. Experience shows that the loading of the atmosphere of mines, factories, and workshops with special kinds of dust produced in different trades is also a powerful indirect cause of pulmonary tuberculosis. The ability for harm of these dusts is apparently largely dependent upon their hardness and angularity, as favouring a catarrhal or mechanically injured condition of the mucous lining of the lungs, and thereby facilitating the entrance and activity of the tubercle bacillus.

Farr long ago stated his belief that the prevalence of phthisis in the armies of Europe, in the Navy, in factories, workshops, and public institutions, such as prisons and workhouses, was probably due in large part to the inhalation of expectorated tubercular matter dried, broken up into dust and floating in the air of close barrack rooms and dormitories. In the light of our present knowledge this belief requires no justification or explanation. Indeed, it is obvious that only in very exceptional instances can overcrowding or defective ventilation be isolated from other injurious conditions, apart from direct contagion, as to be proved the main cause of tubercular phthisis.

There still remains to consider the possibility of tubercular infection by the alimentary canal. It has already been stated that cattle suffer in considerable numbers from tuberculosis, and that, notwithstanding slight morphological differences between the respective bacilli, we may regard the human and bovine diseases as identical. It is notorious that, apart from implication of the flesh, tuberculosis of the udder in the form of softening nodules is not uncommon in milch cows. Such being the case, the danger to man as regards cattle is a double one, for infection may occur both by the ingestion of flesh and milk. It is now universally acknowledged that the flesh of animals suffering from tuberculosis in a severe form, with fever and emaciation, ought to be absolutely condemned as unfit for human food, and ought not to be given to carnivorous animals, but destroyed, though in America it is allowed to be converted into manure. Differences of opinion arise when we have to deal with animals who have not yet suffered in condition, and in whom the disease is limited to certain viscera. Martin's evidence before the recent Royal Commission on Tuberculosis shows that there is danger even in these minor cases, but that it is a danger which may be obviated. He adduced strong evidence that the flesh itself is not infectious, but that it may be rendered so by the process of cutting up and preparing the joints for sale. A knife used for cutting into tuberculous viscera or lymphatic glands will become covered with infective matter, and this may then be smeared on to the joints. That this is a very real danger is further shown by Woodhead's experiments on the effects of cooking. He found that if tuberculous matter were smeared on a piece of meat which was then tightly rolled up, as is done with the rolls of meat sold by butchers, the infective matter was not destroyed by roasting, baking, or boiling, though boiling was more effective than baking, and baking than roasting. There is this further element of danger, as pointed out by the Commission, that tuberculous matter from a diseased carcass may be conveyed by the butcher's hands and knives to the meat from perfectly healthy animals cut up subsequently in the same place and with the same tools.

With regard to milk, the Royal Commission found that the milk of a tuberculous cow is not virulent except when the udder is the seat of tuberculous lesions. Unfortunately, the diagnosis of the nature of the lesions of the udder has not yet attained certainty. Mistakes may be made in both directions. The Commissioners express a hope that the well-considered use of tuberculin in a herd may give valuable aid in picking out the diseased animals, even those as yet in the earliest stages of the disease.

The following are the final conclusions of the Commissioners:—"Provided every part that is the seat of tuberculous matter be avoided and destroyed, and provided care be taken to save from contamination by such matter the actual meat substance of a tuberculous animal, a great deal of meat from animals affected by tuberculosis may be eaten without risk to the consumer. Ordinary processes of cooking applied to meat which has got contaminated on its surface are probably sufficient to destroy the harmful quality. They would not avail to render wholesome any piece of meat that contained tuberculous matter in its deeper parts. The boiling of milk, even for a moment, would probably be sufficient to remove the very dangerous quality of tuberculous milk."

Prevention.—Of the first importance is the provision of proper ventilation, the avoidance of overcrowding, and in certain trades the provision of an air supply free from irritating particles. Next is the maintenance of a proper state of nutrition by sufficient and suitable food. Thirdly, the avoidance of chill, and the removal of all predisposed persons from damp soils and climates, combined with plenty of exercise in the open air.

The sputa of phthisical patients should be carefully collected and destroyed. Patients should be urged not to spit about carelessly, but always use a spittoon, or one of the portable cups now on sale. If tubercular sputa is not burnt or boiled it should be disinfected. All handkerchiefs should be well boiled, or better still, small rags used, which should be burnt immediately afterwards. All tuberculous persons should occupy single beds. Rooms, bedding, and furniture used by the tubercular should be disinfected.

A most important general prophylactic measure relates to the inspection of dairies and slaughter-houses for the detection of tuberculous animals, and the granting of full powers to inspectors to confiscate all suspected animals and carcasses. Slaughtering and dressing should be done under skilled supervision, with the object of securing the removal and destruction of every part of a carcass that contained any tubercle whatever, and also the destruction of the whole carcass in cases where animals are found to have advanced or generalised tuberculosis.

All milk should be boiled, especially that to be used by young children. A mother with tuberculosis should not suckle her child.

TYPHUS FEVER.

Historically, this disease is next in importance to the true or Oriental Plague: it is the common pestilence which has accompanied and followed wars from the earliest times. Most probably the plague of Athens, recorded by Thucydides, was what we now call typhus. This name now in use was first applied to a malady or a group of maladies by Sauvages in 1759, and is synonymous with the older terms, "jail fever," "morbus castrensis," "putrid fever," and the modern German term, "typhus exanthematicus" or "Flecktyphus."

Both in Great Britain and Ireland this disease has prevailed with great severity on repeated occasions during the last two hundred years. Since the commencement of the present century there have been epidemics of typhus in 1803, 1817–19, 1826–28, 1836, 1843, 1846–48, 1856, and 1861–70. It must be noted, however, that in some of the earlier epidemics there was a large admixture of cases of relapsing fever, which was not known to be distinct from typhus until 1843, but can even now be recognised by the small mortality which has always attended it. Typhus is more or less endemic in the poor districts of Edinburgh, Glasgow and Dublin, and was so until recent years in London. As an epidemic it has again and again left its haunts in cities and invaded the whole country. On the Continent and in the United States its course has been chiefly epidemic, and attendant on armies, especially during the miseries of sieges and of retreat. Typhus is rare even as an occasional visitant in the south of Europe, and appears to be almost unknown in India and the tropics generally. It is not uncommon in Northern China.

The disease was introduced into America in 1847 by an infected emigrant ship, and in 1867 by the same means into Australia, but fortunately it has never established itself there. Typhus is unknown among animals: but has been produced by Zülzer in rabbits by injections of blood taken from a sick person when in the height of the disease. These inoculation experiments failed when the blood was drawn from the sick person after the crisis of the disease had passed. Experiments on dogs, made by the same observer, gave negative results.

Influence of Climate and Season.—The disease is essentially one of temperate and cold climates, but by no means unknown in many warm countries, but usually at considerable elevation, such for instance as Mexico, Peru, Persia, North China, and Algeria. In England both the prevalence and mortality of typhus have, on the whole, been greater in the winter and spring than in summer and autumn; but there is a less constant relation to season in respect of this disease than is the case with several of the other epidemic and infective maladies.

Influence of Race, Age, and Sex.—No race is exempt from typhus, but the influence of class and circumstances is shown by the especial incidence of the disease upon the poor and those living under relatively unwholesome conditions.

No age is exempt, but the susceptibility to attack is greatest between the ages of 10 and 20. The mortality from typhus increases from childhood to about 50 years of age, and then declines somewhat. Murchison gives the case mortality of the higher ages as 35·39 in persons between 30 and 40; 43·48 in persons between 40 and 50; 53·87 in those between 50 and 60; and 67·04 per cent. in those over 60. During the first five years of life the fatality is about 6·7 per cent., from 5 to 10 years it falls to 3·6, between 10 and 15 it is not more than 2·3, while from 15 to 20 years of age it rises to about 4·5 per cent.

Although sex appears to have little influence upon liability to attack, the actual fatality is usually somewhat greater for males at all ages taken together, than for females. Of 18,268 cases of typhus at all ages admitted into the London Fever Hospital, 18·9 per cent. ended fatally, or a male fatality of 19·6 per cent. of attacks, and a female fatality of 18·2 per cent. Murchison points out that these, being hospital cases, were doubtless above the average as regards severity, and he gives 10 per cent. as a general estimate of typhus fatality; but this naturally varies in different epidemics.

Mortality.—The following figures, taken from the Annual Reports of the

Registrar-General, sufficiently indicate the more recent history of typhus fever in England and Wales.

Year.	Total Deaths.	Death-rate per million living.	Year.	Total Deaths.	Death-rate per million living.
1874	1762	74	1884	328	12
1875	1499	62	1885	318	12
1876	1165	48	1886	245	9
1877	1104	45	1887	211	8
1878	906	36	1888	160	6
1879	533	21	1889	137	5
1880	530	21	1890	151	5
1881	552	21	1891	137	5
1882	940	36	1892	85	3
1883	877	33	1893	137	4

Etiology.—No materies morbi has yet been detected, though there can be little doubt of its existence. It probably gains entrance in most cases by the breath: the contagion is very sure, but is readily diluted and dissipated, and probably not very persistent. The *incubation* period is variously stated from six to fourteen days, but there appear to be some well-authenticated cases in which it was not more than from two to five days. As regards the period of infectiveness, it is impossible to speak with any certainty. The general opinion is, that the infection is comparatively slight during the first week, but that the disease is most contagious from the end of the first week up to convalescence. This implies that it will probably not be safe to allow a patient to mix with others in less time than a month from the date of attack. In some cases a longer period of isolation may be necessary.

That typhus passes directly to other persons from the sick is established by the clearest possible evidence; and the diffusion of the disease can often be traced from point to point in a town or in a district. The contagion is probably exhaled both by the skin and the lungs, and it may perhaps cause the offensive odour which is so perceptible when near to severe cases. The poison, whatever it may be, can certainly attach itself to clothes and bedding, but typhus is not nearly so apt as some of the other contagious exanthemata to be propagated by means of inanimate objects, or of human beings themselves unaffected by it. Moreover, its poison is easily rendered inert by free dilution with air. It has never been shown to be conveyed by water, or by milk or other food.

The most important etiological factors in this disease are bodily fatigue, mental anxiety, want of sleep, poverty, starvation, and overcrowding. The three last named are among the most certain predisposing causes, and no epidemic of typhus has ever occurred except in association with widespread destitution, and the excessive aggregation of numbers of poverty-stricken, starved, and otherwise morally and physically deteriorated human beings. Besides its obvious influence in increasing the spread of typhus by contagion, overcrowding seems specially to augment the susceptibility of individuals to the poison; but it may safely be inferred from analogy that, without the presence of a specific poison, no intensity of overcrowding or other favouring conditions can originate an outbreak of typhus.

A second attack of typhus is as rare as one of small-pox, but in exceptional instances the disease appears to confer practically no immunity at all. Such cases, however, are very rare.

Prevention.—To prevent the development of the typhus poison, free ventilation and cleanliness are essential and usually sufficient. Although the prevention of poverty is not always possible, the poor may be supplied with airy, wholesome dwellings, and with the means of maintaining personal cleanliness, such as baths and wash-houses. To prevent the spread of the disease, isolation and disinfection of the sick must be carried out stringently. A typhus patient should be treated in a very freely ventilated ward or building, or under canvas, at least 2000 cubic feet being allowed per bed, and the amount of fresh air supplied practically unlimited. As the contagion is specially virulent near and about the patient, attendants should avoid inhaling the emanations, or exposing themselves (unless protected by a previous attack) unnecessarily to such inhalation. Visitors should not be allowed, and the isolation most strictly maintained. All clothing worn by the patient before admission and during treatment must be carefully disinfected. Bedding and furniture must also be disinfected. The same observations apply to all rooms occupied by the patient either before or during the attack.

WHOOPING-COUGH.

Like so many other epidemic diseases, whooping-cough can be traced to only comparatively recent periods—the earliest notice of it is said to have been by Schenck in 1600. It is a very frequent and widespread disease, and, next to scarlet fever, more fatal than any other in childhood; indeed for infants under one year it is probably the most fatal of all.

Influence of Climate and Season.—Climate does not appear to have much influence upon the prevalence of this disease, except that perhaps cold and damp countries are more favourable to it. As regards season, the prevalence of whooping-cough in this country, like the mortality, is greatest about the months of March and April. In this respect its curve of prevalence is almost exactly the reverse of that for scarlet fever. This apparent seasonal prevalence does not probably apply to all countries, as Hirsch, from an analysis of a large number of facts, shows that it is not more apt to be epidemic at one season of the year than another. As regards the effect of weather, Goodhart remarks: "Atmospheric changes have a most important bearing upon pertussis. It has been repeatedly noticed in the whooping-cough ward at the Evelina Hospital that the children are worse, even when otherwise doing well, when the wind turns cold or suddenly changes; and it is notorious that the disease runs a much less determined course in summer than in the colder seasons of the year."

Influence of Sex and Age.—Female children are decidedly more liable to be attacked than males. The age at which whooping-cough is most common is between the first year and the eighth. Of the total deaths over 90 per cent. at all ages occur during the first five years of life. Of Goodhart's 352 cases, 62 were under a year old, 212 were between one and four, 65 between four and six, and 13 between six and ten. The mortality among females is greater at all ages than among males. The case mortality is about 2·5 per cent., but varies with age. Although whooping-cough is most prevalent in the earlier years of life, it is sometimes observed in adults up to forty or fifty, or even a still greater age.

Mortality.—In the following table will be found the mortality recorded from this disease in England and Wales during the last twenty years. It shows that the mortality from whooping-cough in this country is very considerable indeed, and of late years it has destroyed more children than any of the other so-called zymotic diseases, except diarrhœa.

Year.	Total Deaths.	Death-rate per million living.	Year.	Total Deaths.	Death-rate per million living.
1874	10,362	437	1884	11,476	425
1875	14,280	594	1885	13,106	481
1876	10,556	432	1886	12,936	470
1877	11,358	460	1887	11,251	404
1878	17,784	710	1888	12,287	436
1879	12,752	503	1889	12,225	430
1880	13,662	530	1890	13,756	478
1881	10,830	415	1891	13,612	468
1882	15,259	579	1892	13,406	455
1883	10,471	393	1893	10,176	342

It is to be noted that the death-rate in 1893 from this disease showed a considerable decline from the rates in the preceding years; it is, in fact, the lowest rate on record, the nearest approach having been 389 per million in the year 1840.

Etiology.—Recent observations render it probable that the contagious principle of whooping-cough is an organism analogous to those which produce so many other infective diseases, but at present no micro-organism has been satisfactorily shown to stand in causal relation to it. The disease undoubtedly spreads by infection from case to case, but such infection need not necessarily be direct, as the virus may be carried in clothing, &c. On the other hand, it is said to be one peculiarity of the contagion of whooping-cough that it is far less apt than most other contagia to be transmitted to a distance in an active state. We very rarely find the contagion of whooping-cough conveyed by persons not themselves affected with the disease; but some well-authenticated cases are on record of such having occurred, notably that observed by Bristowe, of a case in which a lady clearly conveyed the contagion of the disease from Sydenham to London upon her dress.

Whooping-cough is peculiarly infective in the early stages, and, like measles, is largely spread by the attendance at schools and other public gatherings of children who are sickening for it, but who have not, so far, manifested the characteristic symptoms. There is no evidence that this disease is ever disseminated by the agency of water, milk, food, or domestic animals; neither does it appear to be in any way connected with soil conditions.

The *incubation* period varies from four to fourteen days, and the period of infectiveness is not less than from six to eight weeks after the disease is declared.

Prevention resolves itself into isolation of the sick person, combined with destruction of all discharges from the air-passages, and the disinfection of clothing and bed linen used by the affected persons. The aërial diffusion of some volatile disinfectant may be a powerful adjunct to these preventive measures, but cannot replace disinfection or destruction of all discharges from the nose, pharynx, and lungs.

YELLOW FEVER.

This is an acute febrile disease of tropical and sub-tropical countries, characterised by jaundice and hæmorrhages, and due to the action of a specific virus. The disease prevails endemically in the West Indies, and in certain sections of the Spanish Main, from whence it occasionally extends, and, under suitable conditions, prevails epidemically in other countries. The first epidemic on record was in 1647, when it appeared in Barbadoes; a destructive pestilence of the same kind occurred at Philadelphia in 1693, and again in 1762, 1793, and 1802. It visited Mauritius in 1815, and Gibraltar in 1804, 1814, and 1828. It is endemic in the island of San Domingo, and more or less frequent throughout the West Indies and the adjacent coasts of Mexico, Guiana, and the southern United States. It first appeared on the Brazilian seaboard in 1849, at Buenos Ayres in 1858, and at Callao in Peru in 1853. Between 1780 and 1820 it repeatedly occurred in Cadiz and other Spanish ports, in 1821 at Barcelona, and later at Marseilles and Leghorn. There was a terrible epidemic in New Orleans in 1878, and in Florida in 1888. Lisbon was affected epidemically in 1857, and Swansea in 1865.

The disease exists also on the west coast of Africa. We may say that there are three main areas of infection:—(1) The focal zone, in which the disease is never absent, including Havana, Vera Cruz, Rio, and other Spanish-American ports. (2) Perifocal zone or regions of periodic epidemics, including the ports of the tropical Atlantic in America and Africa. (3) The zone of accidental epidemics, between the parallels of 45° N. and 35° S. latitude.

Influence of Climate and Season.—Yellow fever only flourishes in hot climates, and the regions in which it commonly prevails are all situated near the equator. The occurrence of a local epidemic within the temperate zone seems constantly to be associated with an exceptionally sultry state of the weather at the time. This was the case at St Nazaire in France when it developed itself there in 1861, and also at Swansea in 1865. In its endemic area, the worst months are generally July, August, and September, or periods of great heat and humidity. Although heat is necessary for the development of an epidemic, the disease, when once established, does sometimes persist in spite of cool weather, though it is invariably arrested by frost. But while it is always arrested by frost, its cause is not necessarily destroyed thereby, but may, like cholera, survive the winter and give rise to a fresh epidemic on the return of hot weather. This sequence of events has repeatedly been noticed in the case of infected ships passing from low to high degrees of latitude, and *vice versa*. According to Hirsch, a high degree of atmospheric moisture is generally favourable to yellow fever prevalence, but this is not a factor of universal importance. The possible connection of yellow fever to soil has already been considered on page 475.

Influence of Race, Sex, and Age.—Although no race can be said to be entirely exempt from yellow fever, there can be no doubt that the negroes are distinctly less susceptible than the whites. Negroes are less liable both to attack and to death in the event of attack. Both attacks and deaths are more numerous among males than females, but this is probably due to greater exposure, and to habits of life. As regards the influence of age, during epidemics in endemic localities, the majority of observed cases occur amongst persons in middle life, because visitors and other unacclimatised persons form a large proportion of the cases, and these people are for the most part adult males. In localities in which yellow fever is not actually endemic, but occurs in occasional epidemics, large numbers of children are attacked, for, unlike the children in endemic areas, they are not acclimatised. Sternberg quotes the following table from Bemiss, showing the age distribution of 905 cases occurring in New Orleans during the epidemic of 1878.

Age.	Cases.	Deaths.	Per cent.
Under 5 years of age, .	206	26	12·62
From 5 to 10 years of age,	233	20	8·58
„ 10 „ 20 „ „	183	9	4·92
„ 20 „ 40 „ „	232	39	16·81
„ 40 „ 60 „ „	47	6	12·77
„ 60 „ 80 „ „	4	2	50·00

The mortality seems to vary widely in different epidemics, being sometimes as low as 15 per cent., sometimes as high as 75 per cent.

Etiology.—With regard to the origin of yellow fever there have been great differences of opinion, and up to the present time the specific germ of the disease has not been satisfactorily demonstrated. Several observers, notably Domingos Freire of Brazil, and Carmona of Mexico, have described different micro-organisms which they regard as standing in causal relation to the disease, but in the face of Sternberg's report on the subject to the United States Government, we are unable to accept the organisms described by them as being the true cause of the affection. Formerly, yellow fever was regarded as being allied to if not actually a modified form of malaria. It is now, however, universally admitted that it is quite distinct from any form of intermittent or bilious remittent fever of malarial origin; for its geographical range is quite different, it is epidemic, it is transmissible from place to place, it consists of a single attack and protects against future invasion, albuminuria is constant, the spleen is not enlarged, and quinine, so far from being a specific remedy, is believed to be injurious.

Yellow fever is a disease of the sea-coast, and rarely prevails in regions with an elevation above 1000 feet. Its ravages are most serious in cities, particularly when the sanitary conditions are unfavourable. It is always most severe in the badly-drained, unhealthy portions of a city, where the population is crowded together in ill-ventilated, badly-drained houses. It has already been stated that yellow fever is endemic only in certain localities, and the evidence seems to show that when it has occurred elsewhere, its occurrence has been due to importation. There is practically no evidence of the latter day *de novo* origin of the disease. What was the original cause of the disease is still shrouded in mystery, but Audouard's view, referred to on page 476, may be cited as having much to commend it, namely, that it originated at all its endemic centres from the filth of the slave ships, which filth was the putrid dysenteric discharges of the sick negro. Regarded in this light, yellow fever has been given us in the dejecta of another race, which, brought in considerable quantities in the bilges of ships to ports, has there been discharged into harbour mud and soil. The mud of these harbours, and the foreshores of the adjacent lands, continue to be endemic foci of the disease.

One of the most striking features of yellow fever is that its infectious principle is often transported by ships. It may also be transported by fomites, and also be conveyed from place to place by the sick. The infection has often been found to cling to the hull, or perhaps to the cargo, of a particular vessel, after the crew have been paid off. It is believed in the

West Indies that a cargo of hides or sugar is favourable, and one of salt unfavourable, to the development of yellow fever on board, or to its transfer from one port to another, even when the crew escape. In not a few instances an outbreak of the disease has followed the arrival of ships which, although coming from infected places, have apparently had no actual sickness on board, either at the time of arrival or during the voyage. Similarly, outbreaks in towns have followed the arrival of apparently healthy people from infected localities.

Strong as is the evidence in favour of the view that yellow fever is a communicable disease, equally strong evidence is forthcoming to show that its communicability differs widely from that of small-pox, typhus, and other typically infectious maladies, and that in certain important respects yellow fever resembles, as regards communicability, cholera or enteric fever. Thus, when it prevailed in Lisbon in 1857, 182 persons are said to have left the city for different places in Portugal, carrying away with them the disease, and 86 died, but in no instance was it communicated to other persons in the places whither they went. It is a matter of very general experience that those in close attendance upon the sick do not specially contract the disease. In 1865 Buchanan, having investigated with great care the local epidemic at Swansea, came to the conclusion that "the evidence tending to negative personal contagion was about as strong as such evidence can by its nature ever be." Sternberg says this was also the experience of the physicians in charge of the Charity Hospital of New Orleans. "So long as the hospital and its vicinity remain uninfected, cases do not originate in the hospital, although yellow fever patients may be admitted to the wards with unacclimatised persons suffering with other diseases, and be cared for by susceptible attendants."

All these facts indicate that the yellow fever patient does not commonly infect others directly, but that he nevertheless gives off, probably with his discharges, the virus of the disease, and that this, under suitable conditions, is capable of infecting the particular locality, and of thus indirectly giving rise to the disease in others. Outside the body the micro-organism probably finds a habitat in the soil. It is also notable that the virus of yellow fever shows a special ability to attach itself to ships and dwellings.

There is at present no evidence that yellow fever is spread by infected water or milk, but the absence of evidence on these points must not be taken as excluding these agencies, and, judging from the analogy of cholera and enteric fever, there is an *a priori* probability that the cause is swallowed also in this case, and that it may possibly enter with the drinking water or food.

The *incubation* period is short, and varies from twenty-four hours to five days. One attack of yellow fever usually confers immunity, though even this immunity seems to be lost by long absence from endemic localities. This matter of those habitually residing in yellow fever localities enjoying a relative immunity raises the question whether such immunity is transmissible by heredity, or whether it is entirely acquired by each individual for himself. The weight of evidence is in favour of the view stated by Sternberg that "the creole child owes his immunity not to his parents, but to individual acclimatisation, and not unfrequently, to say the least, to a mild, unrecognised attack of yellow fever."

Prevention.—Recognising that yellow fever is a filth-begotten disease, the chief prophylactic measures will be (1) to provide adequate arrangements for the removal and disposal of excreta and refuse; (2) to provide free ventilation, and avoid overcrowding; (3) to ensure a pure and wholesome water-supply, with proper means of personal cleanliness. Once a case of the disease has occurred, the following special measures should be adopted:—(1) Isolation of the sick person; (2) disinfection of all discharges, especially the vomit and excreta, preferably these should be burned; (3) disinfection of all bedding and clothing; (4) free ventilation of the sick-room.

If an outbreak has occurred in a house or barrack, fumigation, scraping and limewashing of the walls, flushing of sewers, and thorough disinfection in every way must be carried out. Similar procedures are necessary in the case of a ship. Owing to the ready transportability of the contagion in fomites, baggage, cargo, &c., all these materials require careful fumigation and disinfection. The crews and passengers of ships arriving from infected localities should be medically inspected, and if in good health may be allowed to proceed to their destinations, after note has been taken of their names and addresses, and notification of the same made to the sanitary authorities of the localities concerned. The sick and apparently sick should be detained until all doubt of possible infectivity has been removed.

If an outbreak of yellow fever occur in a barrack, it is impossible then to attempt any cleansing of sewers; the only plan is to evacuate the barracks and isolate the infected body of men. This has been done many times in the West Indies with the best results. As a preventive measure, also, evacuation of the barracks and encampment inland, well away from foreshores, is a most useful plan. Before the barrack is reoccupied, every possible means should be taken to cleanse it; sewers should be thoroughly flushed; walls scraped and limewashed, and disinfection of the building, bedding, and clothing most scrupulously carried out. If a barrack cannot be altogether abandoned, the ground floors should be disused. There are several instances in which persons living in the lowest story have been attacked, while those above have escaped.

If it appears on board ship, take the same precautions with regard to evacuations, bedding, &c. Treat all patients in the open air on deck, if the weather permit; run the ship for a colder latitude; land all the sick as soon as possible, and cleanse and fumigate the ship.

A predisposition to the disease is caused by fatigue, especially when combined with exposure to the sun, by drinking, and by improper food of any kind which lowers the tone of the body. No prophylactic medicine is known, neither has any satisfactory method of preventive inoculation been devised, though at one time Freire's efforts in this direction were suggestive of success.

BIBLIOGRAPHY AND REFERENCES.

Abel and Claussen, "Untersuch. u. die Lebensdauer der Cholervibrionen in Fäkalien," *Centr. f. Bakter.*, xvii. No. 3, p. 77; also No. 4, p. 118. Adami, "Notes upon an Epizootic of Rabies," *Brit. Med. Journ.*, Oct. 12th, 1889. Adams, "The Relationship between the Occurrence of Diphtheria and the Movements of Subsoil Water," *Proc. 8th Internat. Cong. of Hygiene and Demogr.*, Buda-Pesth, 1894. Anderson, "Tuberculosis and its Prevention," *Journ. Amer. Med. Assoc.*, 1894, p. 300. Andrewes and Parry Laws, *On the Micro-organisms of Sewage: their relation to Sewer-air, and the relation of the Bacillus of Typhoid Fever to Sewage*; printed by order of Main Drainage Committee of the London County Council, 1894.

Ballard, *On Epidemic Diarrhœa*, Report of Med. Off. to Local Govern. Board, 1887; also *Report on Middlesborough Epidemic*, *Idem*, 1889; also *Report on an Acute Specific Disease Characterised by a Peculiar Diarrhœa—the so-called Welbeck Disease*, Supp. to 10th Rep. Local Government Board, 1880–1. Barnes, "On the Etiology of Diphtheria," *Brit. Med. Journ.*, July 28th, 1888. Barry, *Report on Small-pox*

Epidemic at Sheffield, 1887–8, to Local Govern. Board, published 1889 ; also *Report on the Origin and Progress of the Western Diffusion of Cholera during* 1892, Report of Med. Off. to Local Govern. Board, 1892–3, p. 117 ; also *Report on the Prevalence of Enteric Fever in the Tees Valley*, Supp. to 21st Annual Report of Local Govern. Board, 1891–2. BELLEW, *The History of Cholera in India*, 1862–81, Lond., 1885. BERAUGER-FERAUD, *Traité théorique et clinique de la Dysenterie*, Paris, 1893. BRUCE-LOW, *Report on some Localised Occurrences of Cerebro-Spinal Meningitis in certain Parishes of the Eastern Counties*, 20th Report of the Local Govern. Board, Report of Med. Off., p. 117. BUCHAN and MITCHELL, "Influence of Weather on Mortality," *Journ. Scottish Meteorological Society*, July 1874.

CARTER, "Aspects of the Blood-spirillum in Relapsing Fever," *Brit. Med. Journ.*, ii., 1881, p. 547. CLEMOW, *Epidemic Influenza*, April 1890 ; also *The Cholera Epidemic of* 1892 *in Russia*, Lond., 1893 ; also "The Spread of Cholera by Water," *Brit. Med. Journ.*, ii., 1894, p. 801. COPEMAN, "Variola and Vaccine : their Manifestations and Inter-relationship in the Lower Animals," *Trans. Epid. Soc.*, 1892–3, p. 142. COPPEN-JONES, "Uber die Morphologie u. Systematische Stellung des Tuberkelpilzes u. über die Kolbenbildung bei Aktinomykose u. Tuberkulose," *Centr. f. Bakter.*, 1895, xvii. No. 1. CREIGHTON, *Unconscious Memory in Disease*, Lond., 1886 ; also *History of Epidemics in Britain*, Camb., 1891. CROOKSHANK, *History and Pathology of Vaccination*, Lond., 1889. CUNNINGHAM, "On some Species of Choleraic Commas occurring in Calcutta," *Scientific Memoirs of Med. Off. of Army of India*, Part vi., 1891. CZAJKOWSKI, "Uber die Mikroorganismen der Masern," *Centr. f. Bakter. u. Parasitenkunde*, Bd. xviii., 1895, p. 517.

DAVIDSON, *Geograph. Pathology*, Edin., 1892 ; also Article on "Malarial Diseases," in *Hygiene of Warm Climates*, Lond., 1893, p. 113—this article contains good bibliographical references on the subject. DAWSON-WILLIAMS, "The Route of Asiatic Cholera in 1892," *Brit. Med. Journ.*, Sept. 17, 1892. DONOVAN, "On the Microbian Doctrine of Yellow Fever," *Trans. Epid. Soc.*, N.S., vii., 1887–8, p. 80. DOWNES, "Contribution to a Study of the Causes of Epidemic Diphtheria," *Practitioner*, vol. xxxi. p. 471 ; vol. xxxii. p. 67. DUNCAN, *The Prevention of Disease in Tropical Campaigns*, Lond., 1888. DUNN, "Bacteriological Origin of Puerperal Sepsis," *Richmond, U.S.A., Medical Journal*, 1894, p. 201.

EDWARDES, *Vaccination and Small-pox*, Lond., 1892.

FARR, *Report on Cholera Epidemics in England*, Supplement to the 29th Annual Report of Registrar-General. FAYRER, *Tropical Dysentery and Chronic Diarrhœa*, Lond., 1881. FEHLEISEN, *Die Ætiologie des Erysipels*, Berlin, 1883 ; an English translation by Ogilvie, Lond., 1886. FINKLER, *Die Acuten Lungenentzundungen als Infectionskrankheiten*, Wiesbaden, 1891.

GOLGI, "On the Malarial Parasite," *Fortschritte der Medicin*, 1889, No. 3. GREENFIELD, *On the so-called Wool-sorters' Disease*, 11th Report Local Govern. Board, Rep. of Med. Off., p. 207. GREENHOW, *Report on Districts with excessive Mortality from Lung Disease*, 3rd and 4th Reports of Med. Off. to Privy Council, 1860–61. GRESSWELL, "Diphtheria as a Chronic Malady in Particular Individuals, with Liability in them to Recrudescence," *Trans. Epid. Soc.*, N.S., vol. v., 1885–6 ; also *On the Natural History of Scarlet Fever*, Lond., 1890.

HAMER, *On the Conditions determining Insusceptibility*, 21st Rep. Local Govern. Board, 1891–2, Rep. of Med. Off., p. 201. HANKIN, "Observations on Cholera in India," *Indian Med. Gazette*, March 1895, p. 92. HANSEN, "On the Leprosy Bacillus," Virch. *Archiv.*, Bd. lxxix. and xc. HELLIN, "Das Verhalten der Cholerabacillen in aëroben u. anaëroben Kulturen," *Arch. f. Hyg.*, 1894, Bd. xxi. No. 3, p. 308. HEUBNER, Article upon "Dysentery," in Ziemssen's *Encyclopædia*, vol. i., Lond., 1875. HINSDALE, "The Comparative Rarity of Pulmonary Tuberculosis in the Highlands of Pennsylvania and the adjacent Counties of New York," *Amer. Med. News*, ii., 1894, p. 113. HIRSCH, *Geograph. and Historical Pathology*, New Sydenham Society's Translation, Lond., 1886. HIRSCHBERGER, *Experim. Beiträge zur Infektion der Milch tuberculöser Thiere*, Münschen, 1889.

JAMES, *Report on the Epidemic of Bubonic Plague in Hong Kong in* 1894, Army Medical Department Report, vol. xxxv. p. 330.

KARTULIS, "On the Amœba Coli," *Centr. f. Bakter. u. Parasiten*, Bd. vii. 2 ; also "Zur Ætiologie der Dysenterie in Ægypten," Virch. *Archiv.*, 1885. KELLOG, "On the Identity of B. coli with B. Eberth," *New York Med. Medical and Bacteriological*

Review, No. 2, 1894, p. 29. KELLY, "On the Relation of Soil to Diphtheria," *Lancet*, ii., 1886, p. 350; also "On an Outbreak of Enteric Fever in West Worthing apparently due to Pollution of the Water Mains through Hydrants," *Public Health*, Jan. 1894. KELSCH and KIENER, *Traité des Maladies des Pays chauds*, Paris, 1889. KEMPNER, "Uber den vermeintlichen Antagonismus zwischen dem Choleravibrio u. dem B. coli commune," *Centr. f. Bakt.*, 1895, Bd. xvii. No. 1. KLEIN, Article on the "Pathology of the Infectious Diseases," in vol. ii. of Stevenson and Murphy's *Treatise on Hygiene*, Lond., 1893; also *On Diseases occurring naturally in Cats in Association with Human Diphtheria*, 19th Rep. Local Govern. Board, Rep. of Med. Off., 1889, p. 162; also various papers on the *Etiology of Diphtheria* in 18th, 19th, and 20th Reports, *Idem*; also "On Anti-cholera Vaccination," *Brit. Med. Journ.*, March 25th, 1893, p. 632; also "On the Etiology of Typhoid Fever," *Brit. Med. Journ.*, ii., 1894, p. 797; also on same subject in App. to Rep. Med. Off. Local Govern. Board, 1892–3, p. 345. KOCH, "Further Researches on Cholera," *Brit. Med. Journ.*, Jan. 1886, p. 6; also *Idem*, 1892, ii. p. 540; also "Conferenz zur Erörterung der Cholerafrage," *Berliner Klin. Woch.*, 31, 1884.

LAFLEUR and COUNCILMAN, "On Amœbic Dysentery," *John Hopkins Hospital Reports*, vol. ii. Nos. 7, 8, and 9. LAVERAN, "L'Etiologie du Paludisme," *Revue Scientifique*, 1894, ii. No. 15, p. 449; also *Paludism*, New Sydenham Soc., 1893. LEWIS, "Cholera in Relation to certain Physical Phenomena," from his *Path. and Phys. Researches*, London, 1888. LINGARD, *On the Relation of Scrofula, Lupus, and Tuberculosis*, 18th Rep. Local Govern. Board, Rep. Med. Off., 1888, p. 462. LONGSTAFF, *The Geographical Distribution of Diphtheria in England and Wales*, Supplement to Rep. Med. Off. Local Govern. Board, 1887; also "Phthisis, Bronchitis, and Pneumonia," *Trans. Epidem. Soc.*, 1883, vol. ii., N.S.; also *Studies in Statistics*, Lond., 1890. LÖSCH, "On the Amœba Coli," Virch. *Archiv. f. Path. Anat.*, 1875, Bd. lxv. p. 196.

MACNAMARA, *The History of Asiatic Cholera*, Lond., 1876. MAGGIORA, "On the Amœba Coli," *Centr. f. Bakterien u. Parasit.*, Bd. xi. Nos. 6 and 7—this article contains a good bibliography. MANSON, "On the Nature and Significance of the Crescentic and Flagellated Bodies in Malarial Blood," *Brit. Med. Journ.*, ii., 1894, p. 1306. MARCHIAFAVA and CELLI, "Untersuch. über die Malaria Infektion," *Fortschritte der Medicin*, 1885, pp. 339 and 787; also two Monographs on *Malaria and the Parasites of Malarial Fevers*, New Sydenham Soc., 1894. MARTIN, *On the Chemical Pathology of Diphtheria*, 21st Rep. Local Govern. Board, Rep. Med. Off., 1891–2, p. 147; also *On the Chemical Pathology of Anthrax*, 19th and 20th Rep. Local Govern. Board, Rep. Med. Off., pp. 255 and 235. MASSIATIN, "On the Amœba Coli," *Centr. f. Bakter. u. Parasit.*, Bd. vi. Nos. 16 and 17. M'FADYEAN, "The Suppression of the Contagious Diseases of Animals," *Brit. Med. Journ.*, ii., 1894, p. 758. M'VAIL, *Vaccination Vindicated*, Lond., 1887. MEWINS, "Zur Epidem. der Diphtherie," *Berl. Klin. Wochsch.*, 1894, No. 42, p. 954. MOORE, "Pythogenic Pneumonia," *Dublin Journ. Med. Sci.*, May 1875. MUNRO, "On an Outbreak of Scarlet Fever connected with an Udder Disease of Cows," *Public Health*, Aug. 1893, p. 345.

NEISSER, "On the Leprosy Bacillus," Virch. *Archiv.*, Bd. lxxxiv. NETTEN-RADCLIFFE, *On the Modern History of Levantine Plague*, Rep. Med. Off. Privy Council, No. vii., 1875.

OBERMEYER, "On the Spirillum of Relapsing Fever," *Centr. f. d. Med. Wissensch.*, 1873, No. 10. OGATA, "Uber d. B. Dysenteriæ," *Centr. f. Bakt. u. Parasit.*, March 9th, 1892.

PARSONS, "On the Association of Diphtheria with Scarlet Fever," *Trans. Epidem. Soc.*, 1883–4; also *On an Outbreak of Scarlet Fever, with associated Diphtheria and Sore Throat, occurring in the Macclesfield Rural and Urban Sanitary Districts in connection with a particular Supply of Milk*, 19th Rep. Local Govern. Board, 1889, Rep. Med. Off., p. 89; also *Report on an Epidemic of Pneumonia at Scotter, Lincolnshire*, 20th Rep. Med. Off. Local Govern. Board, 1890, p. 95; also *Reports on the Influenza Epidemics*, 1889–90, to the Local Govern. Board, 1891 and 1893. PFEIFFER, "On the Bacillus of Influenza," *Deutsche Med. Wochsch.*, No. 2, 1892. PFUHL, "Beitrag zur Lehre von dem Cholera Epidemien auf Schiffen," *Zeitch. f. Hyg.*, xviii. heft 2. POWELL, "On Acute Lobar or Croupous Pneumonia," *Brit. Med. Journ.*, ii., 1895, p. 1149. POWER, *Report upon an Outbreak of Milk Scarlatina in London in 1885*, Rep. Med. Off. Local Govern. Board, 1885, p. 73; also *Report upon the Influence of the Fulham Small-pox Hospital upon the Diffusion of the Disease*, 14th and 15th Rep. of Med. Off. Local Govern. Board, 1884–5; also *Report upon Epidemic of Diphtheria in York Town and Camberley*, 16th Rep. Med. Off. Local Govern. Board, 1886.

RANSOME, "On the Form of the Epidemic Wave," *Trans. Epid. Soc.*, 1881–2; also Milroy Lectures "On the Etiology and Prevention of Phthisis," *Brit. Med. Journ.*, vol. i., 1890. REHN, "Typhoide Erkrankung eines 2-jahrigen Kindes nach dem Genuss unzureichend abgekochter Milch. Infektion durch Bacterium coli," *Hyg. Rundschau*, 1894, No. 21, p. 964. *Report of the English Commission on Pasteur's Researches on Hydrophobia*, 1886. *Report of Royal Commission on Tuberculosis*, Lond., 1895. REYBURN, "The Life History of the B. Tuberculosis in its relation to the Cure of Tuberculosis in Man," *Medical Age*, New York, 1894, p. 458. RODET, ROUX, and ARLOING, "On the Identity of B. coli with B. Eberth,' *Trans. Internat. Cong. Hygiene*, Lond., 1891, ii. p. 272. ROUX, "Upon Preventive Inoculation," Croonian Lecture before Royal Society, *Brit. Med. Journ.*, i., 1889, p. 1269.

SCHÄFER, "On the Persistence of Löffler's Bacillus after Diphtheria," *Brit. Med. Journ.*, Jan. 12th, 1895. SEATON, *Report on Epidemic Small-pox in the United Kingdom*, Rep. Med. Off. Local Govern. Board, 1874. SHAKESPEARE, *Report on Cholera in Europe and India*, Washington, U.S.A., 1886. SHARMAN and LAMKIN, "The Relationship between Bovine and Human Tuberculosis," *Med. Record*, ii., 1894, No. 13, p. 412. SIMON, *Public Health Reports*, more especially that contained in 9th Annual Rep. to Privy Council, 1866, and contained in vol. ii. of the Reports as republished by Sanitary Institute, 1887. SISLEY, *Epidemic Influenza*, London, 1891. SOBERNHEIM, "On the Intra-peritoneal Cholera Infection of Guinea-pigs," *Revue d'Hygiene*, 1893, No. 22; also *Practitioner*, March 1894, p. 223. SPEAR, *Report on the so-called Wool-sorters' Disease*, Rep. Med. Off. Local Govern. Board, 1880–1, p. 66; also Report for 1882, p. 82. SQUIRE, "Measles Epidemics, Major and Minor," *Trans. Epidem. Soc.*, 1892–3. STERNBERG, "Report on Yellow Fever to United States Government," *Journ. Amer. Med. Assoc.*, Nov. 30th, 1889. SYKES, "On the Increase of Diphtheria Mortality in London," *Practitioner*, Aug. 1894.

THOMPSON, "Notes on the Observation of Malarial Organisms in connection with Enteric Fever," *Trans. of Assoc. Amer. Physic.*, 1894, p. 110. THOMSON, *On an Epidemic of Enteric Fever in Bow, Worthing, and the Villages of Broadwater and West Tarring*, Report to Local Govern. Board, 1894. THORNE-THORNE, *On an extensive Epidemic of Enteric Fever at Red Hill, Caterham, and adjoining places*, 9th Report Local Govern. Board, 1880, Appendix 8; also *Report on the Recent Occurrence of Epidemic Cerebro-Spinal Meningitis in the Basin of the Mediterranean*, Rep. Med. Off. in 18th Rep. Local Govern. Board, 1888, p. 365; also *Diphtheria, its Natural History and Prevention*, Milroy Lecture, 1891. TOMKINS, "On Epidemic Diarrhœa in Leicester," *Brit. Med. Journ.*, July 27th, 1889. THRESH, "Diphtheria in relation to Manure Nuisances," *Practitioner*, Sept. 1892; also "On an Epidemic of Diphtheria associated with Scarlet Fever and Measles," *Practitioner*, Feb. 1893. TURNER, *On the relation of Diphtheria to the Lower Animals*, Report Local Govern. Board, 1886, Supplement by Med. Officer.

VILLEMIN, *Etude sur la Tuberculose*, Paris, 1868.]

WASHBOURN, "On Acute Pneumonia," *Brit. Med. Journ.*, ii., 1895, p. 1154; also "On Immunity," *Trans. Epidem. Soc.*, April 1895, N.S., vol. xiv. WEIBEL, "Untersuch. u. die Infektiositat des Choleravibrio und über sein Verhaltniss zum Vibrio Metschnikovii," *Archiv. fur Hygiene*, Bd. xxi., 1894, p. 22. WHITTAKER, "Predisposition to Phthisis," *Trans. Med. and Chir. Faculty of Maryland*, 1894, p. 64. WHITELEGGE, "Changes of Type in Epidemic Diseases," Milroy Lecture, 1893, *Brit. Med. Journ.*, i., 1893; also "On Age, Sex, and Season in Relation to Scarlet Fever," *Trans. Epidem. Soc.*, N.S., vii., 1887–8, p. 153. WILLOUGHBY, "Retrospect of the successive Epidemics of Cholera in Europe and America," *Trans. Epid. Soc.*, N.S., vol. x., 1890–1. WOODBRIDGE, "Typhoid Fever," *Journ. Amer. Med. Assoc.*, 1894, p. 311. WOODHEAD, "An Address on the Channels of Infection in Tuberculosis," *Lancet*, ii., 1894, p. 957. WRIGHT and BRUCE, "On Haffkine's Method of Vaccination for Cholera," *Brit. Med. Journ.* Feb. 4, 1893, p. 227.

CHAPTER XIII.

DISINFECTION

THE term *disinfectant*, which has now come into popular use, has unfortunately been employed in several senses. By some it is applied to every agent which can remove impurity from the air; by others to any substance which, besides acting as an air purifier, can also modify chemical action, or restrain putrefaction in any substance, the effluvia from which may contaminate the air; while, by a third party, it is used only to designate the substances which can prevent infectious diseases from spreading, by destroying their specific poisons. This last sense is the most correct, and it is that in which it is solely used here. The mode in which the poisons are destroyed, whether it be by oxidation, deoxidation, or arrest of growth, is a matter of indifference, provided the destruction of the poison is accomplished.

To those substances which suspend vitality and the power of propagation of micro-organisms, thereby restraining or absolutely preventing decomposition, the general term *antiseptics* should be applied. Those substances which merely oxidise the products of decomposition, and thereby destroy or correct offensive odours, are best described as *deodorants*. In a great many instances the substances which are recommended as disinfectants are little more than deodorants, or, at most, antiseptics or means of checking and delaying putrefaction.

The true principle of disinfection is to attack the specific poisons of disease at their seats of origin, as far as these are accessible to us. It was the instinct of genius which led William Budd to point out that the way to prevent the spread of scarlet fever is to attack the skin from the very first; to destroy the poison in the epidermis, or, failing that, to prevent the breaking up and passage into the air of the particles of the detached epidermic scales. Oily disinfectant inunctions of the skin, and the most complete disinfection of the clothing which touches the skin of the patient, are the two chief means of arresting the spread of scarlet fever. The rules for small-pox are almost identical, though it is more difficult to carry them out. In enteric fever, cholera, and dysentery the immediate destruction of all particles of infection in the stools and urine by strong chemical reagents, and the prevention of the poison in its active state getting into sewers or drinking water or food, are the measures obviously demanded by the peculiarities of these special diseases.

The more completely these points are investigated, and the more perfectly the breeding-places in the body are known, the more perfect will be our means of disinfection.

Disinfectants are physical and chemical: the chief physical agent is heat; the chief chemical agents are perchloride of mercury, carbolic acid, and chloride of lime, with certain gaseous bodies of strong germicidal power.

In actual practice, disinfection proper is largely aided by the preliminary removal of infection by the scraping and stripping of paper from walls, the washing and sweeping of floors, to say nothing of air perflation, and the washing, beating, shaking, and exposure of clothes. These procedures, excellent in their way, are uncertain and incomplete; the destruction of germs, or true disinfection, is only attainable by either heat or chemical means. For articles of small value, the safest plan is to burn them.

The value of fresh air and sunlight as aids to disinfection must not be overlooked. Direct sunlight, and especially the most highly refrangible, ultra-violet, rays of the spectrum, have a powerfully restraining action on the growth of bacteria, though neither oxidation nor solar action are actually germicidal, themselves, as to spores. Besides these agencies, a comparative purification of the air can be effected by many substances in use for this purpose, but these latter must be regarded as supplemental to, not as substitutes for, true disinfectants.

Heat as a Disinfectant.—Tyndall was the first to show that, whilst prolonged boiling failed to sterilise an infusion, successive heatings for a short time, even below the boiling point, were successful. The explanation proposed is, that during the period of latency the spores are in a hard state capable of resisting high temperature, but that just before the period of active germination they become softened, and therefore amenable to the influence of heat. As, however, spores in various stages may exist in the same fluid, successive heatings are necessary so as to arrest each group at the proper time; but by repeating the heatings sufficiently often an infusion may be sterilised at a point below the boiling point of water. This method of intermittent heating is now in general use for sterilising cultivating fluids. Important in all ways, this question of the nature of contagia is especially so in a practical sense, viz., that of the easy or difficult destruction of these agents. It does not, however, follow that ordinary putrefactive bacteria are identical with those which may be supposed to produce disease. It is probable that they are quite different, and that disease bacteria (except *B. anthracis*) are more easily destructible by heat. According to Klein *micrococci* of scarlatina are killed at 85° C. (185° F.).

The experiments by Koch on heat as a disinfectant led him to the following conclusions:—

1. As to *dry heat.* "Sporeless bacteria are destroyed in 1½ hour by hot air at a temperature slightly exceeding 100° C. Spores of fungi require 1½ hour at 110° to 115° C.; spores of bacilli require 3 hours at 140° C. Heat penetrates so slowly that even for articles of moderate size, such as pillows, 3 to 4 hours' exposure at 140° C. is insufficient. Exposure for 3 hours to 140° C., which is necessary for thorough disinfection, damages most fabrics more or less."

2. As to *moist heat.* Steam under pressure killed anthrax spores after ten minutes' exposure to a temperature of 110° C. Steam at atmospheric pressure destroyed anthrax spores after exposure of one hour. Koch concludes that in every respect exposure to a current of steam at 100° C. is the most satisfactory method.

Parsons found that the spores of *B. anthracis* were killed after 4 hours' exposure to a dry heat of 212° to 216° F. or of 245° F. for 1 hour. Bacteria without spores were killed in 1 hour at 212° to 218° F., while boiling for one minute, or exposure to steam at 212° F. for 5 minutes, was sufficient to destroy spores.

The greater power of moist heat is principally due to the large amount of latent heat in steam. To convert 1 ℔ of water at 212° F. into steam at

212° F., requires nearly 1000 times as much heat as it does to raise 1 ℔ of water from 211° to 212° F. Conversely, a corresponding amount of heat is liberated when 1 ℔ of steam at 212° F. is condensed into water at 212° F. When an object is heated by being placed in hot dry air, not only is no latent heat yielded up to it by the air, but, on the other hand, before the object can attain the temperature of 212° any water which it may contain (and all textile fabrics, even though dried at ordinary temperatures, retain a quantity of moisture) must be evaporated; in this evaporation, heat passes into the latent form, and the attainment of the desired temperature is thus delayed. When steam penetrates into the interstices of a cold body it undergoes condensation in imparting its latent heat to the body. When condensed into water it occupies only a very small fraction of its former volume. To fill the vacuum thus formed more steam presses forward, in its turn yielding up its heat and becoming condensed, and so on until the whole mass is penetrated. "On the other hand, hot air in yielding up its heat undergoes contraction in volume, but only to a very small extent as compared with that undergone by steam in condensing into water" (Wynter-Blyth).

Dry heat is inferior to moist heat, owing to the difficulty of ensuring the complete penetration of the necessary high temperature throughout the interior of bulky articles. If pillows, bales of goods, &c., are simply placed in a hot-air apparatus, the outside may be scorched, while the inner parts have never reached the proper temperature.

Whitelegge, working with Ransom's hot-air apparatus, obtained the following results; the escaping air having a temperature varying from 245° to 260° F.—a registering maximum thermometer being placed beneath layers of blankets within the apparatus.

Duration of Exposure.	2 Layers.	4 Layers.	6 Layers.	12 Layers.	18 Layers.
	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
4 Hours,	220	206	190	162	139
6 ,,	226	214	208	174	153
8 ,,	230	221	215	196	182

When moist heat was used, a temperature of 212° F. was obtained beneath sixteen layers of blanket after a maximum exposure of seventeen minutes. This temperature, it is to be noticed, was not reached even after eight hours with dry heat with only twelve layers of blankets.

As the result of a large number of experimental observations upon the effect of heat as a disinfectant, it may be accepted that thorough penetration is absolutely essential, though the actual amount of heat and the duration of its application may vary.

As a general rule, it may be said that boiling for a quarter of an hour, or, if this is not practicable, exposure to moist heat (steam) of 212° F. at ordinary pressure for one hour, will render any article absolutely safe. Dry heat is neither so safe, nor is it so easy of thorough application; if used, a temperature of from 245° to 250° F. should be attained and maintained throughout for four hours, even at the risk of some damage to fabrics. This statement is somewhat in excess of theoretical requirements, or what laboratory experiments indicate to be the needs of the case, but it is always advisable to err on the safe side, and keep up the temperature either rather higher or longer than is found to be the experimental limit.

The question of temperature has been much discussed, and with regard to dry heat especially, is of much importance. It is desirable to get as high a temperature as possible so as to ensure the destruction of infective matter. On the other hand, the temperature must not be too high, for fear of destroying the fabrics.

On the Liability to Injury of Articles Disinfected by Heat.—The possible injuries to fabrics when disinfected by heat are practically the following :—

(1) Scorching or partial decomposition of organic substances by heat. In its earliest stage this manifests itself by change of colour, of texture, and of weakening of strength. Scorching occurs sooner in woollen materials, such as flannels and blankets, than with cotton or linen. Most materials will bear a temperature of 230° F. without much injury, but when this temperature is exceeded, signs of damage soon begin to show. Flannel and blankets exposed to steam at 260° F. for half an hour acquire a distinct yellow tinge, and their tensile strength is somewhat diminished. Exposed to dry heat of 220° F. for four hours, or a steam heat of 228° F. for half an hour, white flannel acquires a slight yellow tinge, but its textile strength is not appreciably impaired. Cotton, linen, and silk will bear a dry temperature of 230° F. for four hours without little alteration, and also moist heat of 250° F. for half an hour with little change, beyond a slight loss of glaze. Feathers become yellowish and brittle after four hours' exposure to steam at 260° F.

(2) Overdrying renders things very brittle ; but this injury can be considerably minimised by allowing the materials which have been subjected to dry heat to remain in the air long enough to recover their natural degree of moisture before manipulating them.

(3) Fixing of stains so that they will not wash out. This property of heat is a very inconvenient one from our present point of view, and is specially marked in the case of albuminous materials coagulable by heat, such as blood or excreta. In order to remove organic stains, the cloth or garment must be steeped in cold water. When the grosser dirt has been removed by soaking and rubbing in cold or tepid water, the articles may be boiled without injury.

(4) Melting of fusible substances, as glue and wax. This injury does not often occur, and is most commonly met with in attempts to disinfect books and leather goods by heat.

(5) Alterations in colour, gloss, and shrinkage of dyed and finished goods. Dry heat causes little shrinkage in woven materials. Moist heat, on the other hand, or even wetting without much heat, causes permanent shrinkage in woollen goods, as cloth, flannel, and blankets. To this drawback must be added another, namely, the loss of elasticity and fluffiness, upon which the warmth and softness of woollen materials depend. This elasticity is due to the natural grease of the wool, and is rapidly removed by boiling in water or exposure to moist heat. These materials may be washed in cold water, or exposed to dry heat of moderate temperature without much deterioration, but a frequent repetition of these processes brings about in time a change similar to that effected by boiling water.

(6) Wetting, as when ordinary steam is used, is often undesirable in the case of some kinds of goods, for it produces shrinkage, and causes the colours to run. This wetting is obviated when the steam is used at high temperatures, being superheated by the higher degree of heat corresponding to the extra pressure under which it is applied.

Forms of Apparatus for Disinfection by Heat.—From what has been said, it will be readily seen in what manner heat as a disinfecting agent is best applied. In the earlier forms of disinfecting chambers, a dry heat was employed. In the more modern forms, steam has been used with the best results.

The most important requisites of a disinfecting chamber are: (*a*) uniform distribution of heat in the interior; (*b*) a constant temperature maintained during disinfection; (*c*) means for ascertaining the actual temperature of the interior at any given moment (Parsons). In apparatus heated by steam, these three requirements are satisfactorily met, and in some of the best dry-heat chambers the results are also fair, but in the majority of them the first condition is not fulfilled.

One of the most generally used in this country, and a typical form of steam apparatus for disinfection by moist heat, is that of Washington Lyon. It consists of an oval chamber with double walls, and a door at each end fastened by screw-clamps, one for the introduction of infected articles, and the other for their removal when the process of disinfection is complete. Steam is discharged into the apparatus by two pipes, the one communicating with the cavity formed by the double walls, and the other with the interior of the chamber, the amount of pressure in each case being indicated by pressure gauges. The object of surrounding the chamber with the "jacket" of steam is to prevent loss of heat, and to check condensation. The articles to be disinfected are conveyed to a room at the inlet end of the apparatus, and which must be completely separate from the receiving room at the other or outlet end. The chamber is fitted with a light frame on wheels, or wire cage, in which clothing, &c., can be placed; these are then pushed into the chamber along rails, and the door closely and strongly fastened. Steam, at a pressure of 30 ℔ to the square inch, having a temperature of 273° F., is first turned into the outer jacket, so as to raise the temperature of the inner chamber to sufficiently great a heat as to prevent condensation of the steam when subsequently turned into it. At the ordinary pressure of the air, water boils at 212° F., and the moment the temperature falls below that point steam condenses. At a pressure of two atmospheres, or 28 ℔ on the square inch, water boils at, and steam will not condense at, a lower temperature than 249° F.; while at a pressure of 44 ℔ to the square inch, or 30 ℔ above that of ordinary air, the boiling point of water and condensing temperature of steam is 273° F. If, therefore, the temperature of the inner chamber be kept at this point by steam at this temperature being made to circulate around it in an outer jacket, the steam when turned on into it will be kept constantly superheated, and will not condense into moisture unless the temperature fall below that point. After the temperature of the inner chamber is sufficiently raised by the admission of steam to the outer jacket, the steam is then turned on into it, and kept on for some twenty minutes or so, or even longer, according to the nature and number of the articles within it needing disinfection. When this is done, the steam is cut off from the inner chamber and left on in the outer jacket only. The inner chamber thus becomes a drying cell, and any dampness which the articles, put in for disinfection, may have acquired thoroughly driven off before they are withdrawn. Often the steam pressure employed is not more than 10 ℔ per square inch in the cavity of the walls, and only some 5 ℔ in the interior, but these lessened pressures are only used when high temperatures are not required. To attain and maintain a temperature of 250° F., a pressure of at least 28 ℔ must be employed, and for higher temperatures even a greater pressure still.

A modification of the above disinfecting chamber is that of Alliott and Paton, the principal feature of which is that a vacuum producing apparatus is so attached that the air is exhausted not only from the inner chamber but from the interstices of the articles to be disinfected, thus facilitating the penetration of steam. Further, on the completion of the process, the steam is exhausted by the air pump, so that no deposit of moisture takes place when the doors are opened, leaving the articles, therefore, quite dry. This same apparatus can be also used as a hot-air or dry-heat disinfector.

The apparatus of Geneste-Herscher et Cie, which is extensively used in France, acts also by steam at high pressure. It has been very favourably reported upon. Another form is that of Goddard, Massy, & Warner; in it a pressure of 20 ℔ is used, the temperature of the steam being 240° F.

Unfortunately, all the foregoing high-pressure steam disinfectors are expensive, a fact which renders their general employment by local authorities somewhat difficult. This difficulty seems to have been overcome in the case of Reck's steam disinfector, which is cheaper and at the same time efficient. Its special features are (1) the use of low-pressure steam, delivered to the apparatus by an automatic regulator at a rate which cannot be exceeded; (2) the absence of any steam jacket; and (3) a cold shower introduced into the chamber which has for its object the speedy removal of all steam from the interior. This cold shower is prevented from injuring the clothes by a shielding arrangement which distributes the water over a large surface and completely protects the articles from moisture. The penetrating power of the low-pressure steam (1½ ℔), the temperatures reached in various thicknesses of material, the amount of moisture left in the articles after disinfection, and the destructive power of the apparatus upon bacteria have given satisfactory results. The following table shows the temperature reached in various cases:—

In 15 minutes—Folds of Blankets.			In 35 minutes.		
4 Folds.	8 Folds.	16 Folds.	In Chamber.	In 16 Folds of Blanket.	Between Mattresses.
219° F.	218° F.	212° F.	216° F.	220° F.	211° F.

Thirty-five minutes are recommended as a desirable time for articles to remain in the chamber of this apparatus for disinfection. Moreover, its simplicity is likely to be of immense benefit in places and institutions where the more complicated high-pressure disinfectors are often unworkable.

A simple and comparatively inexpensive non-pressure steam disinfecting apparatus has recently been brought out by Thresh, and by means of which it is said that a moist temperature, exceeding that of steam at normal pressure and under ordinary conditions (212° F.), is obtained. The principle is a new one, and consists in using water to which certain saline ingredients have been added in order to raise its boiling temperature to 225° F.

Fig. 116, which represents in section a Thresh's disinfector, will enable the reader to understand the construction of the apparatus. The central chamber for infected articles, A, is surrounded by a jacket, B, containing the saline solution which is heated by the furnace, K. The steam given off is directed either to the chamber or into the chimney by a valve, G, and in the former case is distributed in the disinfecting chamber by a plate, C, before passing off into the chimney by a pipe, D. As the water evaporates, an equivalent supply is introduced automatically from a cistern, I, with a ball valve arrangement supplied by a pipe, L. After the disinfecting process, the steam is turned off from the chamber and allowed to escape into the furnace flue, and by means of a coil of tubes, E, immersed in the saline solution, air, which enters at the valve, F, is heated and passes through the chamber in order to dry the articles. This apparatus is an ingenious one and is likely to come into general use. Experiments indicate that a moist temperature of 225° F. is readily maintained, and disinfection efficiently performed within an hour.

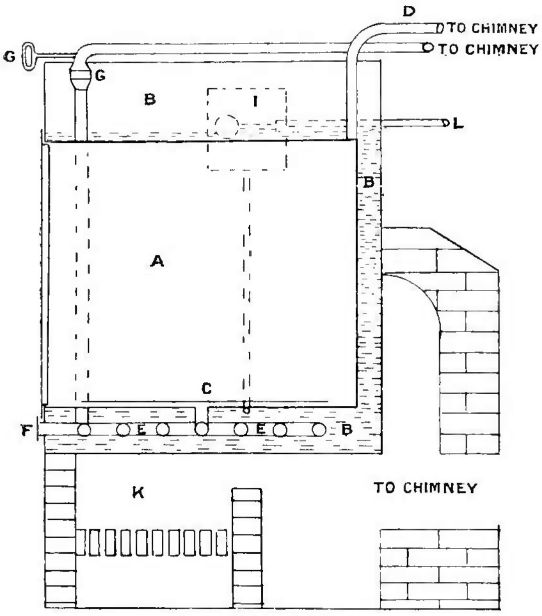


Fig. 116.

As regards disinfection by dry heat, the ordinary drying closet in a good laundry will sometimes give heat enough, but not always. A baker's oven can also be used in case of emergency. A well-known dry-heat or hot-air disinfecting apparatus is that of Ransom, which consists of an iron chamber with an external covering of felt and wood. The heat is supplied by means of a circular gas-burner connected with the under surface of the chamber by a flue which conducts the hot air, together with the products of combustion, into the interior, equal distribution being secured by a perforated plate at the bottom. An outlet flue is placed at the top of the chamber. In both flues a thermometer is fixed to indicate the temperature of the incoming and outgoing air. In addition to this a mercurial regulator is fixed in the inlet flue, by means of which the amount of gas consumed, and consequently the amount of heat produced, can be controlled, and this may be adjusted to any temperature desired. As a precaution against fire, an arrangement is connected with the outlet flue by which, when the temperature reaches 300° F., a link of fusible metal is melted, and by this means a damper is closed and the supply of gas is shut off.

No matter by what form of apparatus carried out, disinfection by hot air or dry heat is not so efficacious as by moist heat, but it is required in the case of some articles, such as leather, bound books, &c. Probably 220° or even 212° F. would be a sufficiently high temperature to destroy all disease germs if thoroughly applied; but this is the great difficulty in Ransom's disinfector, as in other hot-air stoves, the heat being very much greater at some parts of the interior than at others.

Chemical Disinfectants.—If we limit our conception of a disinfectant to that of a substance which is capable, by its own inherent poisonous action upon a pathogenic organism, to destroy the life and power of development of that micro-organism, the number of practical chemical disinfectants is small. Practically, we must set aside all disinfectants that are expensive, as well as all those which are not readily soluble in water, or otherwise are difficult to apply and manipulate. To these conditions we may further add that a good disinfectant must be rapid as well as certain in its action. In no case ought more than twenty-four hours to be allowed for the complete destruction of all germs, and in many cases only a very brief exposure can be obtained.

Chemical disinfectants may be solid, liquid, or gaseous; but from the nature of the case it is evident that solids must be brought into the form of a solution to enable them to penetrate throughout any substance to be disinfected. Disinfectants, therefore, are practically useful only as solutions, or as gases. The most reliable disinfectants appear to be the following:—

Mercuric chloride, or corrosive sublimate, is a well-known and highly poisonous salt. A cold saturated aqueous solution contains about 10 per cent., but two parts of boiling water dissolve one part of the sublimate. It is also readily soluble in alcohol or ether. Of a strength of 1 in 1000 in water, mercuric chloride destroys the bacilli of glanders, anthrax, enteric fever, diphtheria, the spirilla of cholera, and the micrococci of erysipelas in ten seconds. Spores are not so readily destroyed, requiring an exposure of ten minutes at least: a 1 in 5000 solution produces the same effect in a few hours. As a disinfectant, mercuric chloride has three great disadvantages: (1) it corrodes metals, (2) it forms with albumin an inert insoluble compound, (3) it is poisonous.

To guard against this latter fact it has been suggested to colour the sublimate solution with aniline blue; thus, mercuric chloride $\frac{1}{2}$ ounce, hydrochloric acid 1 ounce, commercial aniline blue 5 grains, water 3 gallons, make a solution of the required strength and of a deep blue colour. A better colour is obtained by adding 1 grain of the blue to 10 gallons; this tint is sufficiently characteristic, and does not permanently colour washing fabrics. In the absence of aniline blue any other colouring agent may be added, such as permanganate of potash.

By Schill and Fischer's experiments, it appears doubtful whether the perchloride of mercury can destroy the spores of tubercle bacilli in phthisical sputa, even in the proportion of 1 in 500 solution. This inefficient disinfectant action is probably due to the fact that the salt enters into chemical combination with the proteids of the sputum, or even forms a coating around the bacilli which protects the contained spores from its further action. This peculiarity of the sublimate somewhat detracts from its general utility as a disinfecting agent in albuminous materials, but may be prevented by acidulating the solution.

Lingard's experiments show that a solution of sublimate, 1 in 960, destroys the human tubercular virus in from four to eight hours. Experiments made at Netley on this point indicate that with a 1 in 1000 solution, at least twelve hours' exposure should be allowed for the absolutely complete destruction of all tubercular virus in sputa by mercuric chloride, and even then the reagent must be well mixed with the infected matter. Not less strength than 1 per cent. was necessary to destroy the spores of anthrax and *B. subtilis*. One part of sublimate in 5000 of gelatin is antiseptic, or sufficient to inhibit the growth of most micro-organisms.

Carbolic acid (phenol), when absolute and pure, is in the form of white crystals which melt at 42°·2 C. or 108° F. The solubility of these crystals in water is about that of 1 in 11; a saturated solution in water will contain about 8·6 per cent. of phenol. It is more soluble in weak alkaline solutions than in water; while, when pure, it is soluble in all proportions in ether, alcohol, benzene, chloroform, and carbon disulphide.

The ordinary red or dark brown fluid sold as carbolic acid is a mixture of ortho-, meta-, and para-cresol. It is less soluble than phenol; a saturated aqueous solution will contain only about 3·5 per cent.; it is soluble in weak alkaline liquids, but is precipitated with excess of alkali. The chief impurities of commercial carbolic acid are tar oils. Their presence and approximate quantity can be estimated by shaking a measured volume of the acid with twice its volume of pure soda solution of 9 per cent. strength. The cresylic and carbolic acids are dissolved by the alkaline liquid, while the oils separate, the heavy oils sinking to the bottom, and the light oils rising to the top; their respective volumes can be then read off. These tar oils are apparently without any disinfectant properties.

Numerous "carbolic acid powders" are in the market; these are for the most part mixtures of cresylate and carbolate of lime, and have no appreciable disinfecting properties. Calvert's carbolic acid powder is a type of the best form of carbolic acid powder, as it has not lime for its basis, but is merely a mechanical mixture of the acid with the siliceous residue resulting from the manufacture of aluminium sulphate from shale. Macdougall's powder is another satisfactory preparation of this kind. It is made by adding a certain proportion of crude carbolic acid to an impure sulphite of calcium prepared from the action of sulphur dioxide on ignited limestone.

A considerable number of "carbolic acid soaps," containing more or less free carbolic acid, are also in the market. Soap alone we know to have distinct antiseptic qualities, but it is doubtful whether any of these carbolic acid soaps are of the slightest use for disinfecting purposes, or are in any way superior to ordinary soap.

Innumerable experiments have been made as to the action of phenol and cresol as disinfectants. Their general tenor has been to show that 1 per cent. solutions of them are able to destroy the more feeble micro-organisms in twenty-four hours, but to ensure destruction of spores and the more resistant forms of microbial life it is necessary to use at least 5 per cent. solutions in water, and the action must be prolonged over a day at least. Wynter-Blyth aptly remarks that "if specific excreta are treated, it is doubtful whether 5 per cent. solutions are of sufficient strength, because associated with the hurtful material there is a quantity of organic matter which must on the one hand remove some of the phenol from the sphere of action, and on the other impede the contact of the phenol with the substance which we wish to disinfect." Tubercle bacilli are destroyed by a 5 per cent. solution of carbolic acid in half a minute, but the spores require an exposure of at least two hours, especially when present in phthisical sputa.

Closely allied to phenol and the cresols is *creasote*, which is a mixture of several phenol-like bodies. Owing to its insolubility in water, creasote is of little practical value as a disinfectant. Some experiments made indicate it to be about equal in value to cresol. It possesses marked antiseptic properties, and on this account is largely used in the preservation of timber.

The disinfecting value of the aromatic acids, *phenyl-propionic* and *phenyl-acetic*, have been investigated by Klein. He found that, as regards sporeless anthrax bacilli, they were killed on exposure, even for a few minutes, to solutions of either of the acids in the strength of 1 in 400 or less. A longer exposure was necessary for weaker solutions. Their action on the virus of swine-plague was marked when the strength was not less than 1 in 800, but tubercle bacilli and spores of anthrax appeared resistant to even the strong solutions. Both these acids are strongly antiseptic.

Izal, which is a comparatively new disinfectant extracted from an unknown oil obtained from certain coke ovens, is a creamy-looking emulsion, having an earthy smell, coupled with a faint odour suggestive of phenol. It is readily mixed with water, forming a milky emulsion. Its disinfecting properties have been extensively investigated by us and found satisfactory. A 20 per cent. emulsion destroyed the highly resisting spores of *B. subtilis* and *B. mesentericus* in thirty-five minutes. A 10 per cent. emulsion killed virulent spores of anthrax bacilli in twenty minutes. Non-spore-bearing specimens of the above bacilli were destroyed after five minutes' exposure to 0·5 per cent., or 1 in 200 emulsion. A 0·3 per cent. emulsion destroyed the streptococcus of pus; and exposure for half an hour to a 1 per cent. emulsion was sufficient to destroy the enteric fever bacillus and the spirilla of cholera.

Our observations dispose us to regard izal as a disinfectant of considerable practical value, and that for concrete cases of disinfection of morbid materials from the various infectious disorders, an exposure for fifteen minutes in the strength of 1 per cent. will be sufficient. Moreover, izal, being free from poisonous properties when introduced by injection into the tissues, or when administered by the stomach, possesses qualities which practically no other efficient disinfectant affords. The inhibitory or antiseptic value of izal is equally defined, as neither spores, micrococci, or non-sporing bacilli and spirilla can germinate in medicated media if the amount of disinfectant added is 0·1 per cent.

Chlorine holds the first place among the gaseous disinfectants in common use. It may be prepared for the purposes of disinfection by heating together a mixture of common salt, manganese dioxide, and sulphuric acid, or simply by the action of hydrochloric acid on manganese dioxide. Both these processes are somewhat inconvenient, and it is more easily evolved from chloride of lime ($CaCl_2,Ca(ClO)_2$) or bleaching powder by the addition of an acid; thus, $CaCl_2,Ca(ClO)_2 + 2H_2SO_4 = 2CaSO_4 + 2HCl + 2HClO$; then $2HCl + 2HClO = 2Cl_2 + 2H_2O$. Theoretically, bleaching powder contains 56 per cent. of chlorine, but it is doubtful whether the whole of this gas is obtained on decomposition. Practically, one pound of the powder, on being treated with sufficient acid to completely decompose it, will evolve about 2·8 cubic feet of chlorine gas.

We are indebted to the researches of Fischer and Proskauer, and to Cash for most of our knowledge concerning the disinfectant action of chlorine. In ordinary dry air, 5·38 parts of chlorine per 1000 cubic feet of air appear to be necessary to kill all micro-organisms. If the air be moistened, which may be done by wetting the walls, floors, &c., and by diffusing steam, 0·3 per cent. by volume in each 1000 cubic feet of air is sufficient, disinfection being complete in from five to eight hours. This quantity of the gas can be generated, practically, by decomposing 1½ ℔ of chloride of lime with 6 ounces of strong sulphuric acid for each 1000 cubic feet of space to be disinfected. Or, as an alternative, for the same cubic space the following should be used:—common salt, 8 oz.; manganese dioxide, 2 oz.; sulphuric acid, 2 oz.; water, 2 oz.: the water and acid to be mixed together, and then poured over the other ingredients in a delf basin, which should be placed in a pipkin of hot sand. Or four parts by weight of strong hydrochloric acid may be poured on one part of powdered manganese dioxide. Chlorine decomposes hydrogen and ammonium sulphides at once, and more certainly than any other gas. It doubtless destroys organic matter in the air, as it bleaches organic pigments, and destroys odours, either by abstracting hydrogen, or by indirect oxidation. Its action, however, depends greatly upon the humidity; disinfection by chlorine in dry air being very uncertain. It is an extremely irritant, poisonous gas, and being very heavy tends to fall, necessitating the generating vessel to be placed in an elevated situation, in order to secure anything like equal diffusion. Carpets, curtains, &c., should be removed and disinfected by moist heat, as chlorine fails to destroy organisms in them, and they themselves would be injured by its action.

Euchlorine, a mixture of chlorous acid and free chlorine, obtained by gently heating (by placing the saucer in warm water) a mixture of strong hydrochloric acid and potassium chlorate, has been also used instead of pure chlorine. The odour of euchlorine is more pleasant than that of chlorine; it acts as rapidly on iodide of potassium and starch paper, and appears to have a similar action on organic substances; it is probably inferior to pure chlorine, but the ease of development and its pleasanter smell are in its favour.

Chlorine fumigation, carried out under the best conditions, may fail, and often does fail, to disinfect spore-holding material covered over or lurking in chinks and cracks. Delépine and Ransome's observations, upon the practical disinfection of tuberculous rooms by chlorine, show clearly that, as often perfunctorily carried out, attempts at disinfection by chlorine gas are fallacious. These observers recommend that, in place of evolving the crude gas from inconvenient apparatus, the chlorine in the nascent state may be generated in the places required by thoroughly washing all parts of a room with a 1 in 100 solution of bleaching powder. After the application of the solution, chlorine continues to be evolved so long as all the chlorinated lime has not been decomposed, and that without anything further being required to be done. If necessary, it is easy to increase its activity by adding an acid to the solution, or by saturating the air of the rooms with acid fumes and by raising the temperature for a few hours. This washing with chloride of lime-water should for safety be repeated three or four times in succession. By starting each time at the same corner of a room, each layer would have time to penetrate into the wall and partly dry before the next is applied. The room may be closed afterwards, a small safe petroleum stove being first placed in the middle of the chamber, precautions being taken to prevent any chance of fire. Over this stove a large tin basin full of acidified water or chlorinated lime solution should be placed.

Disinfection by chlorine in this way should be complete in less than three hours. Bleaching powder itself does not spoil things as much as one would expect, and can be used as indicated in rooms from which all draperies and carpets have been removed without any fear of damage, provided the walls and ceilings are not decorated with valuable paintings or papers. The quantity of powder required for a room measuring 10 feet in all directions would not be more than 8 ounces, and the quantity of water 3 pints for one washing.

Sulphurous acid, or sulphur dioxide, has been for many years the most common and favourite disinfecting agent, owing to its cheapness and the ease with which it can be generated. This gas is formed whenever sulphur is burned in air or oxygen. It is usually generated by taking about a pound of roll sulphur, seal up a room as hermetically as possible, light the sulphur in some suitable receptacle, and let it burn as long as it will. A still more convenient method is to take an ordinary benzoline lamp, fill it with carbon bisulphide, and light; as the carbon bisulphide is consumed, the sulphur is evolved as sulphur dioxide. The generation of sulphur dioxide by these means is now largely superseded by the employment of sulphurous acid liquefied under pressure, and which is supplied by the manufacturers in cylinders available for convenient use. When sulphur is burned in a perfectly close space, its consumption is limited by the quantity of air in that space: theoretically, a cubic foot of air will burn up 634 grains of sulphur, but it will not do this unless freely supplied with air. One pound of sulphur, when completely burnt, gives off 11·2 cubic feet of sulphur dioxide, which for 1000 cubic feet of space gives 1·12 per cent. With the addition of alcohol under careful experimental conditions, 40 per cent. of the possible total quantity of sulphur in a closed space can be burnt, but in ordinary rooms not much more than 20 per cent. is usually consumed. To attain the maximum consumption, the sulphur must be broken up into pieces not larger than a hazel nut, and divided about a room, never putting more than one pound in any one vessel.

Sulphur dioxide is a powerful reducing agent, uniting with the oxygen of many substances to form sulphuric acid. It may occasionally give up oxygen, and when mixed with much vegetable matter may itself give rise to sulphuretted hydrogen. Commonly, it destroys hydrogen sulphide, forming water and sulphur.

The bactericidal or disinfectant value of sulphurous acid has been extensively investigated by Cash, Wolffhügel, Koch, and others. On the whole, their results have been unsatisfactory, though, on the other hand, Dubief and Bruhl found it to be an effectual germicide, especially when the air is moist. It has been proved over and over again that the best results with this agent can only be obtained under very strict experimental conditions, such as are quite unattainable in ordinary circumstances. The best results are obtained in imperfectly ventilated places by well moistening the sulphur with methylated spirit, when, under the most favourable conditions, the air of the room thus disinfected may contain 10 per cent. of sulphur dioxide. Koch's experiments show that even when present to this extent, and the air saturated with moisture, micro-organisms grew vigorously after twenty-four hours' exposure. To obtain this percentage of sulphurous acid gas in the air, even under favourable circumstances, it would require at least 10 ℔ of sulphur to be burnt for each 1000 cubic feet of air space; as, however, it is impossible to burn up all the sulphur, even this quantity would not yield the amount of SO_2 theoretically required. As the disinfection of any given place is usually a complex operation, involving afterwards mechanical processes of scrubbing and cleansing, it is possible that a less quantity may suffice, but in any case this should not be placed at a lower limit than 3 ℔ of sulphur for each 1000 cubic feet of space. Too great reliance, however, must not be placed upon disinfection by means of sulphurous acid; at best it is an uncertain agent, and distinctly inferior to either chlorine or nitrous acid. The slightest covering will protect micro-organisms from its action.

Nitrous acid or *Nitrogen tetroxide* can be evolved by placing a piece of copper in nitric acid and a little water. The nitrogen dioxide which is given off takes oxygen from the air, and red fumes, consisting chiefly of nitrogen tetroxide or nitrous acid (NO_2), are formed.

The oxidising action of nitrous acid is very great on organic matter. It removes the smell of the mortuary sooner than any other gas. It is very irritating to the lungs, and in large quantities may cause vertigo, nausea, vomiting, and even death: great care is required in its use.

The action of nitrous acid results from the ease with which it parts with oxygen to any oxidisable substance, being converted into nitrogen dioxide, which again at once combines with atmospheric oxygen, and so on.

For 1000 cubic feet, take copper shavings, 1 oz.; nitric acid, 3 oz.; water, 3 oz.; then pour the mixed acid and water upon the copper in a small jar.

If precautions are taken to reduce leakage to a minimum, disinfection by means of fumigation by any of the three gases above mentioned may be able to destroy most, if not all, of the freely exposed and less resistant micro-organisms; more than this cannot be expected. Exact experiments as regards nitrous acid are wanting, but some few observations that have been made indicate that, as a germicidal agent for disinfection purposes, it holds a position somewhat superior to sulphurous acid but inferior to chlorine. As a deodorant it is undoubtedly superior to both.

Formaldehyde is a well-known antiseptic for the preservation of milk and other foods. Its use in the gaseous state from the incomplete combustion of methylic alcohol has been suggested for the disinfection of rooms. Experiments, however, indicate that its value for this purpose is in no way superior to any of the above-mentioned gases.

In addition to the foregoing, numerous chemical reagents have from time to time been suggested as disinfectants. Of these *iodine* is not well adapted for use as a fumigating agent, chiefly on account of the density of its vapour, which is 8·5 times heavier than air, rendering its equal diffusion very difficult. *Iodine trichloride* possesses marked disinfectant properties in solution of 1 per cent., but its chief value lies in its antiseptic powers, 1 in 3000 preventing the growth of a variety of pathogenic organisms; there is one exception, however, that of the enteric fever bacillus, which resists even a solution of 1 in 500. *Bromine* has been employed as a gaseous disinfectant, but with indifferent success. *Lime* has a powerful germicidal effect, which has been shown to be due to its alkalinity; a 0·1 per cent. solution of quicklime sterilises excreta after five hours' exposure. Of the many other commonly regarded disinfectants, we may mention the *sulphates of copper*, *iron* and *zinc*, also *chloride of zinc* and *potassic permanganate*. All these need to be of 5 per cent. strength, and even then either take several days to kill anthrax spores, or fail to do so. Of the many other chemical and patented substances that have been brought forward at various times as disinfectants, none have been proved to be efficacious in the exhaustive way that mercuric chloride, carbolic acid, and izal have been tested. The greater number are really only antiseptics or deodorants, of considerable value as such, but not to be considered as true disinfectants.

A practical point in regard to even the most powerful of these disinfectants is its effective working strength. If a given reagent has disinfecting powers when of 5 per cent. strength by weight or volume, it is absolutely useless to add a little of a 5 per cent. solution of the salt to any given matter requiring disinfection. We must add the solid reagent, or a highly concentrated solution of it, until it forms not less than 5 per cent. of the whole substance to be disinfected—not 5 per cent. of the stock solution. In the case of a salt like permanganate of potassium this 5 per cent. would, of course, have to be in addition to the amount required to oxidise any organic matter present. So, too, with mercuric chloride, a similar consideration applies, as, if added, without acidulation, to liquids containing organic matter, it forms a precipitate that carries down part of the mercury in an inert form. Reference has already been made to a corresponding need in the case of carbolic acid. It is scarcely necessary to say that these essential conditions are rarely, if ever, observed in practice, and that, in consequence, what is intended to be disinfection more often than not amounts only to deodorisation, or at most to imperfect anti-septicising.

From what has been said, it will be seen that so-called disinfectants and disinfection processes have not all the same value,—the most powerful and reliable being fire, boiling, steam, exposure to dry air at or above 220° F. for from six to eight hours, corrosive sublimate (1 in 1000), carbolic acid of not less strength than 5 per cent., and izal 1 per cent. Among those capable of destroying sensitive but not the more resistant micro-organisms are chloride of lime, nitrous and sulphurous acids, 3 or 4 per cent. solutions of carbolic acid, brief exposures to heat and weak solutions of corrosive sublimate and izal. Finally, among those that have been shown by experiment to be unable to destroy even the more sensitive bacteria, under the conditions occurring in practice, are solutions of chloride of zinc, ferrous sulphate, 1 or 2 per cent. solutions of carbolic acid, and other disinfectants in excessive dilution, boracic acid, hot air, or fumigation applied to bulky objects, or for inadequate periods of time.

Disinfection of Clothing and Bedding.—All articles of little value should be burnt. The application of heat in some way is the most sure and at the same time usually the most practicable method of disinfection. For bulky articles, as bedding, blankets, and clothing generally, moist heat or dry steam will be found the most efficacious. In the case of bedding, the hair or feathers in mattresses or pillows may be taken out and loosened before exposing them to disinfection by heat. Where moist heat cannot be applied or obtained, exposure to dry air at or above 220° F. for from six to eight hours should be secured; but in no case should efforts at disinfection by means of dry heat be substituted for moist heat when the latter procedure is available.

In circumstances where no means exist for disinfecting bulky articles of clothing and bedding by these methods, they should, if possible, be destroyed by burning; failing that, they should be boiled, or at least be allowed to soak for twenty-four hours in some disinfecting liquid, such as one of the following:—(*a*) Izal, 5 parts to 100 of water. (*b*) Chloride of lime, 2 ounces to 1 gallon of water. (*c*) Chloride of lime, 70 grains mixed with 6 grains of herring brine to 1 gallon of water. (*d*) Carbolic acid, 5 parts to 100 of water. (*e*) Bichloride of mercury, $\frac{1}{2}$ ounce; hydrochloric acid, 1 ounce; aniline blue, 5 grains, to 3 gallons of water. After soaking in any one of these solutions, the clothing should be then boiled and thoroughly washed with soap and water.

Disinfection of Excreta and Discharges.—The urine and bowel discharges so frequent in enteric fever, cholera, dysentery, and diarrhœa should be received into a vessel containing either carbolic acid solution (1 in 20), or mercuric chloride solution (1 in 1000, as given above), or izal (1 in 20), with a further application of an equal quantity of the disinfectant directly afterwards. The whole should be well mixed, left for a quarter of an hour for the disinfectant to act, and then either burnt, buried, or discharged down the closet; if the latter is done, it should be well flushed afterwards with water. Chloride of zinc, in the form of Burnett's fluid, is a useful disinfectant for application to alvine discharges. Sulphate of iron, if used in the strength of 1 ℔ to a gallon of water, makes a valuable disinfectant for drains, but owing to its staining powers is unsuited for soaking linen or clothing. In cholera and yellow fever, the vomited matters should be treated in the same way as the stools.

The same care needs to be observed in the treatment of all other discharges from the sick. Thus, all discharges from the mouth, throat, nose, and lungs in diphtheria, whooping-cough, scarlet fever, small-pox, measles, and phthisis should be wiped away with pieces of rag in place of handkerchiefs; these rags to be burnt after use. Failing this, they should be treated in a similar manner as an infectious stool. In diphtheria and scarlet fever direct application of some disinfectant is advisable. In scarlet fever and small-pox, when the infective matter exists in the skin particles so freely given off, care should be taken to render these particles innocuous. This can, to a large extent, be accomplished by washing the skin with warm water and carbolic soap, and then smearing the body surface night and morning with a medicated oleaginous preparation made by mixing 1 drachm of carbolic acid and 3 of eucalyptus oil in 8 fluid ounces of olive or almond oil. In the same diseases, much good results by syringing or swabbing out with pledgets of cotton-wool the mouth and nose, with a warm solution of common salt (about 2 drachms of salt with half a drachm of boric acid to a pint of water), and then burning the wool after use.

Deodorisation of Excretal Discharges.—Apart from their disinfection, it is often convenient and necessary to deodorise excretal discharges. For this purpose, few means are better than well-powdered dry *earth*, especially humus, marly, and clayey soils. *Charcoal* may be used for the same purpose, but it soon loses its power. *Quicklime* and *chloride of lime* are also valuable, the latter, in particular, being most powerful as a deodorant and also as a steriliser. Quicklime, 5 parts, and carbolic acid, 1 part, make a good deodorising mixture.

The preparations in the form of special powders are various, the best perhaps being the different *carbolic acid powders* already alluded to; to these may be added such preparations as *ferralum* and *cupralum*. The latter consists of sulphates of copper and aluminum with potassium dichromate and terebene. It is a fairly powerful deodorant, counteracting ammonia and hydrogen sulphide, and at least masking fæcal odour as much as carbolic acid.

The substance advertised as *Sanitas* is a hydrocarbon derived from turpentine acted upon by steam. It has the advantage of being easily miscible with water, but it is not very powerful either as a deodorant or antiseptic.

Chlor-alum is a weak solution of chloride of aluminum; it is not a very powerful deodoriser, and must be used in large quantity, but its cheapness and want of poisonous properties are recommendations, and when in sufficient amount it is effectual. It is efficacious against ammonia, but not against hydrogen sulphide; it acts moderately against fæcal odour. *Burnett's fluid*, which contains 25 grains of zinc chloride to every fluid drachm, if used in strength of 1 pint to a gallon of water (1 to 8), will deodorise excreta. *Potassium permanganate*, in the form of Condy's fluid, prevents putrefaction for a short time, and removes the fæcal odour, but it requires to be used in large quantity. *Sodium manganate* has similar powers, but needs to be used freely.

These substances are all good deodorants and arresters of putrefaction, but must not be regarded as disinfectants. Practically, their use is very limited.

Disinfection of Rooms and Furniture.—An agent of the first importance for the disinfection of rooms is undoubtedly the free perflation of fresh air, while all woodwork should be well scrubbed with soft soap and hot water, or washed with a corrosive sublimate solution (1 in 5000) or chloride of lime (1 in 100). The walls also should be well washed with the same solutions. The experiments of Chamberland in France, and Delepine in this country, leave little doubt that washing with chloride of lime gives the most satisfactory disinfection of all surfaces to which it can be applied. The difficulty of ordinary room disinfection is that the surfaces and objects to be treated are unduly injured, not merely by this corrosive chemical but by the process of washing with any liquid. An attempt to overcome this objection has been only imperfectly made by means of the Geneste-Herscher sprayer. This is an appliance for mechanically projecting a liquid disinfectant in the form of a spray sufficiently fine to allow each drop to rest where it strikes, and, where necessary, with a velocity sufficient to inject it into any surface irregularities. In order that the velocity may be maintained, the spray nozzle is mounted on a long metal tube, so as to be applied within 2 or 3 inches of the surface. Experience shows that if the spraying is performed at a greater distance than 4 inches, sterilisation is not secured. Moreover, the apparent sterilisation which seems to result from the spraying is often, as in the case of ordinary washing, due merely to the organisms having been mechanically carried off the test-surfaces on to some other part which was not at first examined.

In white-washed rooms the above difficulties do not arise, as the walls can be readily scraped and then well washed with a solution of chloride of lime. In the case of papered walls all the layers, if there be more than one, should be stripped off and the walls washed with the lime before being re-papered. Ceilings need to be scraped and washed with lime in the same way. All fabrics must be removed from infected rooms, and subjected to disinfection by moist heat. All articles of furniture, of wood, or metal must be washed with soft soap and hot water.

As an additional precaution, rooms may be fumigated for three or more hours with chlorine, or nitrous acid, or sulphur dioxide, the doors and windows being subsequently opened, and kept open for twenty-four or thirty-six hours. The difficulties in fumigation arising from the slowness of the diffusion of the disinfectant gas into the air and the consequent uncertainty of the composition of the disinfectant atmosphere at any point are obvious from merely physical considerations. Apart from this, exact bacteriological observations have shown that the disinfecting properties of these gases, when employed for the fumigation of rooms, is most uncertain and unreliable. For these reasons, fumigation of rooms has deservedly fallen into disrepute, and unless supplemented by careful washing and scrubbing is practically valueless. If fumigation is performed, it must be clearly understood that it is quite a subsidiary proceeding, and that it can only be done effectually when the room is unoccupied, as the air must be rendered quite unfit for respiration. For the purification or deodorisation of mortuaries and dead-houses, fumigation with nitrous acid or chlorine is both useful and practicable, but their actual disinfection will be best secured by complete and thorough washing and scrubbing with chloride of lime or corrosive sublimate solutions combined with free perflation of air.

Disinfection of Ships.—Disinfection afloat is practically the same as elsewhere, with the exception that the apparatus commonly employed for the purpose of purifying bedding and clothing on land are too large and cumbersome to be used on ships. Appliances in which the required temperature is obtained by means of gas are, of course, not available on shipboard. These difficulties are overcome by fitting up a hulk or tug with apparatus for means of disinfection by steam, sulphur dioxide, chlorine and nitrous acid, or by means of the mercuric drench. All bedding, ship's linen, cushions, curtains, carpets, rugs, personal baggage, and wearing apparel can be removed from ships and disinfected by steam heat in specially constructed chambers. Leather articles and such as would be injured by moist heat can be treated with the bichloride of mercury solution. The disinfection of the actual ship itself can be secured by first wetting or drenching all available surfaces of the vessel, excepting cargo, but including bilge, ballast, hold, saloons, forecastle, decks, &c., with a solution of mercuric chloride conveyed from the disinfecting hulk or tug by rubber hose. For this drenching with the sublimate, scrubbing and washing with chloride of lime may be substituted. If necessary, these drenchings and washings can be supplemented by fumigations with either chlorine or sulphur dioxide generated on the disinfecting tug and conveyed on board ship by a fumigating pipe and led into the hold. The cargo is not disturbed, but every opening battened down, the process being completed in from three to eight hours. When sulphur dioxide is employed for these fumigations, tubes or tins of the condensed and liquefied gas can be conveniently used in different sections of the vessel.

BIBLIOGRAPHY AND REFERENCES.

ANDRÉ, "De l'assainissement par l'acide sulfureux des barraques occupies par le depôt du 7^e regiment de dragons à Vitry le François," *Rec. de mem. de Med. milit.*, Paris, 1881, xxxvii. p. 110.

BAXTER, *Report on an Experimental Study of Certain Disinfectants*, Report Med. Off. Privy Council, vi. 1875, p. 216. BLYTH, *Manual of Public Health*, Lond., 1890, p. 313. BOND, "On the Conditions of Efficient Disinfection, and on some New Forms of Disinfectant," *Brit. Med. Journ.*, 1875, i. p. 239.

CASH, *Report upon the Action of Disinfectants, more particularly the Halogens*, Rep. Med. Off. Local Govern. Board, being Supplement to 16th Annual Report, 1886–7. CHAMBERLAND and FERNBACH, "La Désinfection des locaux," *Annales de l'Institut Pasteur*, Juin 1893, p. 433.

DE CHAUMONT, "Report on the Effects of High Temperatures upon Woollen and other Fabrics," *Lancet*, 1875, ii. p. 830. DELÉPINE and RANSOME, "Report on the Disinfection of Tubercle-infected Houses," *Brit. Med. Journ.*, 1893, ii. p. 990; also *Idem*, 1895, i. p. 349. DUCLAUX, "Sur l'action antiseptique de l'acide formique," *Annales de l'Institut Pasteur*, Sept. 1892, p. 593.

FISCHER and PROSKAUER, "On the Disinfectant Action of Chlorine and Bromine," *Mittheilungen aus dem Kaiserlichen Gesundheitsamte*, Bd. ii., Berlin, 1884. FLÜGGE, *Micro-organisms in reference to the Etiology of the Infective Diseases*, transl. for the New. Syden. Soc. by Watson Cheyne, Lond., 1890.

HERSCHER, "Des Appareils à désinfection par l'air chaud destinés à la purification des vêtements, des lignes, des objets de literie et de texture," *Revue d'Hygiene*, Paris, 1881, iii. p. 585. HOFMANN, "Uber Desinfectionsmaasregeln," *Deutsch. Vrtljschr. f. öffen. Gsndhtspflg.*, Braunschweig, 1880, xii. p. 41.

KLEIN, *Report on the Disinfectant Action of Perchloride of Mercury*, Supplement, 15th Annual Report of Med. Off. Local Govern. Board, 1885, p. 155. KOCH, "Uber Desinfection," *Mittheil. a. d. K. Gesundhsamte.*, Berlin, 1881, i. p. 1; also "Versuche über die Verwerthbarkeit heisser Wasserdämpfe zu Desinfectionzwecken," *Ibid.*, p. 19.

MAX JOLLES, "Weitere Untersuchungen u. die Desinfectionsfähigkeit von Seifenlösungen," *Zeitsch. f. Hyg.*, Bd. xix. hft. 1, 1895. MEHLHAUSEN, "Versuche u. Desinfection geschlossener Raume," in the *Berichte der Cholera-Kommission f. das deutsche Reich.*, 6, Heft 4, Berlin, 1879, p. 335.

PARSONS, *Report on Disinfection by Heat*, Supplement by Med. Off. to 14th Rep. Local Gov. Board, 1884, p. 218; also 16th Report, 1886, p. 347. POTTEVIN, "Recherches sur le pouvoir antiseptique de l'aldéhyde formique," *Annales de l'Institut Pasteur*, Novembre 1894, p. 796.

RANSOM, Disinfection by Hot Air, *Practitioner*, 1878, xxi. p. 67. REIDEL, "On the Disinfectant Action of Iodine Trichloride," *Arbeit a. d. K. Gsndhtsamte.*, Bd. ii., 1887.

VALLIN, *Traité des Désinfectants*, Paris, 1883; also "De la Désinfection par l'Air chaud," *Mem. de la Société de Médecine Publique et d'Hyg. Professionelle*, 1877. VINCENT, "Sur la désinfection des matières fécules normales et pathologiques," *Annales de l'Institut Pasteur*, Jan. 1895. VOGEL, "Ein neuer Desinfectionsapparat mit starkstromendem, gespanntem Wasserdampf. nebst Bemerkungen über die Bedeutung der Strömung, Spannung, Temperatur des Dampfes bei der Desinfection," *Zeitsch. f. Hygiene*, Bd. xix. Heft 2, 1895, p. 291.

WOLFFHÜGEL, "Uber den Werth der schwefligen Saüre als Desinfectionsmittel," *Mittheil. aus dem Kaiserlichen Gesundhtsamte.*, Berlin, 1881, i. p. 1.

CHAPTER XIV

CLIMATE.

THE word climate (κλίμα, a slope, from κλίνειν, to incline) originally signified that obliquity of the sphere with respect to the horizon from which results the inequality of day and night. In its modern acceptation it may be taken to mean the sum of all the meteorological conditions of a place or region, including not only those of temperature, but the meteorological conditions generally, so far as these exercise an influence on the animal and vegetable kingdoms. There are four principal factors in the production of the climate of any place or country:—(1) Distance from the equator; (2) Height above the sea; (3) Distance from the sea; (4) Prevailing winds.

With regard generally to the effect of climate on human life, it would seem certain that the facility of obtaining food (which is itself influenced by climate), rather than any of the immediate effects of climate, regulates the location of men and the amount of population. The human frame seems to acquire in time a wonderful power of adaptation. The Esquimaux, when they can obtain plenty of food, are large strong men (though nothing is known of their average length of life), and the dwellers in the hottest parts of the world (provided there is no malaria, and that their food is nutritious) show a stature as lofty and a strength as great as any dwellers in temperate climates. Peculiarities of race, indeed, arising no one knows how, but probably from the combined influences of climate, food, and customs, acting through many ages, appear to have more effect on stature, health, and duration of life than climate alone. Still, it would seem probable that, in climatic conditions so diverse, there arise some special differences of structure which are most marked in the skin, but may possibly involve other organs.

How soon the body, when it has become accustomed by length of residence for successive generations to one climate, can accommodate itself to, or bear the conditions of, the climate of another widely different place, is a question which can only be answered when the influences of climate are better known. The hypothesis of "acclimatisation" implies that there is at first an injurious effect produced, and then an accommodation of the body to the new conditions within a very limited time; that, for example, the dweller in northern zones passing into the tropics, although he at first suffers, acquires in a few years some special constitution which relieves him from the injurious consequences which, it is supposed, the change at first brought with it. There are, therefore, two assumptions, viz., of an injurious effect, and of a relief from it. Is either correct?

It may seem a bold thing to question the commonly received opinion that a tropical climate is injurious to a northern constitution, but there are some striking facts which it is difficult to reconcile with such an opinion. The army experience shows that, both in the West Indies and in India, the mortality of the soldier has been gradually decreasing, until, in some stations in the West Indies (as, for example, Trinidad and Barbadoes), the sickness and mortality among the European soldiers are actually less than on home service in years which have no yellow fever. In India, a century ago, people spoke with horror of the terrible climate of Bombay and Calcutta, and yet Europeans now live in health and comfort in both cities. In Algeria the French experience is to the same effect. As the climate and the stations are the same, and the soldiers are of the same race and habits, what has removed the dangers which formerly made the sickness threefold and the mortality tenfold the ratio of the sickness and deaths at home?

The explanation is very simple: the deaths in the West Indies were partly owing to the virulence of yellow fever (which was fostered, though probably not engendered, by bad sanitary conditions) and the general excess of other febrile and dysenteric causes. The simple hygienic precautions which were efficacious in England have been as useful in the West Indies. Proper food, good water, pure air have been supplied, and, in proportion as they have been so, the deadly effects attributed to climate have disappeared. The effect of a tropical climate is, so to speak, relative. The temperature and the humidity of the air are highly favourable to decompositions of all kinds; the effluvia from an impure soil, and the putrescent changes going on in it, are greatly aggravated by heat. The effects of the sanitary evils which, in a cold climate like Canada, are partly neutralised by the cold, are developed in the West Indies, or in tropical India, to the greatest degree. In this way a tropical climate is evidently most powerful, and it renders all sanitary precautions tenfold more necessary than in the temperate zone. But all this is not the effect of climate, but of something added to climate.

Take away these sanitary defects, and avoid malarious soils or drain them, and let the mode of living be a proper one, then the European does not die sooner in the tropics than at home.

It must be said, however, that an element of uncertainty may be pointed out here. In our tropical possessions the European remains now only for short periods, and during this time he may be for some years on the hills, or at any rate in elevated spots. The old statistical reports of the army pointed out that the mortality in the West Indies augmented regularly with prolongation of service, and it may be said that, after all, the lessened sickness and mortality in the tropics is owing, in some degree, to avoidance by short service of the influence of climate. But as the whole long service was constantly passed under the unfavourable sanitary conditions now removed, it does not follow that the inference to be drawn from the statistical evidence as to length of service is really correct.

Facts prove, then, that under favourable sanitary conditions (general and personal) Europeans, during short service, may be as healthy as at home, as far as shown by tables of sickness and mortality, and it is not certain that long service brings with it different results.

It may, however, be urged that, admitting that a non-malarious tropical climate, *per se*, may not increase sickness or mortality during the most vigorous years of life, it may yet really diminish health. This practically is the gist of the whole relationship between climate and health, so that a convenient division of the subject is into: (1) How far is climate injurious to health? and (2) How far is it beneficial to health?

In attempting to answer these questions, it is necessary to inquire what is known of the effects of climatic agencies on the frame. The influences of locality and climate, as far as they are connected with soil and water, have already been sufficiently discussed elsewhere. Setting aside the question of the amount of sunlight, and the actual chemical composition of the atmosphere, the chief climatic conditions or elements which influence health are temperature, humidity, air movement or wind, and atmospheric pressure.

Influence of Temperature upon Health.—The amount of the sun's rays; the mean temperature of the air; the variations in temperature, both periodic and non-periodic; and the length of time a high or low temperature lasts, are the most important points. Temperature alone has been made a ground of classification.

(*a*) *Equable* or *insular* climates; *i.e.*, with slight yearly and diurnal variations; this condition being due to the proximity to the sea, which tends to equalise the temperature; as the specific heat of water is great, it takes a long time to be heated, or to be cooled; the heat is slowly absorbed and slowly given out, therefore the temperature of the neighbouring air is equalised.

(*b*) *Extreme* or *continental: i.e.*, with great variations; the conditions being the reverse of those just stated.

Although the effects of heat cannot be dissociated from the other conditions, it is necessary, however briefly, to notice them. The effect of a certain degree of temperature on the vital processes of a race dwelling generation after generation on the same spot, is a question which has as yet been but imperfectly answered. The problem is generally presented to us under the form of a dweller in a temperate zone proceeding to countries either colder or hotter than his own. In this restricted sense we shall now consider it.

With regard to the effect on the Anglo-Saxon and Celtic races of going to live in a climate with a lower mean temperature and greater variations than their own, we have the experience of Canada, Nova Scotia, and some parts of the Northern American States. In all these, if food is good and plentiful, health is not only sustained, but is perhaps improved. The agricultural and out-door life of Canada or Nova Scotia is perhaps the cause of this; but certain it is that in those countries the European not only enjoys health, but produces a progeny as vigorous, if not more so, than that of the parent race.

The effects of heat exceeding the temperate standard must be distinguished according to origin; radiant heat, or the direct rays of the sun, and non-radiant heat, or that of the atmosphere. In the latter case, in addition to heat, there is more or less rarefaction of the air, and also coincident conditions of humidity and movement of the air, which must be taken into account. The influence, again, of sudden transitions from heat to cold, or the reverse, has to be considered. Europeans from temperate climates flourish, apparently, in countries not much hotter than their own, as in some parts of Australia, New Zealand, and New Caledonia, and apparently the vigour of the race has improved. But there is a general impression that they do not flourish in countries much hotter, *i.e.*, with a yearly mean of 20° F. higher, as in many parts of India; that the race dwindles, and finally dies out; and, therefore, that no acclimatisation of race occurs. And certainly it would appear that in India there is evidence to show that the pure race, if not intermixed with the native, does not reach beyond the third generation. Yet it seems only right to say that so many circumstances besides heat and the other elements of climate have been acting on the English race in India, that any conclusion opposed to acclimatisation must be considered as based on scanty evidence. We have not gauged on a large scale the effects of climate pure and simple, uncomplicated with malaria, bad diet, and other influences adverse to health and longevity.

(*a*) *Influence of the Direct Rays of the Sun.*—It is not yet known to what temperature the direct rays of the tropical sun can raise any object on which they fall. In India, on the ground, the uncovered thermometer will mark 160° and perhaps 212° F.; and in this country, if the movement of air is stopped in a small space, the heat in the direct sun's rays can be raised to the same point. In a box with a glass top Sir H. James found the thermometer mark 237° F., when exposed to the rays of the sun, on the 14th July 1864. In experiments on frogs, when temperature much over the natural amount is applied to nerves, the electrical currents through them are lessened, and at last stop. E. H. Weber's observations show that for men the same rule holds good; the most favourable temperature is 30° R. (=99°·5 F.). It appears also from Kühne's experiments that the heat of the blood of the vertebrata must not exceed 113° F., for at that temperature the myosin begins to coagulate. Perhaps this fact may be connected with the pathological indication that a very high temperature in any disease (over 110° F.) indicates extreme danger.

To what temperature is the skin of the head and neck raised in the tropics in the sun's rays? No sufficient experiments have been made, either on this point or on the heat in the interior of caps and hats with and without ventilation. Doubtless, without ventilation, the heat above the head in the interior of the cap is very great. It is quite possible, as usually assumed, that with bad head-dresses the heat of the skin, bones, and possibly even of the deep nerves and centres (the brain and cord), may be greater than is accordant with perfect preservation of the functions of the nerves, or of the necessary temperature of the blood, or with the proper fluidity of some of the albuminous bodies in the muscles or nerves.

The difficulty of estimating the exact effect of the solar rays is not only caused by the absence of a sufficient number of experiments, but by the common presence of other conditions, such as a hot, rarefied, and perhaps impure air, and heat of the body produced by exercise, which is not attended by perspiration. Two points are remarkable in the history of heat stroke, viz., its extreme rarity in mid ocean and at great elevations. In both cases the effect of the sun's rays, *per se*, is not less, but even greater, than on land and at sea-level; yet in both heat-stroke is uncommon; the temperature of the air, however, is never excessive in either case.

The effect of the direct rays on the skin is another matter requiring investigation. Does it aid or check perspiration? That the skin gets dry there is no doubt, but this may be merely from rapid evaporation. But if the nervous currents are interfered with, the vessels and the amount of secretion are sure to be affected, and on the whole it seems probable that a physiological effect adverse to perspiration is produced by the direct rays of the sun. If so, and if this is carried to a certain point, the heat of the body must rise, and, supposing the same conditions to continue (intense radiant heat and want of perspiration), may pass beyond the limit of the temperature of possible life (113° F.). In the Turkish bath it may sometimes be observed that, on entering the hottest chamber, the skin, which had previously been acting freely, becomes dry. A feeling of oppression accompanies this, but relief is experienced as soon as perspiration is re-established. This would seem to point more to an actual arrest of function than to a mere drying up of the secretion. The same thing in a modified degree may occur in a tropical climate, in which case the intensity of fever will depend upon the time that elapses before accommodation is reached.

The effect of intense radiant heat on the respiration and heart is another point of great moment which needs investigation. The pathological effect produced by the too intense direct rays of the sun is seen in one or two forms of insolation, and in fatal cases apparently entails paralysis of the heart or respiration.

(*b*) *Heat in Shade.*—The effect of high air temperature on the native of a temperate climate passing into the tropics has not been very well determined, and some of the conclusions are drawn from experiments on animals exposed to an artificial temperature.

1. The *temperature* of the body does not rise greatly—not more than 0°·5 or 1° F. (John Davy); from 1° to 2½° and 3° C. (Eydaux and Brown-Séquard). In some experiments not published, the late Dr Becher determined his own temperature in a very careful way during a voyage round the Cape to India. He found the body-heat increased, and in the proportion of 0°·05 F. for every increase of 1° F. in the air. Rattray also found a decided increase, varying from 0°·2 F. to 1°·2 F.; the greatest increase was in the afternoon. We may conclude that the tropical heat raises the temperature of the body of a new-comer, probably because the evaporation from the skin is not capable of counterbalancing the great additional external heat, but it is now known that in old residents the same fact does not hold good. The temperature of the body is the result of the opposing action of two factors—1*st*, of development of heat from the chemical changes of the food, and by the conversion of mechanical energy into heat, or by direct absorption from without; and 2*nd*, and opposed to this, of evaporation from the surface of the body, which regulates internal heat. So accurately is this balance preserved, that the stability of the animal temperature in all countries has always been a subject of marvel. If anything, however, prevents this evaporation, radiation and the cooling effect of moving wind cannot cool the body sufficiently in the tropics. Then, no doubt, the temperature of the body rises, especially if in addition there is muscular exertion and production of heat from that cause. The extreme discomfort always attending abnormal heat of body then commences. In experiments in ovens, Blagden and Fordyce bore a temperature of 260° F. with a small rise of temperature (2½° F.), but the air was dry, and the heat of their bodies was reduced by perspiration; when the air in ovens is very moist and evaporation is hindered, the temperature of the body rises rapidly.

2. The *respirations* are lessened in number in animals subjected to heat. According to Vierordt, less carbon dioxide and presumably less water are eliminated. Rattray proved by a great number of observations that the number of respirations is lessened in persons passing from a cold to a hot climate. The amount of diminution varies; in some experiments the fall was from 16·5 respirations per minute in England, in winter, to 12·74 and 13·74 in the tropics. In another series of experiments the fall was from 17·3 respirations per minute to 16·1; the breathing is also gentler, *i.e.*, less deep. Rattray has also shown that the spirometric measurements of the expired air increases in the tropics and falls in temperate climates, the average variation being about 8·7 per cent. of the total spirometric measurements. This will hold good at all ages, but is less at either extreme of life, and is most marked in persons of largest frame and most full blooded. The explanation of this spirometric increase in the respiratory action of the lungs, as compared with the lessened number of inspirations, is said to be

due to the fact that with a high temperature the quantity of oxygen present in the air is diminished. Thus, a cubic foot of dry air at 32° F. weighs 566·85 grs., which, neglecting the slight amount of carbon dioxide present, gives in that cubic foot of air 436·5 grs. of nitrogen and 130·35 grs. of oxygen. Assuming that a man at rest breathes 16·6 cubic feet of air per hour into his lungs, he will at 32° F. receive 2163·8 grs. of oxygen per hour. At a temperature of 100° F. (which is not unusual in the tropics) a cubic foot of dry air weighs 498 grs., and is made up by weight of 383·5 grs. of nitrogen and 114·5 grs. of oxygen. Therefore, in an hour, breathing as before, the man would receive 1901 grs. of oxygen, or nearly 12 per cent. less than he would breathe in at the lower temperature.

3. The *heart's* action has been usually stated to be quickened in the tropics, but Rattray's numerous observations show that this is incorrect; the average pulse in the tropics was lower by 2½ beats per minute than in the temperate zone. In experiments on animals, moderate heat does not quicken the heart, but great heat does.

4. The *digestive* powers are somewhat lessened, there is less appetite, less desire for animal food, and more wish for cool fruit. The quantity of bile secreted by the liver is not increased, if the stools are to be taken as a guide, though Lawson believes that an excess of colouring matter passes out with the stools; nothing is known of the condition of the usual liver work.

5. The *skin* acts much more than usual (an increase of 24 per cent. according to Rattray), and great local hyperæmia and swelling of the papillæ occur in new-comers, giving rise to the familiar eruption known as "prickly heat." In process of time, if exposed to great heat, the skin suffers apparently in its structure, becoming of a slight yellowish colour from, probably, pigmentary deposits in the deep layers of the cuticle.

6. The *urine* is lessened in quantity. The urea is lessened, as shown by experiments in hot seasons at home and during voyages. It is probable that this is simply from lessened food. The pigment has been supposed to be increased, but this is doubtful. The chloride of sodium is lessened; the amount of uric and phosphoric acids is uncertain.

7. The effect on the *nervous* system is generally considered as depressing and exhausting, *i.e.*, there is less general vigour of mind and body. But it is an undoubted fact that the greatest exertions both of mind and body have been made by Europeans in hot climates. Robert Jackson thought as much work could be got out of men in hot as in temperate climates. It is probable that the depressing effects of heat are most felt when it is combined with great humidity of the atmosphere, so that evaporation from the skin, and consequent lessening of bodily heat, are partly or totally arrested.

The most exhausting effects of heat are felt when the heat is continuous, *i.e.*, very great, day and night, and especially in sandy plains, where the air is highly rarefied day and night. There is then really a lessened quantity of oxygen in a given cubic space. Add to this fact that the respirations are lessened, and we have two factors at work which must diminish the ingress of oxygen, and thereby lessen one of the great agents of metamorphosis.

8. Rattray made observations on the *weight* and *height* of forty-eight naval cadets, aged from 14½ to 17 years, during four successive changes of climate during a voyage. The results show that in the tropics they increased in height more rapidly than in cold climates, but that they lost weight very considerably, and, in spite of their rapid growth, Rattray concludes that the heat impaired the strength, weight, and health of these lads. His figures seem conclusive on these points, and show the beneficial

influence of cold on youths belonging to races long resident in temperate climates.

On the whole, even when sufficient perspiration keeps the body temperature within the limits of health, the effect of great heat in shade seems to be, as far as we can judge, a depressing influence lessening the nervous activity, the great functions of digestion, respiration, sanguification, and directly or indirectly the formation and destruction of tissues. Whether this is the heat alone, or heat and lessened oxygen, and great humidity, is not certain.

So bad have been the general and personal hygienic conditions of Europeans in India, that it is impossible to say what amount of the former great mortality in that country was due to excess of heat over the temperature of Europe. Nor is it possible to determine the influence of heat alone on the endemic diseases of Europeans in the tropics—liver disease and dysentery. There is, perhaps, after all, little immediate connection between heat and liver disease.

Rapid Changes of Temperature.—The exact physiological effects have not yet been traced out; and these sudden vicissitudes are often met by altered clothing, or other means of varying the temperature of the body. The greatest influence of rapid changes of temperature appears to occur when the state of the body in some way coincides with or favours their action. Thus, the sudden checking of the profuse perspiration by a cold wind produces catarrhs, inflammations, and neuralgia. It is astonishing, however, to find how well even phthisical persons will bear great changes of temperature, if they are not exposed to moving currents of air; and there can be little doubt that the wonderful balance of the system is soon readjusted.

Effects of Cold.—The degree of cold which inhabitants of temperate climates can bear without ill effect is well shown in the experiences of Arctic voyagers. Parry noted the thermometer as low as $-55°$ F., or 87° below the freezing point; Franklin at $-58°$ F., or 90° below the freezing point; and Back at $-70°$ F., or 102° below the freezing point. The actual effects of cold naturally vary in degree and kind. Much depends upon the degree of cold, the duration of the exposure, and the medium or manner of application: to these conditions may be added the extent of surface exposed and the general health or physiological condition of the person exposed. It is a matter of common knowledge that moderate cold, acting during a short time, or even very severe cold, during a still shorter time, when followed by the glow of reaction, exercises a tonic and stimulating influence.

In temporary exposure to cold, or even slight exposure, there is first the sensation of cold with pallor of the skin, shivering and tingling, followed by numbness: the pulse becomes slower, excretion of water by the lungs and skin diminishes, while the urine increases in quantity. If the exposure to cold be prolonged, and the circulation and heat-producing powers cannot be maintained, the arterioles become contracted and no longer permit the passage of blood-corpuscles, and thus all physiological and chemical changes are arrested. The extremities become starved, and hence death of these parts takes place by frost-bite and gangrene. Prolonged exposure to extreme cold gives rise to an overpowering sense of languor, sensibility becomes lowered, the individual loses power of reaction and sinks to sleep or becomes delirious, death usually resulting from coma, though it may occur from syncope or asphyxia. Deprivation of food, partial or complete, materially adds to the hurtful influence of cold. In a well-nourished person, cold air, containing bulk for bulk more oxygen than warm air, produces a sensation of well-being, increased appetite, and an inclination towards increased physical and mental activity. It is only in the feeble, or when the cold is pushed to such an extreme as to act as a depressant, that injurious results ensue.

In the production of these effects it must be borne in mind that the actual temperature is not the only factor to be taken into consideration: dryness and stillness of the air permit a much lower temperature to be borne with comfort than when the air is damp or in motion. Even moderate wind renders a low temperature unbearable. It is the stillness and dryness of the air in Arctic regions, and at some health resorts at high altitudes, that renders the extreme degrees of cold there prevalent not only tolerable but even beneficial. We have no evidence to say with certainty that any diseases are directly caused by cold. The specific fevers are generally less prevalent, and micro-organisms generally less active at low than at high or moderate temperatures. Catarrhal affections may be induced by sudden exposures to cold, or the so-called *chill*, but beyond this general statement we are not justified in going.

Influence of Atmospheric Humidity on Health.—According to their degrees of humidity climates are divided into moist and dry. Tyndall's observations show how greatly the humidity of the air influences climate, by hindering the passage of heat from the earth. As far as the body is concerned, the chief effect of moist air is exerted on the evaporation from the skin and lungs, and therefore the degree of dryness or moisture of an atmosphere should be expressed in terms of the relative (and not of the absolute) humidity, and should always be taken in connection with the temperature, movement, and density of the air, if this last varies much from that of sea-level. The evaporating power of an atmosphere which contains 75 per cent. of saturation is very different, according as the temperature of the air is 40° or 80° F. As the temperature rises, the evaporative power increases faster than the rise in the thermometer.

There is a general opinion that an atmosphere which permits free without excessive evaporation is the best; but there are few precise experiments.

The most agreeable amount of humidity to most healthy people is when the relative humidity is between 70 and 80 per cent. In chronic lung diseases, however, a very moist air is generally most agreeable, and allays cough. The evaporation from the lungs produced by a warm dry atmosphere appears to irritate them. On the other hand, a still, cold atmosphere is dry, without much capacity for holding moisture; so that the bracing effects of the cold are felt, without the irritation produced by too rapid evaporation from the respiratory surface. This may be one cause (among others) of the benefit derived in winter from such places as Davos, &c.

The moist hot siroccos, which are almost saturated with water, are felt as oppressive by man and beast; and this can hardly be from any other cause than the check to evaporation, which interferes with elimination of effete matters by transpiration, and the consequent rise in the temperature of the body.

It is not yet known what rate of evaporation is the most healthy. Excessive evaporation, such as may be produced by a dry sirocco, is well borne by some persons, but not by all. Probably, in some cases, the physiological factor of perspiration comes into play, and the nerves and vessels of the skin are altered; and in this way perspiration is checked. We can hardly account in any other way for the fact that, in some persons, the dry sirocco, or dry hot land wind, produces harshness and dryness of the skin and general malaise, which possibly (though there is yet no thermometric proof) may be caused by a rise of temperature of the body.

From the experiments of Lehmann on pigeons and rabbits, it appears that more carbon dioxide is exhaled from the lungs in a very moist than in a dry atmosphere. The pathological effects of humidity are intimately connected with the temperature. Warmth and great humidity are borne on the whole more easily than cold and great humidity. Yet in both cases, so wonderful is the power of adaptation of the body that often no harm results.

The spread of certain diseases is supposed to be intimately related to humidity of the air. Malarious diseases, it is said, never attain their fullest epidemic spread unless the humidity approaches saturation. Plague is said to be checked by a very dry atmosphere. In the dry Harmattan wind, on the west coast of Africa, small-pox is difficult to inoculate; and cow-pox is kept up with great difficulty in very dry seasons in India, but if care is taken in the storage of lymph and in the manipulative procedures necessary to carry out the operation, there is no actual inability to carry on vaccination during the very hot and dry seasons of India and elsewhere. Yellow fever, on the other hand, seems less dependent on moisture, or will at any rate prevail in a dry air. The observations at Lisbon, which Lyons recorded, show no relation to the dew-point.

With regard to other diseases, and especially to diseases of sanguification and nutrition, observations are much needed.

Influence of Air Movement on Health.—This is a very important climatic condition. The effect on the body is twofold. A cold wind abstracts heat, and in proportion to its velocity; a hot wind carries away little heat by direct abstraction, but if dry increases the evaporation, and in that way may in part counteract its own heating power. Both, probably, act on the structure of the nerves of the skin and on the contractility of the cutaneous vessels, and may thus influence the rate of evaporation, and possibly affect also other organs.

The amount of the cooling effect of moving bodies of air is not easy to determine, as it depends on three factors, viz., the velocity of movement, the temperature, and the humidity of the air. The effect of movement is very great. In a calm atmosphere an extremely warm temperature is borne without difficulty. In the Arctic expeditions calm air, many degrees below zero of Fahrenheit, caused no discomfort. But any movement of such cold air at once chills the frame. It has been asserted that some of the hot and very dry desert winds will, in spite of their warmth, chill the body; and if so, it can scarcely be from any other reason than the enormous evaporation they cause from the skin. It is very desirable, however, that this observation should be repeated, with careful thermometrical observations both on the body in the usual way and on the surface of the skin.

The main action which produces change in the character of winds is their being forced to mount up when they meet with any elevation above the surface of the ground. The ascent of air brings it into levels where the pressure is reduced, and it is therefore rarefied. This rarefaction causes the air to fall in temperature, though this fall is, to a certain extent, counteracted by the latent heat set free by the enforced condensation of moisture. When the air has reached the summit of the obstacle, it has no longer to ascend, and the reverse action sets in. The air descends, comes under constantly increasing pressure, and is thereby warmed, while, as the mountain side is not a water surface, it cannot obtain moisture on its way down. It therefore arrives at the plains as a warm and dry wind. This explains why, when any wind sets straight in against a coast line, it is in general wet, and that the bolder and more mountainous the coast is the moister the wind will be.

The more important local winds which have great influence on the health of the countries in which they prevail are the following:—

The Simoom, or poison wind of the desert, is a species of whirlwind which prevails in Arabia, and sometimes buries whole caravans in sand.

The Khamsin of Egypt, from the Arabic word for fifty, as it blows usually for the fifty days from Easter to Whitsuntide, is a hot, dry blast from the desert, laden with sand particles. The Harmattan is another withering desert wind, blowing over the Sahara towards the west coast of Africa, bearing clouds of dust, and making its influence felt as far as the Cape Verde Islands.

A notoriously dry wind in Western Europe is the Föhn of Switzerland, known also as the Schneefresser, or snoweater; it corresponds to the Chinook winds of the Western States of North America. The intense heat and dryness of this wind are due to its having descended from the passes over which it crossed the Alps. Another dry, descending wind is the Mistral of the Riviera, or the Maestro of Italy. It is a north-west wind, intensely dry, rendering places exposed to it most undesirable residences during its prevalence. The first effect of this wind on visitors is agreeable, from its coolness, but from its dryness it soon causes unpleasant sensations in the nose and mouth, and often pains in the limbs. In consumptives its appearance has been sometimes followed by an attack of hæmoptysis.

Going farther eastward we find a wind from the same quarter, known as the Tramontane, on the lakes of Maggiore and Garda. At Trieste and in Dalmatia it is known as the Bora, blowing so furiously that streets are provided with guide ropes to act as bannisters to enable wayfarers to hold on against the blast. At Nice, and in the Riviera generally, the same wind is called the Bise; it is a cold, blustering north-east wind coming straight from the Maritime Alps.

The south-east wind, or Scirocco of the Mediterranean basin, is just the reverse to the Mistral. It is a warm, moist wind, generally preluding rain. It is supposed to arise in the Sahara, and to gather moisture in crossing the Mediterranean. In Syria this wind is regarded as a dry wind; in Malta and Sicily it is hot, moist and very relaxing, while in Corsica it is less so, and in the Genoese Riviera is very moist but not very warm. The names of other local winds are almost countless, most of them being blasts of ill-repute; the more important being the "Brickfielders" of Sydney, and the "Painter" or "Barber" of Callao, so called from their dust-laden character.

The permanent winds, like the north-east and south-east trades, vary their prevalence with the season of the year. Of the seasonal winds, the north-east and south-west monsoons are the most important. These prevail in India and China during certain times of the year, and are really the winter and summer monsoons respectively. The north-east monsoon corresponds to the north-east trade, and is a cool, dry wind, while the south-west monsoon is hot, moist, and accompanied by low barometric pressure and heavy rains. In Western Europe the most frequent wind in winter is the south-west, while both in Eastern Asia and in Eastern South America it is the north-west. As influencing the amount of rise and fall of temperature, as compared with the mean, we find the south-west wind is the warmest in Central Europe, raising the temperature 5° F., while the north-east, the coldest wind in Central Europe, lowering the temperature 7° F., is in the west one of the least frequent of winds; whereas on the eastern coasts of Asia and

America the most frequent wind—the north-west—lowers the temperature as much as 5° F., while the south wind, which raises the temperature more than 10° F., is the rarest of all.

In these islands by far the most prevalent wind is the south-west, next the west, these two prevailing three times more frequently than the north-east, and six times more so than the east wind; though probably the latter makes its prevalence more felt (Glaisher). The north-east is the rarest wind, and next to it come the south-east, the east, and the north. The west and the south-west winds in this hemisphere are the result of the equatorial current and Gulf Stream: they are warm and bring rain; whereas the north-east and east winds, blowing from the continents of Europe and Asia, and only moistened by passing over the narrow strip of the North Sea, are dry and cold. As bearing upon their influence on health, we may summarise by saying, that warm and moist winds, such as the south-west wind in these islands, are mild and relaxing; dry, cool winds, such as our east wind, are bracing; but this wind, on account of its penetrating character, is often dangerous to those having any weakness of the lungs, and is also hurtful to those liable to rheumatism or liver congestion.

Influence of Atmospheric Pressure on Health.—When the difference of pressure between two places is considerable, a marked effect is produced, so much so that the influence of mountain localities plays a very important part in modern therapeutics. From the hygienic point of view, this subject involves the consideration of (1) the effects of lessened pressure, and (2) the effects of increased pressure.

Effects of Lessened Pressure.—In ascending mountains there is rarefaction, *i.e.*, lessened pressure of air; on an average (if the weight of the air at sea-level is 15 ℔ on every square inch) an ascent of 900 feet takes off half a pound; but this varies with height; about one-eighth of the atmospheric pressure is lost at 2500 feet, a sixth at 5000 feet, a quarter at 7500 feet, and at 16,000 feet about one-half. There are also lowered temperature and lessened moisture above 4000 feet, greater movement of the air, increased amount of light, greater sun radiation if clouds are absent; the air is freer from germs; owing to the rarefaction of the air and lessened watery vapour, there is greater diathermancy of the air; the soil is rapidly heated, but radiates also fast, as the heat is not so much held back by vapour in the air, hence there is very great cooling of the ground and the air close to it at night.

The physiological effects of lessened pressure begin to be perceptible at 2800 or 3000 feet of altitude (= descent of 2½ to 3 inches of mercury); they are—quickened pulse (fifteen to twenty beats per minute); quickened respiration (increase = ten to fifteen respirations per minute), with lessened spirometric capacity, increased evaporation from skin and lungs; lessened urinary water. At great heights there is increased pressure of the gases in the body against the containing parts; swelling of superficial vessels, and occasionally bleeding from the nose or lungs. A sensation of weight is felt in the limbs from the lessened pressure on the joints. At altitudes under 6000 or 7000 feet the effect of mountain air (which is, perhaps, not owing solely to lessened pressure, but also, possibly, to increased light and pleasurable excitement of the senses) is to cause a very marked improvement in digestion, sanguification, and in nervous and muscular vigour. It is inferred that tissue change is accelerated, but nothing definite is known.

The rapid evaporation at elevated positions is certainly a most important element of mountain hygiene. At Puebla and at Mexico the hygrometer of Saussure will often mark 37°, which is equal to only 45 per cent. of saturation, and yet the lower rooms of the houses are very humid, so that in the town of Mexico there are really two climates—one very moist, in the *rez-de-chaussée* of the houses; one very dry, in the upper rooms and the outside air.

The diminution of oxygen, in a certain cubic space, is precisely as the pressure, and can be calculated for any height, if the barometer is noted. Taking dry air only, a cubic foot of air at 30 inches, and at 32° F., contains 130·4 grains of oxygen. An ascent (about 5000 feet) which reduces the barometer to 25 inches will lessen this $\frac{1}{6}$th, or $\left(\frac{25 \times 130\cdot4}{30}\right) = 108\cdot6$ grains. But it is supposed that the increased number of respirations compensates, or more so, for this; and, in addition, it must be remembered that in experiments on animals, as long as the percentage of oxygen did not sink below a certain point (14 per cent.), as much was absorbed into the blood as when the oxygen was in normal proportion. Jourdanet has indeed asserted that the usual notion that the respirations are augmented in number in the inhabitants of high lands is "completely erroneous"; that the respirations are in fact lessened, and that from time to time a deeper respiration is voluntarily made as a partial compensation. But Coindet, from 1500 observations on French and Mexicans, does not confirm this; the mean number of respirations was 19·36 per minute for the French, and 20·297 for the Mexicans.

As a curative agent, mountain air (that is, the consequences of lessened pressure chiefly) ranks very high in all anæmic affections from whatever cause (malaria, hæmorrhage, digestive feebleness, even lead and mercury poisoning); and it would appear, from Hermann Weber's observations, that the existence of valvular heart disease is, if proper rules are observed, no contra-indication against the lower elevations (2000 to 3000 feet). Neuralgia, gout, and rheumatism are all benefited by high Alpine positions. Scrofula and consumption have been long known to be rare among the dwellers on high lands, and the curative effect of such places on these diseases is also marked; but it is possible that the open-air life which is led has an influence, as it is now known that great elevation is not necessary for the cure of phthisis. Weber and others have shown how in the true Alpine region, in Dauphiné, in Peru and Mexico, and in Germany, phthisis is decidedly averted or prevented by high altitudes. The more recent experience of Davoz Platz is certainly confirmatory of this.

Although on the Alps phthisis is arrested in strangers, in many places the Swiss women on the lower heights suffer greatly from it; the cause is a social one: the women employed in making embroidery congregate all day in small, ill-ventilated, low rooms, where they are often obliged to be in a constrained position; their food is poor in quality. Scrofula is very common. The men, who live an open-air life, are exempt; therefore, in the very place where strangers are getting well of phthisis the natives die from it,—another instance that we must look to local conditions and social habits for the great cause of phthisis; that is, that in most cases this disease is due to the breathing of impure air, containing the infective bacillus. It would even seem possible that, after all, it is not indeed elevation and rarefaction of air, but simply plenty of pure air and exercise which are the great agents in the cure of phthisis.

Jourdanet, who differs from so much that is commonly accepted on this point, gives additional evidence on the effect of elevation on phthisis. At Vera Cruz phthisis is common; at Puebla and on the Mexican heights it is almost absent (*à peu près nulle*).

The diseases for which mountain air is least useful are—rheumatism, at the lower elevations where the air is moist (above this rheumatism is improved), and chronic inflammatory affections of the bronchial tubes and pleura, and neuralgia. The "mountain asthma" appears, however, from Weber's observations, to be no specific disease, but to be common pulmonary emphysema following chronic bronchitis.

It seems likely that pneumonia, pleurisy, and acute bronchitis are more common in higher Alpine regions than lower down.

Effects of Increased Pressure.—The effects of increased pressure have been noticed in persons working in diving-bells, caissons, &c., and in those submitted to treatment by compressed air, especially at Lyons and at Reichenhall. When the pressure is increased to from $1\frac{1}{4}$ to 2 atmospheres, the pulse becomes slower, though this varies in individual cases; the mean lessening is ten beats per minute; the respirations are slightly lessened (1 per minute); evaporation from the skin and lungs is said to be lessened (?); there is some recession of blood from the peripheral parts; there is a little ringing and sometimes pain in the ears; hearing is more acute; the urine is increased in quantity; appetite is increased; it is said men will work more vigorously. When the pressure is much greater (2 or 3 atmospheres), the effects are sometimes very marked; great lowering of the pulse, heaviness, headache, and sometimes deafness. It is said that more oxygen is absorbed, and that the venous blood is as red as the arterial; the skin also sometimes acts more, and there may even be sweating. The main effect is to lessen the quantity of blood in the veins and auricles, and to increase it in the arteries and ventricles; the filling of the ventricle during the relaxation takes place more slowly. The diastolic interval is lengthened, and the pulse is therefore slower.

In pneumatic chambers and tubes used for pier driving and laying the foundations of bridges the pressure in the air chambers is usually of from 3 to 4 atmospheres, and if due precautions are taken to neither increase nor lower the pressure too rapidly, no symptoms or inconvenience are experienced by workmen when employed in them for hours together. What accidents and ill effects have occurred are chiefly in the form of prickings, muscular pains, nose bleedings, and paralysis, and these have occurred commonly after leaving the high-pressure chambers or tubes, and when the reduction of pressure has been too rapid. Very few unfavourable effects appear to occur under the actual high pressure. The great danger in all these cases appears to be in the too sudden reduction of pressure. If time be given, the body seems to be quite able to accommodate itself to the extreme variations of pressure; thus, in a balloon ascent made by Glaisher and Coxwell, these observers were able to withstand as low a pressure as indicated by 8 inches of mercury, while, on the other hand, men who worked in sinking piers for the Forth Bridge did so in air chambers in which the barometer stood as high as 72 inches. These two instances give a range of atmospheric pressure extending over 64 inches supportable by man.

As a curative agent in phthisis, the use of compressed air has so far been unfavourable, but is of more benefit in asthmatic cases. In the "compressed air bath" at the Brompton Hospital the pressure rarely exceeds an addition of 10 ℔ to the square inch, or $\frac{2}{3}$ of an atmosphere. Half an hour is given to reach this pressure, it is maintained for an hour, and half an hour is occupied in reducing it to the natural pressure; thus all danger of sudden change is taken away.

Some observations made by Bert show that oxygen, when it enters the blood under pressure (such as that given by 17 atmospheres of atmospheric air, or 3½ atmospheres of pure oxygen), is toxic to birds, producing convulsions. Convulsions are produced in dogs when the pressure is only 7 or 8 atmospheres and when the oxygen amounts to only double the normal, or, in other words, reaches 32 c.c. per 100 c.c. of blood. Bert conjectured that the toxic influence of oxygen was on the nervous centres, like strychnine. The animal temperature fell 2 or 3 degrees (C.) during the convulsions, so that excess of oxygen did not cause increased combustion. In the case of a dog kept under a pressure of 9½ atmospheres for some time, gas was found in the ventral cavity and in the areolar tissue. In man the pressure of only 5 atmospheres appears to be dangerous.

Acclimatisation.—The doctrine of acclimatisation has been much debated, but probably we do not know sufficiently the physiological conditions of the body under different circumstances. In the case of Europeans living till puberty in a temperate region, near the sea-level, and in a moist climate like England, and then going to the tropics, the question of acclimatisation would be put in this form,—Does the body accommodate itself to greater heat, to lessened humidity in some cases, or greater in others, and to varying altitudes?

There can be little doubt that the body does accommodate itself within certain limits to greater heat, as we have seen that the lungs act less, the skin more, and that the circulation lessens when Englishmen pass into the tropics. There is so far an accommodation or alteration impressed on the functions of the body by unwonted heat. And we may believe that this effect is permanent, *i.e.*, that the lungs continue to act less and the skin more as long as the Europeans remain in the tropics. Doubtless, if the race were perpetuated in the tropics, succeeding generations would show fixed alterations in these organs.

We may conclude that the converse holds true, and that the cold of temperate regions will influence natives of the tropics in an opposite way, and this seems to be rendered likely by the way in which lung affections arise in many of them.

We may admit there is an acclimatisation in this sense, but in no other. The process is one of adaptation rather than acclimatisation. The usual belief that the constitution acquires in some way a power of resisting unhealthy influences—that is, a power of not being any longer susceptible to them—is not supported by any good evidence. The lungs in Europeans will not regain their weight and amount of action in the tropics; a change to a cold climate only will cause this; the skin retains its increased function until the cause producing it is removed. So also there is no acclimatisation in any sense of the word for malaria.

From the results of a long extended inquiry into the effects of climate on different races of people, Stokvis concludes "that the power of resistance of the healthy adult European living in the tropics quite equals, and in some measure is even superior to, the vital power of the native races." On the other hand, there are certain peculiarities of the race which have been gradually acquired by inheritance from generation to generation, and that the longer the European resides in the tropics the more likely is he to lose his superior resisting powers; and it is possible that the European Creole is both bodily and mentally inferior to the European.

Classification of Climates.—The simplest plan of classifying climates is based upon geographical limits, and largely according to latitude. This at best is imperfect unless allowance be made for the influence of warm or cold sea-currents, large ocean areas, and the nearness or distance of mountain ranges. These latter in particular greatly affect rainfall and exposure to winds. Allowing for these modifying influences, and based upon the principle or limits of latitude, a commonly accepted classification of climates is as follows:—

Warm Climates.—These include the greater part of Africa and its islands; Southern Asia, embracing India and China; Polynesia, including all Australia except Victoria; North America south of California; and South America north of Uruguay, with the West Indies. These climates are marked by high temperature, heavy rainfall, and more or less well-defined dry and wet seasons. Such climates are usually met with in places lying between the equator and 35° of latitude north or south of it. They can be subdivided into equatorial, tropical, and sub-tropical groups. In the equatorial the mean annual temperature is from 80° F. to 84° F., the minimum being 54° F. and the maximum 118° F. The mean temperature decreases slowly as we recede from the equator. The difference of temperature during the day is slight, but there is a marked fall at night from radiation. The rainfall is rarely less than 40 inches annually, and it is this which tempers and reduces the otherwise extreme heat.

Though possibly all the diseases usually attributed to the influence of warm climates are not rightly so, still these climates are peculiarly apt to be associated with such affections as heat-stroke, yellow fever, cholera, dengue, liver abscess, dysentery, small-pox, and various forms of malarial fever, while scarlet fever and measles are comparatively rare.

Temperate Climates.—These have a mean temperature of 60° F., often with great extremes; four well-defined seasons, usually most rainy during autumn and winter; and the geographical limits of from 35° to 50° of latitude. The temperate climates are inhabited by the most vigorous races of the world, and would seem to have been in all ages specially favourable to the physical and intellectual growth of the human race. The most prevalent diseases are for the most part the ordinary diseases of Europe and America, especially rheumatism, acute and chronic pneumonia, various affections of the air-passages, and the large group of exanthemata. Pulmonary consumption is common, but cannot be said to be the special production of these climates, "though doubtless immunity from the disease has been shown to exist under various and indeed opposite climatic conditions" (Williams).

Cold Climates.—These belong to regions situated between 50° of latitude and the poles. In them the summer is short, often lasting but a few weeks, while the winter is long. Snow is extensive, but of rain there is little or none. The temperature falls rapidly between latitudes 55° and 75°, and the fall amounts to 22° F. to 27° F., the coldest region being not at the pole, but about 10° from it north of Behring's Straits, the mean temperature there ranging between 17° F. and 19° F.

Scurvy and scrofula are the principal affections which can be directly attributed to these climates,—the former arising from a deficient supply of fruit and vegetables, and the latter from the overcrowding and general poorness of living which prevails. Ophthalmia and amaurosis are also reported to be present, from the reflection of light from the snow in the polar regions. The extreme and dry cold, which is the feature of these climates, has a bracing effect on the system, improves the appetite, promotes the performance of muscular work, and, as it is fatal to all micro-organisms, is a good antiseptic.

Mountain Climates.—These are peculiar, being marked by extremes of temperature, great clearness and rarefaction of the atmosphere, and lessened barometric pressure. Among the more important of these climates are (1) the Alpine, where the winter is very cold, dry, and calm, but the sun's rays are most powerful; (2) the Rocky Mountains of North America, where the climate resembles that of the Alpine resorts, but warmer, drier, less snow, but more dust; (3) the sanitaria of the Andes, with a climate generally dry, warm, and bracing, except at La Paz, where the winter is cold; (4) Himalayan stations, where the climate is cool, but subject to considerable extremes, and damp owing to the excessive rainfall; (5) the South African Highlands of Cape Colony, Orange Free State, and the Transvaal, where the climate is warm, with seldom any extreme of cold except during the rainy season and a few days of winter.

Mountain climates are peculiarly favourable to those having imperfect chest development, with hereditary or other tendencies to consumption; but are unsuitable for those troubled with chronic bronchitis, or acute diseases of the lungs, kidneys, liver, or brain. The peculiar effects of mountain climates appear to be due to the increased aëration of the blood which takes place during the act of breathing mountain air, and, as a result of this, these climates are best suited for those capable of taking abundant exercise, and distinctly hurtful to the aged and very feeble.

Marine climates are those prevailing upon islands, capes, and sea coasts, in which the temperature is remarkably equal, rarely reaching extremes, and in which, owing to the increased moisture and rainfall, a certain softness of atmosphere is experienced. The climates of Great Britain, Norway, and Iceland may be taken as types of these so-called marine climates.

The principal diseases which appear to be in any way peculiar to marine climates are rheumatism, and the various affections of the lungs and air-passages, the greater part of which may be due to the dampness and constant weather changes which are so characteristic of these climates.

BIBLIOGRAPHY AND REFERENCES.

Blanford, *The Climate and Weather of India*, 1889. Burdon-Sanderson, "The Salt and Compressed Air Cures of Reichenhall," *Practitioner*, vol. i. No. 4, p. 217.

Cullimore, *The Book of Climates*, Lond., 1890.

Felkin, "The suitability of Tropical Highlands for European settlement," *Prov. Med. Journ.*, Nov. 2, 1891. Foley, "Du Travail dans l'air comprimé," *Gaz. Hebdom.*, Paris, 1863, No. 32.

Hirschfeld, "Uber das Vorkommen der Lungentuberkulose in der warmen Zone," *Deutsches Archiv. f. Klin. Med.*, Bd. liii. heft 5 and 6, p. 457.

Johnston, "Remarks on the Normal Temperature of the Body in the Tropics," *A.M.D. Report*, xviii. p. 255. Jourdanet, *Influence de la pression de l'air sur la vie de l'homme*, Paris, 1875.

Rattray, "On the Effects of Change of Climate on the Human Economy," *Proc. Roy. Soc.*, 1869–72, Nos. 122–126 and 139.

Stokvis, "Address on Colonial Pathology," *Transac. Internat. Medical Congress*, Berlin, 1890.

Tait, "On the Mortality of Eurasians," *Statistical Journal*, Sept. 1864.

Weber, *On the Climate of the Swiss Alps*, Lond., 1864. Williams, "Aero-Therapeutics," London, 1894; also "Climate in Relation to Health and Geographical Distribution of Disease," *Journ. Sanitary Institute*, vol. xv. Pt. 2, July 1894.

Yeo, *Climate and Health Resorts*, Lond., 1885.

CHAPTER XV

METEOROLOGY

METEOROLOGY is the science of the weather; while the word weather connotes the general condition of the atmosphere at any particular time, and especially of that portion of the atmosphere near the surface of the earth. These definitions suggest that weather is a general result produced by the combined action of several different elements, each consisting of a special set of phenomena in the physics of the atmosphere, such as those depending on its warmth, motion, dryness, humidity, transparency, and the like; while the leading principles of modern scientific meteorology are first, the making of accurate and systematic observations of these phenomena, and secondly, their practical interpretation. The making of meteorological observations presents for the most part no great difficulty, the essential qualification being "a capacity for doing a small piece of routine work at stated times without losing interest in it, and so becoming careless." To be of any value, the observations made at different places must be comparable; the instruments used must be similar in form, exposed in a similar way, and the errors peculiar to them and to the observer must be known.

TEMPERATURE, HOW OBSERVED AND CALCULATED.

Thermometers.—The principle of these instruments is that they measure temperature by the expansion of bodies. The first thermometer is supposed to have been invented by Sanctorio, of Padua, in 1590; but the history of the instrument practically dates from 1714, when Fahrenheit of Dantzic constructed the thermometer known by his name.

Liquids are the bodies best suited for the purpose of indicating, by their expansion or contraction, the intensity of heat, in the construction of thermometers; the expansion of gases being too great, and that of solids too small. Of liquids, mercury and alcohol are practically the only ones used; the former because of its equal expansion at different temperatures, its low freezing point ($-37^{\circ}\cdot 9$ F.), its high boiling point ($675^{\circ}\cdot 1$ F.), its high conductivity of heat, and its low specific heat; alcohol is used because at atmospheric pressure it does not solidify at the greatest known cold. For these reasons, mercury is used for recording high degrees of heat, and alcohol for low temperatures.

A thermometer consists of a capillary glass tube of uniform bore, hermetically sealed at one end, and blown at the other into a bulb filled with mercury or spirit. The steps in the construction of a thermometer are: (1) calibrating the tube, or dividing it into parts of equal capacity; (2) filling the bulb and tube with mercury or alcohol, and expelling all air by heat; (3) curing, or laying the instrument aside for a year or so after filling, so that the glass may assume a permanent shape, and so obviate the error known as "displacement of zero"; (4) graduation, or the marking of the scale on the thermometer stem, the fixed points of temperature of melting ice, and of boiling water under standard pressure, being duly ascertained by direct experiment in each case.

The melting point of ice is used in preference to the freezing point of water, because distilled water, if perfectly still, may be chilled to a temperature several degrees below that at which, if not perfectly still, it would freeze. Under such circumstances, if it is suddenly agitated, it will congeal instantly. Again, water which holds a salt in solution has a freezing point considerably below that which has no such salt in solution. The boiling point of water is a still more variable quantity than the freezing point; hence the term must be qualified by the words "at mean sea-level," the barometer standing at 29·92 inches in the latitude of London, and at 760 mm. in the latitude of Paris.

On the continent of Europe the scale of a thermometer is divided into 100 parts or so-called Centigrade, after the method of Celsius, a professor of Upsala, who suggested this in 1742. This division is really the simplest, and now generally used in this country in connection with all scientific work. In this scale the zero or melting point of ice (so-called freezing) is at 0 degree, while the boiling point is at 100 degrees.

Another scale introduced by Réaumur, a French physicist, in 1731, has the same fixed points as in the Centigrade, but the interval between them is divided into 80 instead of 100 parts; that is to say, 80 degrees Réaumur equal 100 degrees Centigrade, or 1 degree Réaumur is $\frac{5}{4}$ of a degree Centigrade, or 1 degree Centigrade is $\frac{4}{5}$ of a degree Réaumur. Consequently, to correct Réaumur degrees into Centigrade ones, it is necessary to multiply them by $\frac{5}{4}$. Similarly, Centigrade degrees are converted into those of Réaumur by multiplying them by $\frac{4}{5}$.

In England and America, for general use, the thermometric scale invented by Fahrenheit is still employed. In this scale the higher fixed point is, like that in the Centigrade and Réaumur scales, that of boiling water; but the lower fixed point or zero is not the temperature of melting ice, but that obtained by mixing equal parts of snow and sal ammoniac, and the interval between the two is divided into 212 parts or degrees. The zero temperature on this scale is lower than that of melting ice, with the result that when a Fahrenheit scale thermometer is placed in melting ice, it stands at 32 degrees, and, therefore, 100 degrees on the Centigrade scale and 80 on the Réaumur equal 212 less 32, or 180 degrees on the Fahrenheit, or 1 degree Fahrenheit equals $\frac{5}{9}$ of a degree Centigrade, and $\frac{4}{9}$ of a degree Réaumur. For the conversion of any given number of degrees Fahrenheit into Centigrade or Réaumur degrees, the number 32 must be first subtracted in order that the degrees may count for the same part of the scale, and the result then multiplied by the relative value of the two degrees. Conversely, Centigrade and Réaumur degrees may be converted into Fahrenheit by adding 32 after multiplying by the ratio value.

Thus,

$$\tfrac{9}{5}\text{C.} + 32 = \text{F.} \qquad \tfrac{9}{4}\text{R.} + 32 = \text{F.}$$

$$(\text{F} - 32)\tfrac{5}{9} = \text{C.} \qquad (\text{F} - 32)\tfrac{4}{9} = \text{R.}$$

In the case of the Centigrade and Réaumur scales all temperatures below the melting point of ice have a minus sign. As the zero on the Fahrenheit scale is 32° below the melting point of ice, the minus sign is, therefore, very seldom required for temperatures occurring in the British Isles. The value

– 40° represents the same temperature on the Fahrenheit and Centigrade scales.

A good mercury thermometer should answer to the following tests. When completely immersed in melting ice, the top of the mercury should exactly indicate zero or 32°, according as to whether the scale be Centigrade and Réaumur or Fahrenheit; and when suspended in the steam of water boiling in a metal vessel with the barometer at 29·92 inches, the mercury should be stationary at either 100° or 212° according to the kind of scale. The value of the degrees should be uniform, as shown by a detached piece of mercury occupying an equal number of degrees in all parts of the tube.

The thermometers used in meteorological observatories are:—standard thermometers, ordinary thermometers, registering thermometers, sometimes called maximum and minimum thermometers, self-recording thermometers, and radiation thermometers.

A *Standard thermometer* is made with every precaution to secure accuracy, and is intended less for daily use than for testing from time to time the correctness of the ordinary instruments. Except for use in extremely cold climates, a standard thermometer should be made with mercury. Its scale must be cut on the stem, and should range from far below zero to the boiling point of water. The scale should not be marked for several years after the tube has been filled, in order to guard against the defect known as the displacement of zero, arising from the gradual contraction of the bulb which results from the slowness with which fused glass returns to its original density. As the bulb contracts, it holds less mercury, which is forced into the tube to a higher level than the temperature warrants, whereby the instrument tends to read too high.

Ordinary thermometers need no special remarks beyond that they should be constructed of mercury, and have a certificate of verification from some recognised scientific institution. At least once a year each instrument should be tested for "displacement of zero" by being plunged into a mass of melting snow and ice.

Registering thermometers are those instruments which are so constructed as to enable us to read off from them the highest or lowest temperature to which they have been exposed in a given length of time. The thermometer which is used for registering the highest or maximal temperature of the day or period is called a "maximum thermometer." Similarly, that which registers the lowest or minimal temperature is called a "minimum thermometer." In both these instruments the contrivance by means of which we are able to read the extremes of temperature is called the "index."

Maximum thermometers are of two kinds, called, after their designers, Phillip's and Negretti's. Both these instruments have mercurial columns, a detached portion of which serves as an index for the highest temperature reached. In Phillip's the detached portion of the mercurial column is separated from the rest by a bubble of air. In Negretti's the detachment is made by means of a slight contraction of the tube, which, while allowing the expanding mercury to pass when the temperature is rising, is sufficient to overcome the natural cohesion of the metal when contracting, to prevent it drawing it back on cooling. Both these instruments are placed horizontally, and both can be reset by lowering the bulb, and then either gently tapping or swinging the thermometer.

Minimum thermometers are also of two kinds: Rutherford's, a spirit thermometer, and Casella's, a mercurial instrument. The former is the minimum thermometer in almost universal use at home and colonial stations, while the latter is a beautiful instrument especially adapted for use in tropical climates, where the intense heat causes alcohol to volatilise quickly.

In Rutherford's instrument a small metallic index is immersed in the spirit with which the bulb and part of the stem are filled. When the temperature falls, and the alcohol contracts, the capillary attraction of the liquid draws the index back with it towards the bulb; but when the temperature rises again, the alcohol passes the index, and leaves the extremity of it farthest from the bulb at the lowest temperature reached. The instrument, after having been read, is readily set by partially inverting it and letting the index fall to the top of the spirit column; it is then hung up in a horizontal position. Occasionally air bubbles appear in the alcohol and fix the index, while at other times some of the alcohol volatilises and condenses at the top of the tube. Both these faults can be easily cured by holding the thermometer bulb downwards and swinging it rapidly round; this will usually cause the air bubbles to disperse, and displace any condensed alcohol from the top of the tube. If, by chance, as the result of this procedure, the index be thrown into the bulb, a little tapping and patience will bring it out again.

To avoid the annoyance arising from breakage of the column by bubbles of air, and from vaporisation in alcohol minimum thermometers, Casella has invented a *mercurial* minimum thermometer (fig. 117). In this instrument there is no steel or other index employed; its general form is shown in the figure, *c* being a tube with large bore, at the upper end of which a flat glass diaphragm is formed by the abrupt junction of the small chamber *ab*, the inlet to which at *b* is larger than the bore of the indicating tube. The result of this is that, having set the thermometer, the contracting force of the mercury in cooling withdraws the fluid in the indicating stem only; whilst on its expanding with heat, the long or indicating column does not move, the increased bulk of mercury finding an easier passage through the larger bore into the small pear-shaped chamber attached. To set this instrument, it is necessary to raise or lower the bulb end, so as to cause the mercury to flow slowly, until the best part of the tube *c* is full and the chamber *ab* quite empty; if at any time mercury will not readily flow from the small chamber as above, a tap or jerk with the hand will cause it to do so.

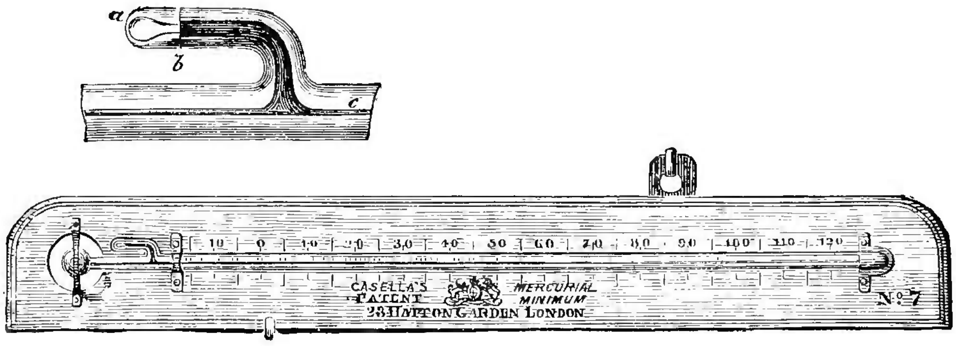


Fig. 117.

Previous to the invention of these maximum and minimum thermometers, a registering instrument known as Six's thermometer (fig. 118), from the name of its inventor, was much used, and is so now. The tube of the instrument is long and U-shaped. One limb constitutes the cold tube, and has at its extemity a bulb, while the other limb is the heat tube, having at its top or end a small chamber in which is confined some air. The middle portion of the tube contains mercury extending round the bend and part of the way up each limb. The bulb and both tubes or limbs above the mercury contain alcohol. Inside the alcohol are two steel indices, one being in the cold and the other in the heat tube. These are readily set, or caused to rest gently upon either column of mercury by moving them by means of a magnet. This being done, if the temperature rises, the alcohol in the bulb will expand and push down the mercury in the cold leg, but raise that in the heat leg, and by so doing drive up the index in it until the temperature ceases to rise, when the point of maximum heat will be indicated by the lower end of that index. On a fall of temperature precisely the reverse will happen, for then the spirit within the bulb will contract, and the pressure in the air chamber at the top of the heat leg will force the mercury down in it, but up in the cold limb, while the cold index will continue to go up so long as the temperature continues to fall. Of course the scales read downwards on the cold leg and upwards in the heat one, and in each the lower end of the index shows respectively the lowest and highest temperature reached since the instrument was last set. The presence of the air chamber makes a Six's thermometer unsuited for travelling, and necessitates the vertical position. The instrument is further liable to error, owing to the fact that sometimes alcohol will ooze round by the side of the mercury, and so pass from the cold to the heat leg. As the scales run in opposite directions, it is obvious that if this defect occurs, it gives rise to a large error in the reading of the temperature. No one but a skilled optician can rectify this evil.

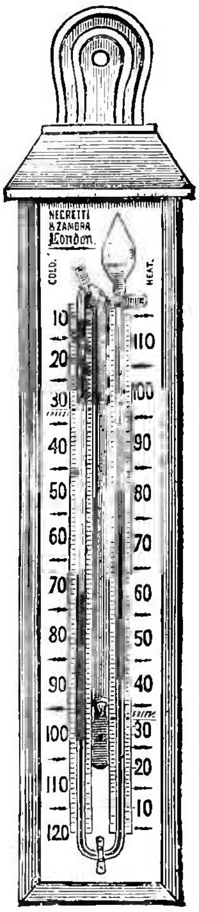


Fig. 118.

Self-recording thermometers, or thermographs, are so arranged as to record their own readings, independently of the observer, either at frequent intervals in the case of electrical thermographs, or continuously, as in the case of photographic thermographs. Of these instruments those of Cripp or Richard are familiar examples. The bulb is a large curved flattened tube, filled with a liquid which tends to straighten with an increase of heat, and this, being connected with a long lever in such a manner as to rise with increase of temperature and to fall with decrease, marks a tracing line upon a revolving cylinder. This cylinder depends upon a clockwork arrangement, and can be wound up, started and left untouched for given periods of time, at the end of which records of temperature will be found for every instant during the period. As the curvature of the tube and the spring mechanism are apt to alter, these instruments need to be corrected and compared periodically with an accurate mercurial thermometer.

Radiation thermometers are commonly employed to afford a measure of the intensity of the heat radiations received from the sun, or given off by the surface of the earth.

Some idea of the intensity of the sun's heat is obtained by means of what are called *solar radiation thermometers* or maximum thermometers placed direct in the sun's rays. In order to avoid loss of heat by reflection from the bright glass surface of the bulb, this and one inch of the stem is coated with lamp-black, and this again, to protect it from being washed off by rain, is placed in a glass case out of which air has been pumped to make it a vacuum. Unfortunately, the presence of the outer glass covering largely interferes with the cooling influence of wind, which materially affects the distribution of heat by the sun in nature. Notwithstanding this theoretical defect, the blackened bulb maximum thermometer *in vacuo* is the best instrument we have for measuring the amount of heat given out or radiated by the sun. The instrument is exposed freely to the sun and air by fixing it horizontally 4 feet above the ground, well away from trees or walls, and with its bulb, in this country, pointing south-east. The heat recorded by such an instrument will be the temperature at which an equilibrium or balance is established between the heat produced by the direct rays of the sun on the bulb, and the cooling caused by radiation or loss of heat from the bulb to the glass jacket or covering; this latter, of course, will have practically the same temperature as that of the air. It follows, therefore, that the excess of the temperature of the black bulb over that of the outer air, as registered by a maximum thermometer in the shade, will be an approximate measure of the power of the actual sun's rays, or in other words, the power of the sun's radiation of heat. Thus, suppose the black bulb thermometer shows a reading of 116°, and the shade or air maximum be 76°. The difference between them of 40° will be the approximate measure of the sun's intensity. As an alternative method, it has been suggested to expose alongside of the black bulb *in vacuo* a similar thermometer also *in vacuo*, only with its bulb bright, and to register the difference between the readings of the two instruments as the amount of solar radiation. It has been objected, with some reason, to both these methods that the indications of the black bulb or sun maximum thermometer are not of much value, because, in the first place, the sun's rays do not necessarily have their greatest power at the hour of maximum air temperature, but much earlier, and that to obtain reliable results we should therefore subtract from the black bulb reading, not the maximum, but the actual air temperature at the moment the black bulb reaches its highest point. What is really wanted is a measure of the total heat received from the sun, not a record of its maximum intensity at any instant. The helio-pyrometer of Southall, and the actinometers of Pouillet, Crova, Langley, Herschel, and Richard, which to a certain extent give this, are, unfortunately, not suited for general use; but "much may be learned from the *duration* of direct solar radiation, even without attempting to estimate its intensity."

Not only is there a constant gain of heat by the earth from the sun, but there is also a more or less constant loss of heat from the earth and from all objects on it. This loss of heat is spoken of as *terrestrial radiation*, and is very much greater when the sky is clear than when overcast with clouds. The amount of this loss of heat by radiation is determined by placing a minimum thermometer, as already described, on short supports some 4 inches off the ground, preferably on a plot of grass. Should the ground be covered with snow, the instrument should be laid upon the surface of the snow. Where a grass plot is not available, the thermometer should be placed on a large black board laid upon the ground. The difference or defect of this minimum temperature below that of the air minimum in the shade is taken as the amount of terrestrial radiation. The bulb of minimum thermometers used for this observation is often modified so as to present the greatest amount of surface relatively to its contents, either by making it in the form of a hollow cylinder, or by arranging it in the form of a fork, or by drawing it out and bending it back upon itself.

Thermometer Exposure.—The method of exposing radiation thermometers has been definitely stated, but the proper exposure of other or shade thermometers so that they may indicate the true temperature of the air is a matter of some difficulty. Two conditions are required: (1) a constant circulation must be kept up round the thermometer bulbs, and in its passage to the instruments the air must not have its temperature changed by passing over hot or cold surfaces; (2) the thermometer bulbs must be protected not only from the direct rays of the sun, but from radiations of all kinds from surrounding objects. These conditions are probably most nearly realised by the sling thermometer, which is attached to a cord some 2 feet in length and swung round like a sling in the shade. Obvious objections exist to observations of this kind, and various kinds of thermometer shelter have been devised. Perhaps the best is that used in this country and called after its inventor the "Stevenson" screen. It consists merely of a hut or box made of stout boards, with a ridge roof and louvred sides, open below, and standing some 4 feet off the grass on four legs. It should be placed where it will be freely exposed to the movements of the air, and at least 20 feet away from any house or building.

Reading of Thermometers.—All good thermometers can be read by the eye to tenths of a degree. The maximum and minimum thermometers are read once a day, usually at 9 A.M.; the former marks the highest point reached on the *previous* afternoon, and must be so entered on the return; the latter, the lowest point reached on the *same* morning. For the army returns the ordinary thermometer is read twice a day, at 9 A.M. and 3 P.M. If three readings are taken daily, the hours of 6 A.M., 2 P.M., and 10 P.M. are the best.

Range of Temperature.—The maximum and minimum in shade give most important climatic indications; the difference between them on the same day constitutes the range of the diurnal fluctuation. The range is expressed in several ways.

The extreme daily range in the month or year is the difference between the maximum and minimum thermometer on any one day.

The extreme monthly or annual range is the difference between the greatest and least height in the month or year.

The mean monthly range is the daily ranges added and divided by the number of days in a month (or the difference between the mean of all the maxima and the mean of all the minima).

The yearly mean range is the monthly ranges added and divided by 12.

Mean Temperature.—The mean temperature of the day is obtained in the following ways:—

(*a*) At Greenwich and other observatories, where by means of photography the height of the thermometer at every moment of the day is registered, the mean of the hourly readings is taken. This has been found to accord with the absolute mean (found by taking the mean of the whole curve) to within $\frac{1}{10}$th of a degree. It may also be recorded by means of a self-registering instrument.

(*b*) Approximately in several ways. Taking the mean of the shade maximum and minimum of the same day. In this country, during the cold months (December and January), the result is very close to the truth; but as the temperature increases a greater and greater error is produced, until in July the mean monthly error is + 1°·9 F., and in some hot days is much greater. In the tropics, the mean of the maximum and minimum must give a result still further from the truth.

Monthly corrections can be applied to bring these means nearer the truth. Lloyd has suggested the following rule for this country, the result being the approximate mean temperature. Multiply the difference between the observed maximum and minimum by the proper factor obtained from the following table, and add the product to the minimum.

Month.	Factor.
January and December,	0·520
February and November,	0·500
March and October,	0·485
April and September,	0·476
May and August,	0·470
June and July,	0·465

In a great number of places the mean temperature of the day and year, as stated in books, is derived solely from the mean of the maximum and minimum; if a Stevenson's screen is in use this is very nearly the truth. According to Scott, the approximation to the true mean is very close in most parts of the world, especially if the observations be taken as near the *end* of the period as possible, near midnight, for instance, for the mean of the civil day of twenty-four hours. The approximate mean temperature may also be obtained by taking observations at certain times during the day. If these be taken at 7 A.M., 2 P.M., and at 9 P.M., or at t, t' and t'', the following formula by Herschel may be used, $\frac{t+t'+2t''}{4}$ = mean temperature of day. If the hours are 8 A.M., 3 P.M., and 10 P.M., the formula is—$\frac{7t+7t'+10t''}{24}$ = mean of day. If the temperature be taken twice a day at homonymous hours, such as 9 A.M. and 9 P.M., the mean of these is practically the true daily mean.

The nearest approach to the mean temperature of the day by a single observation is given at from 8 to 9 P.M.; the next is in the morning—about 8 o'clock in July and 10 in December and January. The mean monthly temperature is the mean of the daily means: the mean annual temperature is the mean of the monthly means.

The nearest approach to the mean annual temperature is given by the mean of the month of October. Observations made from a week before to a week after the 24th April, and again in the corresponding weeks of October, give a certain approximation to the yearly mean temperature.

The changes in temperature of any place, during the day or year, are either *periodic* or *non-periodic*. The former are dependent on day and night, and on the seasons, *i.e.*, on the position of the place with respect to the sun. The periodic changes are sometimes termed fluctuations, and the differences between day and night temperatures, or the temperatures of the hottest and coldest months, are often called the amplitudes of the daily or yearly fluctuations.

Daily Periodic Changes.—On land, the temperature of the air is usually at its lowest about 3 o'clock A.M., or just before sunrise, and at its maximum about 2 o'clock P.M.; it then falls nearly regularly to 3 o'clock A.M. At sea, the maximum is nearly an hour later.

The amount of diurnal periodic change is greater on land than on water; in the interior of continents than by the seaside; in elevated districts than at sea-level. As far as land is concerned, it is least on the sea-coast of tropical islands, as at Kingston in Jamaica, Colombo in Ceylon, Singapore, &c.

In Sinde and Baluchistan, and throughout the dry tract to the west of the Jumna, the daily range of the thermometer is greatest in October and November, when the difference between sunrise and afternoon averages not much less than 30° F., and sometimes 40°. The same occurs in the northern districts of Bombay in the earlier months of the year, when land winds, from between west and north-west, blow most steadily. In the north-west provinces it averages 28° to 32° F., both in March and April. These variations take place daily, and with much regularity.

Yearly Periodic Changes.—In the northern hemisphere the coldest month is usually January; in some parts of Canada it is February. On the sea the coldest month is commonly March. The hottest month is in most places July, in some few August; on the sea it is nearly always August. The coldest days in this country are about the 21st January; the hottest about the 21st July. At Toronto the hottest day is about thirty-seven days after the summer solstice; and the coldest fifty-five days after the winter solstice.

It is thus seen that both for the diurnal and annual alterations of heat the greatest heat is not simultaneous with, but is after, the culmination of the sun; this is owing to the slow absorption of heat by the earth.

The amplitude of the yearly fluctuation is greater on land than sea, and is augmented by land, so that it reaches its highest point in the interior of great extra-tropical continents.

It increases towards the pole for three reasons,—

1. The geographical fluctuation of the earth's position causes a great yearly difference of the angle with which the sun's rays fall on the earth.
2. The duration of incidence of the sun's rays (*i.e.*, the number of hours of sunshine or shade) has greater yearly differences than in the tropics.
3. In the northern hemisphere especially there is a very great extent of land, which increases radiation.

The amplitude of the yearly fluctuation is very small in the tropical lands at sea-level. At Singapore it is only 3°·6 F. (Jan. 78°·8, July 82°·4), while it is immense on continents near the pole. At Yakoutsk, in North Asia, it is 112°·5 F. (January − 44°·5 and July + 68°). All fluctuations depend to a large extent upon the distance from the sea, although local causes may have some influence, such as the vicinity of high lands.

In any place there may be great undulations and small fluctuations, or great changes in each way. At Brussels, the greatest possible yearly undulation is 90° F. In some parts of Canada immense undulations sometimes occur in a day, the thermometer ranging even 50° to 70° F. in one day.

The difference between the highest and lowest readings recorded at Leh, which is the most northerly and driest station where observations are recorded in India, averages 94° F., and has been as much as 103° F. On the plains of the Punjab it varies from 80° (at Mooltan) to 86° F. at Peshawar, and sometimes reaches 92° F. At the hill stations it is much less, 69° F. at Murree and 63° F. at Simla: at Darjiling it is only 47° F. At Quetta the average range in the course of the year is 80° F., while at Jacobabad the average is 86° F., and the greatest 89° F. At Bombay it averages 31° F., at Madras 48° F., and at Colombo only 25° F.

Temperature of the Air of any place.—This depends on the following conditions:—

Latitude.—The nearer the equator the hotter the air. For 23½° on either side the equator the sun's rays are vertical twice in the year, and are never more oblique than 47°. The mean yearly temperature of the equator is 82° F.; of the pole, about 2°·5 F.

Relative Amount of Land and Water.—The sun's rays passing through the air with but trifling loss fall on land or on water. The specific heat of land being only one quarter that of water, it both absorbs heat and gives it out more rapidly. Water, on the other hand, absorbs heat more slowly, stores up a greater quantity, and parts with it less readily. The temperature of the superficial water, even in the hottest regions, seldom exceeds 80° to 82°F., and that of the air is generally below (2° to even 6°) the temperature of the water (J. Davy). Consequently, the more land the greater is the heat, and the wider the diurnal and yearly amplitudes of fluctuation. The kind of soil has a great effect on absorption. The evaporation from the water also greatly cools the air.

Altitude.—The greater the elevation the colder the air, on account (1) of the lessening amount of earth to absorb the sun's rays, (2) of the greater radiation into free space. The decline of temperature is taken as being about 1° F. for each 300 feet of ascent, or 1° C. for each 200 metres. The decline is by no means regular, being influenced by currents, clouds, &c. In Glaisher's balloon ascents in a *cloudy* sky, it was found to be about 4° F. for each inch of barometric fall, at first; but when the barometer had fallen 11 inches, the decline of temperature was more rapid. Under a *clear* sky, there was a fall of 5° F. for each of the first 4 inches of descent: then 4° per inch till the thirteenth inch of descent, and then 4°·5 for fourteenth, fifteenth, and sixteenth inches of descent.

There are other influencing circumstances of local importance, the chief being *aspect* and the *nature of the soil*. To these may be added *forests*, which, in hot climates especially, greatly moderate the heat, by shielding the soil from the sun's rays, and by evaporation from the leaves.

Distribution of Temperature.—The manner in which heat is distributed over the globe is shown by maps on which are drawn *isothermal* lines, or lines connecting places that have the same mean temperatures: these mean temperatures may be either for the year or for the several months. The region of highest mean monthly temperature, shown by an isothermal line of 90° F. for July, encloses a tract extending from about 8° W. long. in north Central Africa, to about 72° E. long. in the Punjab, forming a belt of about 18° in width; its southern limit in Africa being about 9° N. lat., its northern limit reaches nearly 35° N. lat.

The hottest places on the earth are—in the eastern hemisphere, near the Red Sea at Massowah, and at Khartoum (15° N. lat.), and on the Nile in Lower Nubia; annual temperature = 90°·5 F.: in the western hemisphere, on the Continent, near the West Indies, the mean annual temperature is 81°·5 F. These are sometimes called the climatic poles of heat. The highest readings of a well-shaded verified thermometer in India have been 123°·1 F. at Pachpadra, in Rajputana, and 122°·2 F. at Jacobabad, both on May 25th, 1886. The poles of cold are in Siberia (Yakoutsk to Usjausk, 62° N.) and near Melville Island. The lowest readings recorded have been - 69° F. by Kane at Rensselaer harbour in Greenland, and - 81° F. by Govochow at Wenchojausk in Siberia.

SUNSHINE.

The duration of the sunshine is a very important factor in all climates, and the extent of this duration is recorded by either (1) the Campbell-Stokes Burning Recorder; (2) the Whipple-Casella Universal Sunshine Recorder; (3) the Jordan Photographic Recorder. The principle of the first two of these instruments is the same, the second being really a modification of the first. They consist mainly of a glass sphere, so mounted that when the sun shines its rays are focussed as by a lens upon a strip of cardboard, with the result that a burnt track or hole is left for such periods of time as the sun shines. The cardboard is so placed in the instrument that definite sections of it correspond to periods of time in hours.

Jordan's instrument (fig. 119) is, strictly speaking, rather a recorder of sunlight than of sunshine. The improved pattern consists of two semicylindrical boxes, one to hold the forenoon, the other the afternoon record, and on the inside of each of which a sheet of sensitive cyanotype paper is carefully placed day by day. A slit, through which the beam of sunlight finds entrance, is placed in the centre of the rectangular side of each box, so that the length of the beam within the chamber is the radius of the cylindrical surface on which it is projected. The path of the sunbeam, therefore, follows a straight line on the sensitive paper at all seasons. The instrument must be carefully adjusted to the meridian and to the latitude of the place, and must be firmly fixed.

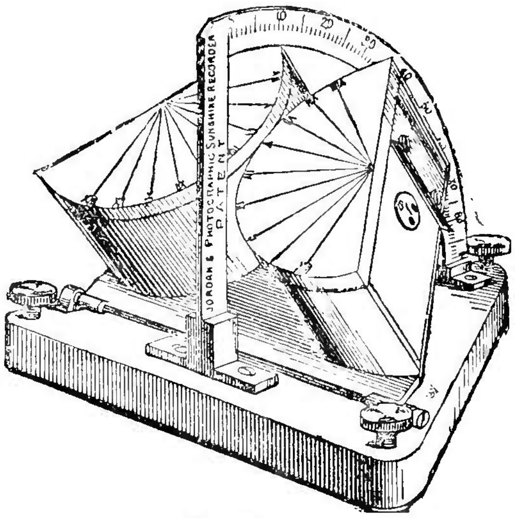


Fig. 119.

WIND.

The facts to be observed relating to winds are practically limited to those connected with direction, force or pressure, and velocity.

Direction.—The point of the compass from which the wind is blowing is obviously best ascertained by observing for a few moments the movements of a properly set and freely movable vane or weathercock. When a weathercock is not available, the smoke from a chimney will readily give the information, provided, of course, the observer has a precise idea as to where lies his north or south. Under all circumstances, the bearings should be true and not magnetic (by compass). In this country the variation of the compass at the present time ranges from 16° in the extreme east of England to 23° in the extreme north-west of Ireland, the true north lying so many degrees to the east of the compass or magnetic north. Roughly speaking, a true north and south line lies along the line N.N.E. to S.S.W. by compass.

In the absence of a mariner's compass, we can ascertain the north by means of the pole star, or the south by means of the sun. The pole star is practically the north in January and July at 6 A.M. and 6 P.M., in February and August at 4 A.M. and 4 P.M., in March and September at 2 A.M. and 2 P.M., in April and October at noon and midnight, in May and November at 10 A.M. and 10 P.M., in December and June at 8 A.M. and 8 P.M.

For ascertaining the position of due south, we must know the longitude of a given place and also true *local time*. As a matter of fact, the sun is not always on the meridian at 12 noon, but in this country it is practically so, or within a minute thereof, during the following periods: April 11th to 18th, June 9th to 18th, August 28th to September 3rd, and December 22nd to 25th. If, therefore, a pole be erected vertically as tested by a plumb line, the shadow from it will fall true N.W at 9 A.M., N. at noon, and N.E. at 3 P.M. But before this observation can be of value it is necessary to know the true *local time*. This can be always obtained from uniform time, *i.e.*, Greenwich time, by subtracting four minutes for every degree of west longitude, or by adding four minutes for every degree of east longitude. Thus, Dublin is 6° 15′ W. of Greenwich. These degrees and minutes of longitude multiplied by 4 give minutes and seconds of time, or 25 minutes. Then, as Dublin is west of Greenwich, local time is earlier than Greenwich time, and noon at Greenwich becomes 11 hours 35 minutes A.M. by Dublin, or local time. In other words, on the dates above mentioned the sun at Dublin is due south at 0 h. 25 m. Greenwich time.

All wind direction observations should be recorded to the nearest point of the compass. To calculate the mean direction, it is usual to give an arbitrary numerical value to each observation, and then to analyse them. Thus, suppose we read to 16 points of the compass, and give a numerical value of 4 to each observation; if the wind be due N., we should give to N. the full value of 4; if the reading were N.W., we should give half the value of the observation, or 2 to N., and the other half to W. If the reading were N.N.W., then N. would get 3, and W. get 1, as their shares of the numerical value of the observation. Suppose we have the following observations of wind direction recorded: S., S.E., E., S.S.E., N.W., W.N.W., N.E., E.N.E., N., N.E. The calculation of the mean direction is done in the following way. Giving to each observation a numerical value of 4, we get—

		N.	S.	E	W.
S.	=	...	4	...	...
S.E.	=	...	2	2	...
E.	=	...	...	4	...
S.S.E.	=	...	3	1	...
N.W.	=	2	...	...	2
W.N.W.	=	1	...	...	3
N.E.	=	2	...	2	...
E.N.E.	=	1	...	3	...
N.	=	4	...	...	..
N.E.	=	2	...	2	...
		12	9	14	5

Then, deducting the opposite directions from each other, we get:—

N.	12	E.	14
S.	9	W.	5
Net N.	3	Net E.	9

That is, the mean direction lies in the N.E. quarter of the compass, and nearer E. than N. Since each quarter consists of 90°, the precise mean direction is at a point on the compass $\frac{3}{4}$ of 90° from N. in favour of E., or at an angle of $67\frac{1}{2}°$ from N., which is a mean direction of E.N.E.

Pressure and Velocity: Anemometers.—The instruments for the measurement of wind, either as regards pressure or velocity, are called *anemometers*. The earlier forms of these instruments were rectangular plates hung on hinges on a horizontal axis. The angle which these plates made with the vertical indicated the wind's pressure. In another kind, the movements of the plates, resisted by either springs or weights, recorded upon a chart by means of a connected pencil the degree and amount of their displacement. In another form, the pressure of the wind is measured by making it blow into the mouth of an open tube kept facing the current by means of a vane, and then noting the degree of pressure exerted upon a column of water or mercury in an U tube. The later and better forms of anemometer in most general use are those known as Robinson's, consisting of four arms, each provided with a hollow cup and rotating horizontally on a vertical axis, which, by means of an endless screw, causes movements to be recorded on a series of dials in terms of miles and parts of a mile. These instruments are graduated on the principle that, allowing for friction, the cups revolve three times slower than the wind moves; so that if the centres of the cups be, as they usually are, 1·12 foot apart, each revolution corresponds to 3·52 feet of movement, or 10·56 feet of actual wind-motion, and that 500 rotations of the cups indicate 1 mile of wind. Owing, however, to the allowance of friction being placed probably too high, and the cup motion being nearer two than three times slower than the wind, the velocity of wind movement, as recorded by many of these instruments in general use, is something like 20 per cent. too high. All anemometers to be reliable need to be kept scrupulously clean, well-oiled, and placed in a thoroughly open position at least 20 feet from the ground.

Estimation of Wind Force.—Various proposals have been made for estimating and describing roughly the force of the wind. The earliest was that of Admiral Beaufort, who, in 1806, devised a scale having a relation to the pressure of the wind upon the sails of a ship, and the amount of canvas which she could carry. This is given in the following table:—

Beaufort Scale.	Description of Wind.	Velocity in miles per hour.
0	Calm	3
1	Light air	8
2	Light breeze	13
3	Gentle breeze	18
4	Moderate breeze	23
5	Fresh breeze	28
6	Strong breeze	34
7	Moderate gale	40
8	Fresh gale	48
9	Strong gale	56
10	Whole gale	65
11	Storm	75
12	Hurricane	90

Attempts have been made to express the wind's force as a pressure of so many pounds to the square foot. From experiments with various kinds of anemometers, Dines calculates the pressure (P) of the wind in pounds per square foot from the recorded velocity in miles per hour, on the assumption that the pressure equals one two-hundredth ($\frac{1}{200}$) of the square of the velocity, or $P = 0{\cdot}005 \times V^2$. According to this formula, a wind blowing with a velocity of 50 miles an hour exercises a pressure of 12½ lb on the square foot. Unfortunately for the value of this formula, the factor 200 is nearly as doubtful as that of three for the friction ratio of Robinson's anemometer.

Diurnal Variation of Wind.—In this country the wind has an average velocity of 8 miles an hour, and rarely exceeds 40; but its direction and force are subject to certain diurnal variations. As a rule, at mid-day the wind blows from sea to land, and from plains to hills, while in the evening the direction will be reversed.

In all parts of the world the upper air currents move faster than the lower, following in the northern hemisphere a direction slightly to the *right*, in the southern to the *left*. Now during the day the heating of the lower air strata causes them to ascend, thereby increasing the friction between the upper and lower currents, and proportionately reducing the difference of velocity. The lower current, under the influence of the upper, is deflected to the right in the northern hemisphere, to the left in the southern, and has its speed increased in both cases, while the upper, under the influence of the lower, is deflected in the opposite direction with diminution of velocity. These effects are naturally more marked the greater the diurnal heating of the lower strata relatively to the upper, and the greater the normal angle between the two currents. For these reasons: (1) Near the equator, and over the open sea, there is little diurnal variation of wind either in direction or speed. (2) On plains and similar land surfaces, even at great elevations, the wind shifts with the hands of the clock, and attains its maximum strength during the afternoon, backing and diminishing again at night in the northern hemisphere. The changes of direction are reversed in the southern hemisphere. (3) On mountain peaks the wind shifts against the hands of the clock, and diminishes in strength during the afternoon, and veers and increases again at night. The changes in direction are reversed in the southern hemisphere.

ATMOSPHERIC ELECTRICITY.

Even in fine weather the atmosphere is charged with electricity. Bodies are said to be electrified when, after having been rubbed or placed in communication with an electrified object, they exercise an attraction or repulsion upon other bodies. Closer inquiry indicates that the electricity developed by friction from different substances, such as glass on one hand and sealing wax on the other, is not identical, and that there are consequently two electricities varying from each other in some of their characters. In order to distinguish between the two kinds of electricity, the one is called vitreous electricity, from its being generated from glass, and is known as *positive;* while the other is called resinous electricity, and is known as *negative.* Electricities of different kinds attract each other, and electricities of the same kind repel each other.

It has been found that the atmosphere always contains free electricity, which is almost invariably positive. When the sky is cloudless, the electricity is always positive, but the intensity varies with the height, being greatest in the highest and most isolated situations. Positive electricity is only found at a certain height above the ground; on flat ground it becomes manifest at a height of 5 feet. It is not found in houses, in streets, or under trees. The observations of negative electricity almost all occur during heavy rain. When the sky is clouded, the electricity is sometimes positive and sometimes negative, according to the electrified condition of the clouds. In relation to the atmosphere the earth's surface is always negative.

The electricity of the atmosphere is stronger in winter than in summer, increasing from June to January. It is subject to a double maximum and minimum each day. The first maximum occurs from 7 to 8 A.M. in summer, and from 10 A.M. to noon in winter; it then falls slightly to the first minimum between 5 and 6 P.M. in summer, and between 2 and 3 P.M. in winter; it rises to a second maximum a little after sunset, and then decreases to a second minimum which occurs about daybreak. These variations are best observed in clear settled weather.

Sources of Atmospheric Electricity.—The chief of these are: (1) Evaporation; (2) Vegetation; (3) Combustion; (4) Friction. Electricity is produced when impure water is evaporating, or water in which some degree of chemical decomposition takes place, none whatever being produced by the evaporation of pure water. Vapour rising from water containing a salt or an alkali is charged with positive electricity, while the water retains negative electricity; but when the water contains acid, negative electricity is given off, and positive is left behind. Hence it is supposed that seas, lakes, and rivers are abundant sources of atmospheric electricity, especially positive electricity.

The vegetable kingdom is also a source of electricity, (1) from the evaporation going on, and (2) from the giving off of oxygen and carbonic acid, which is charged with positive electricity. During the process of burning, bodies give off positive electricity, and become themselves negatively electrified. This frequently occurs during volcanic eruptions. Wind, by the friction it produces on terrestrial objects, the particles of dust, and the watery particles in the vesicular state which it carries with it, contributes to the electricity of the air. Electricity is not generated if the moisture be in the form of pure vapour.

Atmospheric electricity may, from time to time, reveal its presence by very unequivocal phenomena, of which the chief are: (1) Thunder and Lightning; (2) Hailstones; (3) Aurora—the aurora borealis being peculiar to the northern hemisphere, and the aurora australis to the southern. But apart from these manifestations, observations may be made upon the electricity existing in the air under ordinary circumstances, so as to determine, firstly, whether it is positive or negative; secondly, what is its intensity or tension.

The Electroscope is intended to demonstrate the kind of electricity present in the air. The most sensitive instrument for this purpose is the gold-leaf electroscope, in which electricity collected from the atmosphere is made to pass through a metal rod, called a conductor, upon two delicate gold leaves suspended at the end of the rod, and between the poles of two dry piles charged with opposite electricities. The leaves, when brought under the influence of the same kind of electricity, will diverge or repel each other. As very little electricity can be observed near the ground, the conductor should be placed in contact with the air at some height above the earth's surface, by means of a *collector*, which may be a metallic arrow tied to one end of a conducting string and then shot upwards into the air. The electroscope will be found electrified as the arrow mounts. A gilded fishing-rod may be substituted as a conductor, its lower end being insulated by caoutchouc.

The Electrometer is an instrument for measuring the amount of electricity, that is, its intensity or tension. There are two chief forms in common use, namely, the Quadrant electrometer for observatories, and the Portable electrometer. In the quadrant, or modified divided-ring electrometer, a needle of thin aluminium, cut so as to resemble in form a figure 8 with the hollows filled in, and carrying above it a small light mirror, is suspended from its centre by two fine silk threads. The needle swings horizontally inside a shallow cylindrical box, which is cut into four equal segments or quadrants, each insulated separately by glass supports, but connected alternately by thin wires. Each pair of quadrants is also connected to wires forming the two electrodes or terminals for the attachment of the collecting and earth wires. The base of the electrometer contains a Leyden jar, partially filled with strong sulphuric acid, and a platinum wire, hung from the lower surface of the needle, is made to dip into the acid. A lamp and a divided scale are placed about a yard in front of the instrument, and the light shining through an aperture in the frame of the scale is reflected by the mirror on the scale, where the position of the image of a wire stretched across the hole can be accurately observed.

In order to use this electrometer the needle must be charged with electricity from a small electrophorus or electricity bearer, brought into contact with a wire dipping into the sulphuric acid at the bottom of the Leyden jar. One of the electrodes connected with the segments is then joined by a wire to the collector; the other is placed in communication with the earth. The needle will then be deflected towards either one side or the other, according as the electricity of the atmosphere is of the nature to repel or attract it, and the extent of repulsion, as measured by the scale, is proportional to the amount of difference between the potentials of the atmospheric and terrestrial electricities. The scale value of each such electrometer must be experimentally determined by means of a galvanic battery of constant intensity, such as Daniell's. Knowing the electro-motive force of the cell employed in the battery, the indications of the electrometer scale may be readily converted into terms of the absolute unit of electro-motive force or "volts" (see Scott's *Instructions in the use of Meteorological Instruments*).

The Portable electrometer of Lord Kelvin collects the electricity by means of a burning fuse at the extremity of a vertical wire. Another electrometer much commended is Peltier's.

Thunderstorms are classified into Cyclonic Thunderstorms and Heat Thunderstorms. The former belong to winter and to insular climates, the latter to summer and to hot climates. *Cyclonic thunderstorms* are so called because they accompany atmospheric depressions, such as traverse the Atlantic and north-western coasts of Europe, especially in winter. While these cyclonic thunderstorms are not so violent, they are quite as dangerous as the summer thunderstorms, because in them the clouds drift at a low level, whereby the lightning is more likely to strike the ground.

Heat thunderstorms are especially associated with sudden and extreme variations in air temperature. As the result of rapid evaporation, clouds surcharged with positive electricity form in the upper air. Subsequently, in the lower strata of the air, negatively electrified cloud strata form. The interaction of these cloud masses result in the phenomena of a thunderstorm. These heat thunderstorms show a diurnal and even an annual periodicity. It is not uncommon to find them breaking over the same line of country on consecutive days, as if there was a direct electrical attraction between the earth of certain localities and the superincumbent atmosphere for the time being; and this no doubt is in reality the case.

Speaking generally, much negative electricity in the air forecasts rain; on the other hand, a sudden development of positive electricity in wet weather is a certain sign of fine weather.

Lightning is the brilliancy produced by the generation of heat along the path of an electric discharge so intense as to render the various constituents of the air momentarily incandescent. This heat is due to the resistance of non-conductors in the air to the discharge which takes place when clouds charged with different electricities approach each other (Balfour Stewart).

Lightning is usually either zigzag or forked; diffused or sheet; or globular or so-called ball lightning.

Thunder is probably due to the instantaneous expansion of the air by the heat produced by the lightning along the path of the electric discharge, and then by an inrush of air to fill up the vacuum so caused. From the rate at which sound travels, if thunder be not heard till five seconds after the flash the distance is about a mile. Thunder has not been heard at a greater distance than 15 miles from the lightning flash.

St Elmo's Fire is the Castor and Pollux of the ancients. It is an induction phenomenon, occurring when an electrified cloud approaches a prominent obstacle like a flagstaff, the mast of a ship, a tree, or a lightning conductor. The electricity of the cloud and of the earth combine, not in a flash of lightning, but more slowly and continuously, so that a flame seems to rise from the projecting body.

Hailstorms are modifications of the thunderstorm, and seldom occur during the night or in winter, but are most frequent in summer and during the hottest part of the day. *Hail* itself is intimately related to atmospheric electricity, its formation requiring (1) an excess of moisture, (2) a temperature below freezing, (3) the presence of electrified clouds. Typical hailstorms are nearly always associated with thunder and lightning, the hailstones being kept in a state of constant oscillation between two oppositely electrified clouds, until by continued condensation they grow so heavy that they fall to the earth.

Aurora.—This is an electrical phenomenon rarely seen in low latitudes, consisting of a luminous appearance in the northern and southern skies, most frequently in this hemisphere between the parallels of 66° and 75° The aurora borealis is now generally considered to be due to positive electricity from the sea between the tropics being carried into the upper regions of the air, and thence wafted to the poles by the higher aërial currents. In the vicinity of the poles it descends towards the earth and meets the terrestrial negative electricity in a rarefied atmosphere. Luminous discharges then take place, being possibly increased in brightness by the presence of masses of ice-particles in the atmosphere.

OZONE.

If a succession of electric sparks from a powerful electric machine be passed through a tube of oxygen, a peculiarly pungent odour is developed, due to the production of a body to which the name of ozone has been given, from the Greek ὄζω, *I have a smell.* Only a small proportion of oxygen can be converted into ozone by the electric discharge; but a constant and considerable diminution of volume accompanies the change, 100 volumes of oxygen contracting to 92 volumes. Hence ozone must be denser than oxygen.

It is now generally considered that ozone is an allotropic condition of oxygen, and that its formation consists in the condensation of another atom of oxygen into each dyad molecule of ordinary oxygen. So that the chemical formula for free oxygen being O_2 that for ozone is O_3, and the density of ozone is one-half greater than that of oxygen. When 100 volumes of oxygen are reduced by ozonisation to 92, 8 volumes of oxygen combine with 16 volumes to produce 16 volumes of ozone.

The chief points of difference between ozone and ordinary oxygen are (1) it possesses a curious smell, like weak chlorine, whilst oxygen is odourless; (2) it destroys vegetable colours; (3) it rapidly oxidises the precious metals; (4) it liberates iodine from iodide of potassium.

Variations in the amount of ozone have been supposed to be a cause of climatic difference, but, in spite of all the labour which has been given to this subject, the evidence is very inconclusive. The reaction with the ozone paper is liable to great fallacies. Yet it seems clear that some points are made out: the ozonic reaction is greater in pure than impure air; greater at the sea-side than in the interior; greater in mountain air than in the plains; absent in the centre of large towns, yet present in the suburbs; absent in an hospital ward, yet present in the air outside. In this country it is greater with south and west winds; greater, according to Moffat, when the mean daily temperature and the dew-point temperature are above the mean; the same observer found it in increased quantity with decreasing readings of the barometer, and conversely in lessened quantity with increasing readings.

On account of the irritating effect of ozone when rising from an electrode, Schönbein believed it had the power of causing catarrh, and inferred that epidemics of influenza might be produced by it. He attempted to adduce evidence, but at present it may safely be said that there is no proof of such an origin of epidemic catarrhs.

A popular opinion is, that a climate in which there is much ozone (*i.e.*, of the substance giving the reaction with potassium iodide and starch paper) is a healthy, and, to use a common phrase, an exciting one. The coincidence of excess of this reaction with pure air lends some support to this, but, like the former opinions, it still wants a sufficient experimental basis.

On the whole, the subject of the presence and effects of ozone, curious and interesting as it is, is very uncertain at present; experiments must be numerous, and inferences drawn from them must be received with caution.

Determination of Ozone.—Papers saturated with a composition of iodide of potassium and starch, and exposed to the air, are supposed to indicate the amount of ozone present in the atmosphere. Schönbein, the discoverer of ozone, originally prepared such papers, and gave a scale by which the depth of blue tint was estimated. Subsequently, similar but more sensitive papers were prepared by Moffat, and Lowe afterwards improved on Moffat's papers, and also prepared some ozone powders.

The papers are exposed for a definite time to the air, if possible with the exclusion of light, and the alteration of colour is compared with a scale.

Schönbein's proportions are 1 part of *pure* iodide of potassium, 10 parts starch, and 200 parts of water; Lowe's proportion is 1 part of iodide to 5 of starch; Moffat's proportion is 1 to 2½. The starch should be boiled for ten minutes, and filtered so that a clear solution is obtained; the iodide is dissolved in another portion of water, and is gradually added. Both must be perfectly pure; the best arrowroot should be used for starch.

The paper, prepared by being cut into slips (so as to dry quicker and to avoid loss of the powder in cutting) and soaked in distilled water, is placed in the mixed iodide and starch for four or five hours, then removed with a pair of pincers, and slowly dried in a cool dark place, in a horizontal position. The last point is important, as otherwise a large amount of the iodide drains down to one end of the paper, and it is not equally diffused. The papers when used should hang loose in a place protected from the sun and rain: a box is unnecessary; they should not be touched with the fingers more than can be helped when they are adjusted.

When Schönbein's papers are used they are moistened with water after exposure, but before the tint is taken. Moffat's papers are prepared somewhat similarly to Schönbein's, but do not require moistening with water.

The estimation of ozone is still in a very unsatisfactory state, and this arises from two circumstances.

1. The fact that other substances beside ozone act on the iodide of potassium, especially nitrous acid, which is formed in some quantity during electrical storms. If such be suspected, in order to be quite sure that it is ozone only which has turned the paper blue, it is advisable to use a second test, which is to soak red litmus paper with a very dilute solution of the iodide of potassium. The potassium oxide produced causes an alkaline reaction, and turns the red paper to blue.

2. The fact that the papers can scarcely be put under the same conditions

from day to day; light, wind, humidity, and temperature (by expelling the free iodine) all affect the reaction.

Chemical objections have also been made. Supposing that iodine is set free by ozone, a portion of it is at once changed by additional ozone into iodozone, which is extremely volatile at ordinary temperatures, and is also changed by contact with water into free iodine and iodic acid. Hence a portion of the iodine originally set free never acts on the starch, being either volatilised or oxidised. Again, the iodine and caustic potash set free by the ozone combine in part again, and form iodate and iodide of potassium ($\frac{1}{6}$th of the former and $\frac{5}{6}$ths of the latter), and in this way the blue colour of iodide of starch first produced may be removed. The ozone may possibly act on and oxidise the starch itself, and hence another error.

CLOUDS.

A cloud is a collection of particles of aqueous vapour condensed into watery particles and floating in the atmosphere at some height above the ground. This height varies from a few hundred feet to several miles. In the words of Tyndall, the minute particles of water, condensed from aqueous vapour, which go to make up a cloud, may be aptly called "water dust."

The "cloud line," or that level below which cloud formations seldom or never take place, varies in different parts of the world. In South America it is about 9000 feet; in the Tyrol it falls to about 5000 feet; and in the British Islands it is as low as 2500 feet.

Classification of Clouds.—The following is the cloud classification of Hildebransson and Abercromby, as now universally accepted, and confirmed by the last meeting of the International Meteorological Committee at Upsala in August 1894. Those marked with (*a*) are detached or rounded forms, most frequently seen in dry weather; those marked with (*b*) are wide-spread or veil-like forms, most frequent in wet weather.

A. Highest clouds, mean height 9000 metres.
    (*a*) 1. Cirrus.
    (*b*) 2. Cirro-stratus.
B. Clouds of mean altitude, 3000–7000 metres.
    (*a*) 3. Cirro-cumulus.
          4. Alto-cumulus.
    (*b*) 5. Alto-stratus.
C. Low clouds, below 2000 metres.
    (*a*) 6. Strato-cumulus.
    (*b*) 7. Nimbus.
D. Clouds formed by the diurnal ascending currents.
    8. Cumulus. Top, 1800 metres; base, 1400 metres.
    9. Cumulo-nimbus. Top, 3000–8000 metres; base, 1400 metres.
E. Elevated fog, below 1000 metres.
    10. Stratus.

The following is the description of the above ten principal forms of cloud, as suggested by the International Committee:—

(1) CIRRUS (Ci.).—Isolated feathery clouds of fine fibrous texture, generally of a white colour. Frequently arranged in bands which spread,

like the meridians on a celestial globe, over a part of the sky, and converge in perspective towards one or two opposite points of the horizon. (In the formation of such bands, the two following forms often take part.)

(2) Cirro-Stratus (Ci. S.).—Fine whitish veil, sometimes quite diffuse, giving a whitish appearance to the sky, and called by many cirrus haze, sometimes of more or less distinct structure, exhibiting confused fibres. The veil often produces halos around the sun and moon.

(3) Cirro-Cumulus (Ci. Cu.).—Fleecy cloud. Small white balls and wisps without shadows, or with very faint shadows, which are arranged in groups and often in rows.

(4) Alto-Cumulus (A. Cu.).—Dense fleecy cloud. Larger whitish or greyish balls with shaded portions, grouped in flocks or rows, frequently so close together that their edges meet. The different balls are generally larger and more compact (passing into S. Cu.) towards the centre of the group, and more delicate and wispy (passing into Ci. Cu.) on its edges. They are very frequently arranged in stripes in one or two directions.

(5) Alto-Stratus (A. S.).—Thick veil of a grey or bluish colour, exhibiting in the vicinity of the sun and moon a brighter portion, and which, without causing halos, may produce coronæ. This form shows gradual transitions to cirro-stratus, but, according to the measurements made at Upsala, has only half the altitude.

(6) Strato-Cumulus (S. Cu.).—Large balls or rolls of dark cloud which frequently cover the whole sky, especially in winter, and give it at times a wave-like appearance. The stratum of strato-cumulus is usually not very thick, and blue sky often appears in the breaks through it. Between this form and the alto-cumulus all possible graduations are found. They are distinguished from nimbus by the ball-like or rolled form, and because they do not tend to bring rain.

(7) Nimbus (N.).—Rain clouds. Dense masses of dark formless clouds with ragged edges, from which generally continuous rain or snow is falling. Through the breaks in these clouds there is almost always seen a high sheet of cirro-stratus or alto-stratus. If the mass of nimbus is torn up into smaller patches, or if smaller clouds are floating very much below a great nimbus, the former may be called Fracto-nimbus ("Scud" of the sailors).

(8) Cumulus (Cu.).—Piled clouds. Thick clouds whose summits are domes with protuberances, but whose bases are flat. These clouds appear to form in a diurnal ascensional movement which is almost always apparent. When the cloud is opposite the sun, the surfaces which are usually seen by the observer are more brilliant than the edges of the protuberances. When the illumination comes from the side, this cloud shows a strong actual shadow; on the sunny side of the sky, however, it appears dark with bright edges. The true cumulus shows a sharp border above and below. It is often torn by strong winds, and the detached parts (Fracto-cumulus) present continual changes.

(9) Cumulo-Nimbus (Cu. N.).—Thunder cloud; shower cloud. Heavy masses of clouds, rising like mountains, towers, or anvils, generally surrounded at the top by a veil or screen of fibrous texture ("false cirrus"), and below by nimbus-like masses of cloud. From their base generally fall local showers of rain or snow, and sometimes hail or sleet. The upper edges are either of compact cumulus-like outline, and form immense summits, surrounded by delicate false cirrus, or the edges themselves are drawn out like cirrus. This last form is most common in "spring squalls." The front of storm clouds of great extent sometimes shows a great arch stretching across a portion of the sky, which is uniformly lighter in colour.

(10) STRATUS (S.).—Lifted fog in a horizontal stratum. When this stratum is torn by the wind or by mountain summits into irregular fragments, they may be called Fracto-stratus.

Observation of Clouds.—As the whole subject of our knowledge of clouds is at present in a somewhat elementary condition, considerable efforts have been made to obtain comparable and international observations and reports. To attain this result the following instructions are suggested for observing clouds, so that at each observation there may be recorded:—

(1) *The Kind of Cloud*, designated by the international letters of the cloud name. Those having access to the Hildebransson-Köppen-Neumayer Atlas of cloud forms may more exactly define their own observations by giving the number of the picture of the Atlas most nearly representing the observed form.

(2) *The Direction from which the Clouds come.*—If the observer remains completely at rest during a few seconds, the motion of the clouds may be easily observed relatively to a steeple or mast erected in an open space. If the motion of the cloud is very slow, the head must be supported. Clouds should be observed in this way only near the zenith, for if they are too far away from it the perspective may cause errors. In this case nephoscopes should be used, and the rules followed which apply to the particular instrument employed.

(3) *Radiant Point of the Upper Clouds.*—These clouds often appear in the form of fine parallel bands, which, by an effect of perspective, seem to come from one point of the horizon. The radiant point is that point where these bands, or their direction prolonged, meet the horizon. The position of this point on the horizon should be recorded in the same way as the wind direction, north, north-north-east, &c.

(4) *Undulatory Clouds.*—It often happens that the clouds show regular, parallel and equidistant streaks, like the waves on the surface of water. This is the case for the greater part of the cirro-cumulus, strato-cumulus (roll-cumulus), &c. It is important to note the direction of these streaks. When there are apparently two distinct systems, as is to be seen in clouds separated into balls by streaks in two directions, the directions of the two systems should be noted. As far as possible, observations should be made on streaks near the zenith, to avoid effects of perspective.

(5) *Density and Position of Cirrus Banks.*—The upper clouds frequently take the form of felt or of a more or less dense veil, which, rising above the horizon, resembles a thin white or greyish bank. As this cloud form has an intimate relation to barometric depressions, it is important to note:—

(*a*) The density—

0 meaning very thin and irregular.
1 meaning thin but regular.
2 meaning rather dense.
3 meaning dense.
4 meaning very dense and of dark colour.

(*b*) The direction in which the veil or bank appears densest.

Remarks.—All interesting details should be noted, for example:—

(1) On summer days all low clouds generally assume particular forms resembling cumulus more or less. In this case, there should be put under *Remarks*, "Stratus or Nimbus Cumuliformis."

(2) It sometimes happens that a cumulus has a mammillated lower surface. This appearance should be described by the name of "Mammato-cumulus."

(3) It should always be noted whether the clouds appear stationary, or whether they have a very great velocity.

HUMIDITY OF THE AIR.

The question of the amount of moisture in the air is somewhat complicated, and is usually spoken of as the degree of humidity. Reference has been made elsewhere to the fact that water is constantly evaporating into the air, and that the amount of water or moisture which the air can hold or retain is constantly varying with its temperature. Thus at 32° F. a cubic foot of dry air can only take up 2·13 grains of water, while at 100° F. it can take up as much as 19·84 grains. When air is so full of moisture that it can contain no more, it is said to be saturated. In this country the air upon an average contains about three-fourths of the amount of water needed to saturate it, that is, it has an humidity of about 75 per cent.; but if the air containing this amount of moisture be cooled down, it will reach a temperature at which that same amount of moisture will suffice to saturate it, and if cooled still more it will reach a temperature insufficient to retain that moisture, with the result that it must part with some of it, the amount so parted with being precipitated or deposited as rain, snow, mist, or dew. For instance, 100 cubic feet of air, three parts saturated with moisture, at a temperature of 70° F. would hold 600 grains of water; if for some cause or other the temperature of that 100 cubic feet of air were reduced to 61° F., that volume of air would become quite saturated, bcause at that temperature it could only hold 600 grains; and if the temperature were still further reduced, say to 56° F., it could only retain 500 grains of moisture; therefore the difference between 600 and 500 grains, or 100 grains of water, would be released or deposited as mist, dew, or rain.

Mist, Fog, and Dew.—Aitken and some others have pointed out that occasionally, in perfectly pure air, a pressure of vapour may be maintained greater than that corresponding to the temperature of saturation. In fact, that condensation will not in general begin unless some nucleus is present to which the particles of water can attach themselves. It is on the presence of solid particles of dust in the air that the formation of mists and fogs depends; the precise degree of mist or fog depending on the amount of dust present, and on the size and constitution of the particles. When the number of dust particles is large or their size considerable, and the quantity of vapour condensed is small, we get the phenomenon of a town or so-called dry fog. The condensation of water upon invisible particles so increases their size as to make them visible. Often in the case of town fogs, their obviousness is not so much due to the action of the moisture condensed on the particles as to the excessive size and quantity of the particles themselves. What are known as sea fogs probably occur in air which is comparatively dry, because the dust in their case consists largely of salt grains derived from spray or surf, and which have a great affinity for moisture. If the quantity of condensed moisture is large, or the amount of dust and other solid nuclei small, we get what is called a mist, and it is merely a question of the degree of the moisture present which determines where the mist ends and actual rain begins.

The formation of dew is precisely analogous; in this case the solid substance on which the moisture is precipitated or condensed is the surface of the ground, or a blade of grass, and not solid nuclei like soot or dust floating about in the air, as in the formation of fogs. Owing to the rapidity with which the earth, under certain circumstances, loses heat by radiation, as, for instance, on a fine clear night, the strata of air containing moisture, in contact with the cooling earth, themselves become reduced so much in temperature that they are no longer able to retain their water vapour, but actually lose it by condensation upon the ground, where it constitutes what we call dew. The particular temperature at which air saturated or loaded with moisture deposits its water is called the *dew-point.*

Hygrometers.—For the determination of the temperature of the dew-point, certain instruments called hygrometers are used; these are either direct or indirect.

All direct hygrometers experimentally illustrate the principle or theory of the *dew-point*, or that critical temperature at which dew begins to be deposited. We have seen that the capacity of the atmosphere for taking up and holding aqueous vapour in suspension varies with the temperature, or in other words, with what is called the elastic force or tension of aqueous vapour. If the temperature falls, and with it the tension of aqueous vapour, a point is reached eventually at which the air is saturated with moisture. If the cooling process continues, a deposition of dew takes place—in fact, the temperature has fallen to or below the dew-point. Now, in direct hygrometers the cooling process is continued until a film of condensed moisture or dew develops on a surface of glass or polished metal. At this moment an attached thermometer is read off, giving the temperature of the dew-point. Three direct hygrometers call for notice: they are Daniell's, Regnault's, and Dine's.

Daniell's Hygrometer.—This consists of a bent tube with a globe at each end, and is partly filled with ether, the rest of the space in the tube being filled with the ether vapour, all the air having been expelled. One globe is made of blackened glass, and contains a thermometer, while the other is covered with muslin. Before using the instrument, the ether is made to pass into the blackened globe containing the thermometer, while the muslin surrounding the second globe is moistened with ether. This ether rapidly evaporates, causing a condensation of some of the ether vapour inside the tube; this in its turn produces an evaporation of the ether in the blackened bulb. Now, whenever evaporation occurs, there is absorption of heat, so that the black bulb gradually becomes colder and colder, and the moment is soon reached when the air in contact with it begins to deposit dew on its surface. So soon as this happens, the temperature shown by the contained thermometer is read off and recorded as the dew-point.

Regnault's Hygrometer is a modification of Daniell's. In it are two thermometers; one shows the temperature of the air, the other dips through a stopper into a small vessel of polished silver, and is exposed during an experiment to the influence of a current of air made to bubble either by means of an aspirator or by blowing through ether contained in the silver vessel. As the air bubbles through the ether it causes it to volatilise, and by so doing so reduces the temperature that dew is deposited on the outside of the polished silver vessel, at which instant the temperature of the contained thermometer is read off as that of the dew-point.

Dine's Hygrometer consists of a wooden stand, on which is a vessel to contain ice-cold water; from this a pipe proceeds along the wooden stand into a space in which rests the bulb of a thermometer. The roof or covering of this space or chamber consists of a plate of polished metal or of blackened glass. By means of a tap the ice-cold water is allowed to flow into the space beneath the glass or metal plate, and immediately dew is seen to be deposited on the polished surface the temperature of the adjoining thermometer is read off as that of the dew-point.

The necessity for ether in Daniell's and Regnault's instruments renders them costly and inconvenient, especially in tropical countries; for this reason, of the direct hygrometers, that of Dine is in most general use.

Of indirect hygrometers there are two principal kinds, namely, the hair hygrometer of Saussure, and the wet and dry bulb thermometer.

Saussure's Hygrometer consists of a human hair that has not been roughly handled, and that has been freed from grease by digestion in ether or liquor potassæ. Such a hair elongates when moist and contracts when dry. It is fixed at one end, and stretched by a small weight at the other, the connecting cord being passed round a pulley to which is attached an arm or pointer marking on a scale. This scale is graduated by wetting the hair to complete saturation, and marking the point 100, then placing it over sulphuric acid and marking 15° of saturation; the intervening space is then marked off in degrees, indicating degrees of relative humidity. This instrument is fairly sensitive, but needs frequent comparison and verification with a more precise hygrometer. Wolpert's hygrometer is of horsehair.

The wet and dry bulb thermometer, or *psychrometer*, really consists of two ordinary thermometers mounted on a frame side by side. One of these has its bulb covered with muslin, and kept constantly moist by being connected with a small vessel containing distilled water, by means of the capillary action of a piece of cotton wick, which has been previously well freed from grease by being boiled in ether. The dry bulb gives, of course, the temperature of the air, while the wet one, in consequence of the evaporation constantly going on from its surface, gives a lower reading. The difference between the two temperatures recorded indicates the rapidity with which evaporation is proceeding, and, moreover, since evaporation is faster as the air is drier, the indication of the degree of evaporation is a measure of the dryness or moistness (otherwise humidity) of the air. If the air be saturated with moisture, of course no evaporation is going on, and the two thermometers will record the same temperature. In frosty weather, frequently the muslin covering and the water in the vessel will freeze, with the result that evaporation will not take place. In such case, it suffices to brush the frozen muslin over with a brush dipped in cold water and allow this to freeze; at such time evaporation will be going on from the ice surface, so that it will be equivalent to its having a damp but unfrozen bulb. Occasionally in thick fog, or during very calm cold weather, the wet bulb may read higher than the dry; the latter temperature is then to be taken as that of saturation.

From the respective readings of the wet and dry bulb thermometers many valuable deductions may be made; for example, the dew-point, the tension or elastic force of vapour (or the amount of barometric pressure due to the vapour in the air), the relative humidity, the weight of vapour in a cubic foot of air, the amount of vapour required to saturate the air, and the weight of a cubic foot of air at the prevailing atmospheric pressure.

Calculation of the Dew-Point.—The dew-point has already been explained as being that temperature at which the air is saturated with moisture, so that the least further fall in temperature causes a deposit of water in the form of dew. Its determination is obvious by means of a direct hygrometer; its calculation from the readings of the dry and wet bulb thermometers can be roughly made by taking it to be as much below the wet bulb reading as that is itself below the dry; but for greater accuracy it is better calculated out in either of the two following ways:—

(*a*) *By Glaisher's Factors.*—By comparison of the results of Daniell's hygrometer and the dry and wet bulb thermometers for a long term of years, Mr Glaisher has deduced an empirical formula, which is thus worked. Take the difference of the dry and wet bulbs, and multiply it by the factor which stands opposite the *dry-bulb* temperature in the preceding table, deduct the product from the *dry-bulb* temperature; the result is the dew-point. From this formula Glaisher's tables are calculated.

Glaisher's Factors.

Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.
10	8·78	33	3·01	56	1·94	79	1·69
11	8·78	34	2·77	57	1·92	80	1·68
12	8·78	35	2·60	58	1·90	81	1·68
13	8·77	36	2·50	59	1·89	82	1·67
14	8·76	37	2·42	60	1·88	83	1·67
15	8·75	38	2·36	61	1·87	84	1·66
16	8·70	39	2·32	62	1·86	85	1·65
17	8·62	40	2·29	63	1·85	86	1·65
18	8·50	41	2·26	64	1·83	87	1·64
19	8·34	42	2·23	65	1·82	88	1·64
20	8·14	43	2·20	66	1·81	89	1·63
21	7·88	44	2·18	67	1·80	90	1·63
22	7·60	45	2·16	68	1·79	91	1·62
23	7·28	46	2·14	69	1·78	92	1·62
24	6·92	47	2·12	70	1·77	93	1·61
25	6·53	48	2·10	71	1·76	94	1·60
26	6·08	49	2·08	72	1·75	95	1·60
27	5·61	50	2·06	73	1·74	96	1·59
28	5·12	51	2·04	74	1·73	97	1·59
29	4·63	52	2·02	75	1·72	98	1·58
30	4·15	53	2·00	76	1·71	99	1·58
31	3·60	54	1·98	77	1·70	100	1·57
32	3·32	55	1·96	78	1·69		

(*b*) *Apjohn's Formula.*—From a most philosophical and exhaustive analysis of the conditions of this complicated problem, Apjohn derived his celebrated formula, which is now in general use. Reduced to its most simple expression, it is thus worked :—A table of the elastic tension of vapour, in inches of mercury at different temperatures, must be used. From this table take out the elastic tension of the temperature of the *wet* thermometer, and call it f'. Let $(t - t')$ be the difference of the two thermometers, and p the observed height of the barometer. Apjohn's formula then enables us to calculate the elastic tension of the dew-point, which we will call f''; and, this being known, by looking in the table we obtain, opposite this elastic tension, the dew-point temperature.

The formula is :—

$$f'' = f' - 0{\cdot}01147(t - t')\frac{p - f}{30}.$$

The fraction $\frac{p-f}{30}$ differs but little from unity, and may be neglected; the formula then becomes, for the temperature above 32° F.,

$$f'' = f' - \frac{(t - t')}{87}.$$

If below 32° the formula is : $f'' = f' - \frac{(t - t')}{96}$.

The constants 87 or 96 represent the specific heat of air and vapour.

Elastic Force of Vapour.—In an atmosphere of pure steam or aqueous vapour its force, or tension, at the earth's surface is the pressure it exerts—

that is, its weight. So, in an atmosphere composed partly of dry air and partly of steam or vapour, the elastic force of each is the weight of each. This is commonly expressed either in inches or millimetres of mercury. The tension e of aqueous vapour in the atmosphere may be calculated from the indications of the two thermometers by means of the following empirical formula :—

$$e = e' - 0{\cdot}00077\ (t - t') \times h,$$

in which e' is the maximum tension corresponding to the temperature of the wet bulb, h is the barometric reading in millimetres, and t and t' are the respective readings of the dry and wet bulb thermometers in Centigrade degrees. To express inches as millimetres, multiply by 25·4. The tension or elastic force of aqueous vapour is, however, more conveniently obtained by direct reference to the following table :—

Temp. Fahr.	Tension in inches of Mercury.	Temp. Fahr.	Tension in inches of Mercury.	Temp. Fahr.	Tension in inches of Mercury.	Temp. Fahr.	Tension in inches of Mercury.
0	0·044	24	0·129	48	0·335	72	0·785
1	0·046	25	0·135	49	0·348	73	0·812
2	0·048	26	0·141	50	0·361	74	0·840
3	0·050	27	0·147	51	0·374	75	0·868
4	0·052	28	0·153	52	0·388	76	0·897
5	0·054	29	0·160	53	0·403	77	0·927
6	0·057	30	0·167	54	0·418	78	0·958
7	0·060	31	0·174	55	0·433	79	0·990
8	0·062	32	0·181	56	0·449	80	1·023
9	0·065	33	0·188	57	0·465	81	1·057
10	0·068	34	0·196	58	0·482	82	1·092
11	0·071	35	0·204	59	0·500	83	1·128
12	0·074	36	0·212	60	0·518	84	1·165
13	0·078	37	0·220	61	0·537	85	1·203
14	0·082	38	0·229	62	0·556	86	1·242
15	0·086	39	0·238	63	0·576	87	1·282
16	0·090	40	0·247	64	0·596	88	1·323
17	0·094	41	0·257	65	0·617	89	1·366
18	0·098	42	0·267	66	0·639	90	1·410
19	0·103	43	0 277	67	0·661	91	1·455
20	0·108	44	0·288	68	0·684	92	1·501
21	0·113	45	0·299	69	0·708	93	1·548
22	0·118	46	0·311	70	0·733	94	1·596
23	0·123	47	0·323	71	0·759	95	1·646

The tension or elastic force of vapour represents the pressure of all the aqueous vapour in the air above the place of observation. It is greatest near the equator, least near the poles; greater over the ocean than over dry land, in summer than in winter, by day than by night, and at sea-level than in the upper strata of the atmosphere.

Relative Humidity.—This is merely a convenient term used to express comparative dryness or moisture. Complete saturation being assumed to be 100, any degree of dryness may be expressed as a percentage of this, and is obtained at once by dividing the weight of vapour actually existing by the weight of vapour which would have been present had the air been saturated. In other words, the hygrometric state or relative humidity (H) may be expressed as the ratio of the elastic force of aqueous vapour at the temperature of the air (E) to the elastic force of the vapour at the temperature of the dew-point (e); that is, $\mathrm{H} = \frac{e}{\mathrm{E}} \times 100$.

To find the relative humidity, therefore, we require to know, (1) the actual temperature of the air; (2) the dew-point; (3) the elastic tension of vapour present in the air, which is the tension of the dew-point, and is found in the table of tensions or by formula; (4) the tension of vapour saturated at the air temperature, also found in the table.

Example.—The dry-bulb thermometer reads 62° F., the wet-bulb 56° F.; required the relative humidity. The dew-point $=62-\{(62-56)\times1{\cdot}86\}=50^{\circ}{\cdot}84$.

A reference to the table shows the tension at 62°, or the tension which would exist if the air were saturated with moisture, to be 0·556 in. (E); the same table gives the tension of vapour actually present in the air, or the tension at the temperature of the dew-point, 50°·84, to be 0·372 (*e*). From these facts, H or the relative humidity $=\frac{0{\cdot}372}{0{\cdot}556}\times100$, or 66·9, say 67 per cent. of saturation.

Relative humidity is greatest near the surface of the earth during night, when the temperature, being at or near the daily minimum, approaches the dew-point; it is also great in the morning, when the sun's rays have evaporated the dew, and the vapour is as yet only diffused a little way upwards; and it is least during the greatest heat of the day (Buchan). This percentage saturation of the air is practically an inverse measure of the drying power of the air, and as such has a most important bearing upon climatic conditions, more particularly the degree of radiation from the earth's surface. We are all familiar with the peculiarly unpleasant effects of a hot moist atmosphere, and with the invigorating influence of dry and crisp air. A saturated atmosphere at from 35° to 50° F. will be found to be intolerably chilly, and although the evaporation may be checked, and this source of heat-loss removed, yet the conduction and radiation due to the vapour in the air will be enormous. A temperature of 50° to 65° F. in a nearly saturated atmosphere seems to be not uncomfortable, as under those conditions an equilibrium seems to be established between the cooling action by conduction and radiation, due to the vapour in the air, and the supply of heat from checked skin evaporation. A saturated atmosphere with a temperature of from 65° to 80° F. becomes oppressive and sultry. Above 80° F. a saturated air becomes most oppressive, and it is doubtful whether life could be long sustained in a saturated atmosphere of 90° to 100° F., as the surplus heat cannot be removed by conduction or radiation, while at the same time the natural effort of the system to produce evaporation is enormously exaggerated. Humidity of the air is very generally supposed to be associated with the spread, or rather prevalence, of disease; much moisture in the air certainly favours the continuance of colds, but at the same time appears to relieve bronchitis by assisting expectoration and the general discharge of mucus. Malarial diseases are said never to attain their worst form except the air be saturated with moisture, but on this point the evidence is not very strong.

The differences between the temperatures marked in the sun and shade by two maximum thermometers are chiefly dependent on the amount of humidity. The maxima of insolation (measured by the difference between the sun and shade thermometers) occur in those stations and on those days when humidity is greatest. Thus, at Calcutta, the relative humidity being 80 to 93, the insolation (or difference between the thermometers) is 50° F.; at Bellari, the relative humidity being 60 to 65, the insolation is 8° to 11° F. These results are explained by Tyndall's observations, which show that the transparent humidity will scarcely affect the sun's rays striking on the sun thermometer, while it greatly obstructs the radiation of invisible heat from the thermometer; when the air is highly charged with moisture, the sun thermometer is constantly gaining heat from the sun's rays, while it loses little by radiation, or, if it does lose by radiation, gains it again from the air.

The Weight of Vapour required to saturate a cubic foot of air at varying temperatures is given in the table which follows; and, knowing the relative humidity, it is easy to calculate from it the weight of vapour actually present in any given volume of the atmosphere.

Temp. Fahr.	Weight in grains of a cubic foot of Vapour.	Temp. Fahr.	Weight in grains of a cubic foot of Vapour.	Temp. Fahr.	Weight in grains of a cubic foot of Vapour.	Temp. Fahr.	Weight in grains of a cubic foot of Vapour.
0	0·55	26	1·68	51	4·24	76	9·69
1	0·57	27	1·75	52	4·39	77	9·99
2	0·59	28	1·82	53	4·55	78	10·31
3	0·62	29	1·89	54	4·71	79	10·64
4	0·65	30	1·97	55	4·87	80	10·98
5	0·68	31	2·05	56	5·04	81	11·32
6	0·71	32	2·13	57	5·21	82	11·67
7	0·74	33	2·21	58	5·39	83	12·03
8	0·77	34	2·30	59	5·58	84	12·40
9	0·80	35	2·39	60	5·77	85	12·78
10	0·84	36	2·48	61	5·97	86	13·17
11	0·88	37	2·57	62	6·17	87	13·57
12	0·92	38	2·66	63	6·38	88	13·98
13	0·96	39	2·76	64	6·59	89	14·41
14	1·00	40	2·86	65	6·81	90	14·85
15	1·04	41	2·97	66	7·04	91	15·29
16	1·09	42	3·08	67	7·27	92	15·74
17	1·14	43	3·20	68	7·51	93	16·21
18	1·19	44	3·32	69	7·76	94	16·69
19	1·24	45	3·44	70	8·01	95	17·18
20	1·30	46	3·56	71	8·27	96	17·68
21	1·36	47	3·69	72	8·54	97	18·20
22	1·42	48	3·82	73	8·82	98	18·73
23	1·48	49	3·96	74	9·10	99	19·28
24	1·54	50	4·10	75	9·39	100	19·84
25	1·61						

Thus, if 5·77 grains of vapour are required to saturate a cubic foot of air at 60° F., and the relative humidity of a given volume is 70 per cent., the weight of vapour actually present, per cubic foot of that air, is 5·77 × 0·7 or 4·03 grains. The difference between this and the weight of water required to saturate a cubic foot of the air at the given temperature, or 5·77 − 4·03 = 1·74 grain, is a measure of the drying power of the atmosphere under those conditions.

The Weight of Air at a given temperature, pressure, and humidity can be determined from similar data. Thus, say it is required to know the weight of a cubic foot of air containing 60 per cent. of moisture at 60° F. and 29·92 inches barometric pressure. Now, a cubic foot of moist air at 60° F. is nothing more than a mixture of (1) a cubic foot of dry air at 60° F. under the existing barometric pressure *minus* the tension of the vapour present, and (2) a cubic foot of aqueous vapour at that temperature. The tension of the vapour present will be that corresponding to the vapour pressure at the dew-point. Reference to the table on page 738 shows that the maximum tension of vapour at 60° F. is 0·518 inch, and the relative humidity being 60 per cent., the maximum vapour pressure at the dew-point, or actual vapour tension in the air, is 0·518 × 0·6 = 0·31 inch. As the barometer stands at 29·92 inches, therefore, 29·61 inches would be supported by the pressure of the dry air, and the remaining 0·31 inch by the vapour. Now, the weight of a cubic foot of dry air at 32° F. and 29·92 inches is 566·85 grains; and remembering that (see page 128) density varies inversely as absolute temperature, and directly as pressure, it is obvious that the weight of 1 cubic foot of dry air at 60° F. and 29·61 inches will be $\frac{566{\cdot}85 \times 29{\cdot}61}{29{\cdot}92 \times (1 + (0{\cdot}002036 \times (60 - 32)))} = 530{\cdot}72$ grains. The weight of a cubic foot of vapour at 60° F. is 5·77 grains, but as the relative humidity is 60 per cent., its weight under those circumstances is 5·77 × 0·6 = 3·46 grains. The weight of 1 cubic foot of air containing 60 per cent. of moisture at 60° F. will, therefore, be 530·72 + 3·46 = 534·18 grains.

EVAPORATION.

Evaporation is the process by which water is changed from the liquid or solid state into vapour, and is carried off as such into the atmosphere. Various instruments termed atmometers or atmidometers (ἀτμός, *vapour*; μέτρον, *a measure*) have been suggested for the determination of the amount of evaporation, but with indifferent success. Evaporation takes place most quickly into dry air at a high or increasing temperature. It is also favoured by high wind and by a low barometric pressure. In these islands and in Western Europe generally it is most active during spring, when the capacity of the atmosphere for moisture is increasing under the influence of dry easterly winds and a sun of daily increasing power. On the other hand, in the late autumn evaporation is practically non-existent, because the temperature of the air is falling, and its capacity for moisture is diminishing, until it virtually becomes so charged with vapour as to be *saturated*. When this latter condition is reached, evaporation ceases absolutely, and the slightest further fall in temperature causes condensation of the watery vapour into fog, cloud, or rain.

The rate of evaporation may be calculated from the depression of the wet-bulb thermometer, by deducting the elastic force of vapour at the dew-point temperature from the elastic force at the air temperature, and taking the difference as expressing the evaporation. Thus, with the dry-bulb temperature at 53° F., and that of the dew-point at 45° F., the difference of the tensions of vapour at those respective temperatures will be 0·403 − 0·299 = 0·104 inch of mercury. This difference expresses the force of the escape of vapour from any moist surface under those conditions.

Various atmometers have been devised, the principles of which have been either the measurement of the evaporation by the volume of water removed from some exposed vessel, or by the loss in weight of a similar vessel containing water in a given period of time. A manifest fault in these instruments exists in the exposure of the water to gusts of wind at all seasons, and to frost in winter.

In de la Rue's atmidometer the water evaporates from a surface of moistened parchment paper, stretched over a shallow drum kept full of water, which is supplied from a cylindrical reservoir giving about 6 inches of head. "Into this vessel dips a narrow metal tube forming the only opening into a graduated cylinder of glass about 6 inches high and 1½ inch in diameter. The glass cylinder is in the first instance filled with water, and the tube leading from it, which dips into the reservoir, is perforated laterally. The water in the reservoir is therefore maintained at a constant level by a flow from the glass cylinder whenever the lateral opening becomes exposed to the air. The amount of water evaporated is indicated by the graduations on the glass cylinder, which are so drawn as to express the evaporation in hundredths of an inch."

Richard Frères, of Paris, have invented another form of atmidometer which consists of a pair of scales, one of which bears a basin of water or a plant. Weights are placed in the opposite pan to establish an equilibrium. A pen is attached to the scale beam, which records its movements on a revolving drum.

The amount of vapour annually rising from each square inch of water surface in this country has been estimated at from 14 to 24 inches. Symons, from his own observations, calculated the average annual evaporation from a water surface in London in the years 1885–91 to have been 14·5 inches. In the tropical seas evaporation has been estimated at from 80 to 130, or even more inches. In the Indian Ocean it has been estimated to be as much as an inch in twenty-four hours, or 365 in the year, an almost incredible amount. No doubt, however, the quantity is very great.

This distillation of water serves many great purposes. Mixing with the air it is a vast motive power, for its specific gravity is very low (0·6230, air being 1), and it causes an enlargement of the volume of air; the moist air is therefore much lighter, and ascends with great rapidity; the distillation also causes an immense transference of heat from the tropics, where the evaporation renders latent a great amount of heat, to the extra-tropical region, where this vapour falls as rain, and consequently parts with its latent heat. The evaporation also has been supposed to be a great cause of the ocean currents (Maury), which play so important a part in the distribution of winds, moisture, and warmth.

RAINFALL.

The physical cause of rain is the sudden cooling of comparatively warm air, more or less laden with moisture, either (1) by its ascent into the upper and colder regions of the atmosphere, or (2) by its impact against cold mountain slopes, or (3) by its impact against the colder surface of the ground, as in the case of our own west coasts in winter, where the land is colder than the sea surface. The mixture of masses of air of different temperature is generally supposed to be a cause of rain, but from a comparison between the units of heat set free by condensation and the weight of aqueous vapour per cubic foot of air at any two given temperatures, one high and the other low, it seems very probable that the mere mixture of volumes of air cannot be very effective in causing precipitation. In fact, Hann has demonstrated that the latent heat set free in the process of condensation largely prevents that fall of temperature which is assumed to take place and to be the cause of rainfall.

Of the more immediate causes producing rain, winds are the most important. Winds blowing from high latitudes to low ones are generally dry, those moving in the opposite direction are generally moist. Winds blowing off shore are dry, those blowing from the sea are damp. For these reasons we find the wettest regions of the globe to be the equatorial belt of calms, and certain localities where damp winds meet mountain ranges, and are there suddenly chilled. The greatest rainfalls known are on the Western Ghâts on the Malabar coast of India, as at Mahableshwar, where the fall is 263 inches yearly, so again at Cherrapunji, in the Khasia hills to the north of the Bay of Bengal, the rainfall averages 600 inches annually—in 1861 it was as much as 805 inches. Even in our own country the warm moist air over the Gulf Stream, impinging on the Cumberland Hills, causes, in some districts, a fall of 80, 100, 150, or even more inches in the year. On the other hand, the regions with least rainfall are the desert tract reaching from the Sahara through Arabia and Persia to Central Asia, the Kalahari desert in South Africa, and the Great Salt Lake region in North America.

The amount of rain which falls varies, of course, very much with the place; but in determining the average fall at any station, it is necessary to deal with observations extending over long periods. In England and Wales the average rainfall each year is 33·76 inches; in Scotland 46·56 inches; in Ireland 38·54 inches. The average annual rainfall for the United Kingdom is 37·30 inches, for Great Britain 36·69 inches. On the east coast of England not much more than 20 inches of rain falls in a year, while on the west coasts of both Scotland and Ireland it averages as much as 60 or 80 inches; in some parts of Cumberland as much as 150 inches a year have been known to fall. It is very rarely that more than 1 inch of rain falls anywhere in Great Britain in one day; though occasionally as much as 5 inches have been known to fall. For furnishing meteorological returns, a minimum record of 0·01 inch is considered as characteristic of a rainy day in this country.

Observation of Rainfall.—Rain is estimated in inches; that is, the fall of an inch of rain implies that on any given area, say a square yard of surface, rain has fallen equal to an inch in depth. The amount of rain is determined by a rain-gauge.

The most convenient rain-gauge for practical purposes consists of a copper or japanned tin cylinder, at the upper end of which is fixed a turned brass ring with a sharp edge whose diameter is accurately known (fig. 120). Some 6 inches below the ring the cylinder narrows to a funnel, terminating in a long and narrow tube which leads to a metal collecting vessel. Very often the lower end of this tube is curled upward to check evaporation. In this country a rain-gauge is usually circular, with a diameter of either 5 or 8 inches, so that its area in square inches is accurately known. The rain, having been collected in the receiver, is measured in a graduated glass vessel, the divisions of which correspond to hundredths of an inch. The measuring vessel is divided proportionately to the area of the gauge, the diameter of which should always be some simple unit, like 5 or 8 inches, so that, if the original measure get broken, a new one can be readily improvised and graduated. Thus, take an 8-inch gauge, the diameter being 8 inches, its receiving area is 50·26 square inches; therefore, 1 inch of rainfall, or rain 1 inch deep over a town, would deposit in that particular rain-gauge 50·26 cubic inches of water, or 29 fluid ounces, or 12,688 grains of water. It is found in practice more convenient to make

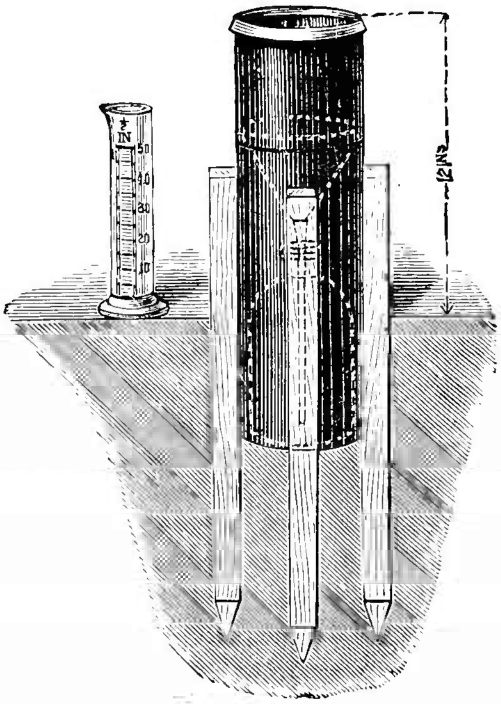


Fig. 120.

the measuring glass hold half an inch. Therefore, if 14½ fluid ounces, or 6344 grains, of water be poured into the proposed measuring glass, and the vessel be marked with a line at the level of its top, that line will represent the graduation of 0·5 inch of rain; fifty subdivision markings are similarly made, or one for each $\frac{1}{100}$th inch of rain, the graduations being marked at 0·10, 0·20, 0·30, 0·40, and 0·50.

The best place for a rain-gauge is on the ground in a well exposed position, with the rim about 1 foot above the earth. A rain-gauge should never be placed upon a house roof, unless, as in towns, no sufficiently open space is available. The spot on which a rain-gauge is exposed should be clear of all objects whose height is greater than their distance from the gauge. Rain should not be collected in the measuring glass, as this is liable to break, especially during frosts. Snow or hail can be measured by thawing the quantity collected and measuring the water which results. When snow falls, its measurement demands constant attention. Should the wind be high and the temperature very low, drifting of snow dust will be apt to vitiate the measurements. Snow will be drifted into the gauge on the one hand, or blown out of it on the other. The depth of snow in a sheltered place, free from drifting, should be carefully measured by a two-foot rule. On a very rough estimate, 1 foot of dry snow may be taken to represent an inch of rain. Should the snow have been lifted out of the funnel by the wind, a good plan is to take the outside cylinder of the gauge, which has the same diameter as the funnel, and to insert it in the snow where it lies level and of an uniform depth. The solid cylinder or section of snow, thus cut out, should then be melted and the resulting water measured.

All observations should be made every day at 9 A.M., and the amount collected entered as having fallen on the previous day.

Theoretically, square gauges are simpler than circular ones, but in practice the latter are mostly used because they are not so apt to get out of shape as the former, and the least denting of the rim of a rain-gauge would affect its accuracy of measurement (Moore).

Besides the foregoing instrument, or, as it is sometimes called, the Meteorological Office Gauge, there are several other kinds; the more important are the following:—

The *Mountain Gauge*, as suggested by G. J. Symons, is intended for rough mountain work. It really is a "float-gauge," and can hold 48 inches of rain; if may be read off to tenths of an inch by means of a rod attached to the cup of the float.

Another variety is *Symon's Storm Rain-Gauge.* It is not intended for general use, or for continuous records, but rather to record in detail the rate at which heavy rains fall during thunderstorms. In this instrument the rain passes into a copper cylinder in which is a float, which rises as the rain falls. The float has a string passing round a pulley, and kept tight by a weight: therefore, when the float rises, the pulley turns. The axle of the pulley is connected with two hands or pointers which, on a graduated dial, complete revolutions when 1 and 5 inches of rain have fallen respectively. With this gauge it is easy to read from a window the rainfall to hundredths of an inch, and if this is noted at short intervals of time, the minutest details of the fall of rain can be recorded.

Crosley's rain-gauge is self-registering, and has an area of 100 square inches. It was invented in 1829. Beneath the tube leading from the funnel there is a divided bucket, balanced on a pivot. When one compartment of this bucket has received a cubic inch of water, that is, when 0·01 inch of rain has fallen, the bucket tips, the index advances on the first dial, and the second compartment begins to fill, and so on indefinitely.

Yeates' electrical self-registering rain-gauge is a modification of the preceding, having as its essential feature the arrangement that at each turn of the bucket an electrical contact is made, whereby an index hand moves one division.

Richard Frères, of Paris, have invented a float pattern, and a tipping bucket pattern of self-recording rain-gauges. In them a style, carrying a writing pen, follows the motion of the float and oscillating tipping bucket, with the result that the amount of rain which falls is graphically recorded on a revolving drum.

Seasonal and Diurnal Fall of Rain.—In these islands and on the western shores of Europe the winter rainfall exceeds that of summer. This is mainly due to the prevalence of westerly winds laden with moisture, and to the relative coldness of the highlands and coast-line on the Atlantic sea-board. In the middle of Europe the summer rainfall is in excess of that in winter, apparently owing to the heavy rains which accompany summer thunderstorms. These summer rains are really evaporation rains which fall from cumuli formed by evaporation and their ascent above the saturation or condensation line. The seasonal rains of India, accompanying the south-west monsoon, are caused by the condensation of the vapour in those winds blowing in from over the Indian Ocean, condensing against the cold highlands of the Himalayas.

The diurnal fall of rain is dependent on season. As a rule, in winter more rain falls by night than by day, while in summer the reverse is the case; in spring and autumn there is not much difference. According to Hellmann, the diurnal variation of rainfall, like that of cloudiness, can be classified according to a number of typical curves. An afternoon maximum occurs in many places, especially in summer, corresponding to the hour of maximum frequency of thunderstorms; and another maximum late at night or in the very early hours of the morning is connected with peculiarities in the diurnal variations of pressure, temperature, and even wind. This latter maximum is more or less characteristic of Western Europe at all seasons, and is specially marked in winter.

ATMOSPHERIC PRESSURE.

We have already seen in Chapter II. that the atmosphere has weight, and by virtue of that weight exercises pressure. The instrument used for ascertaining this effect is called the barometer (*βάρος, weight; μέτρον, a measure*), so called because it measures the weight of the atmosphere from the height of a column of mercury or other liquid supported by the pressure of the atmosphere. The heights of the columns of two fluids in equilibrium are inversely as their specific gravities; and since, in terms of mercury at sea-level in this country, the atmospheric column equals that of 29·92 cubic inches of mercury; and since 1 cubic inch of mercury weighs 3426¾ grains, the weight of 29·92 cubic inches will be 14·64 ℔. Thus the pressure of the atmosphere generally on a square inch of the earth's surface is 14·64 ℔. The pressure of the atmosphere is not expressed by the weight of the mercury sustained by that pressure, but by the perpendicular height of the column. Thus, when the height of the column is 29·92 inches, we do not say that the atmospheric pressure is 14·64 ℔ on the square inch, but that it is 29·92 inches, meaning that the pressure will sustain a column of mercury at that height. In this country and America the usual measurement is by inches, tenths, and hundredths; on the Continent, and for scientific observations everywhere, the metrical system is adopted; the standard pressures at sea-level being taken as 29·92 inches and 760 millimetres respectively, at standard temperatures of 32° F. and 0° C.

Barometers.—These are usually either mercurial, glycerin, water, or aneroid barometers. As commonly constructed, the mercurial barometer consists of a tube of glass about 33 inches long, closed at one end, filled with mercury and placed vertically with the open end dipping into a cup containing mercury, called the cistern. As the mercury in the tube balances, as it were, the pressure of the air, it is obvious that it falls with a lessened pressure, but rises with an increased pressure. Since, when the mercury column falls, some mercury flows out of the tube into the cistern, and when it rises out of the cistern into the tube, the level of the mercury surface in the cistern varies with every change of pressure; and some means must be adopted for adjusting either the zero end of the scale, which marks the height of the vertical column, to the mercury surface in the cistern, or the mercury surface to the zero end of the scale, or else some proper allowance must be made for the error introduced in the absence of such adjustment. In some common forms of barometer the scale is laid off from a zero at some fixed point in the cistern, with the result that, except at one particular point, the instrument reads wrongly, because, during the changes which take place in the length of the column, the level of the mercury in the cistern also changes, being sometimes higher and sometimes lower than the fixed zero point. In order to overcome this difficulty and source of error, various expedients have been resorted to, so as to compensate for the ever changing level of the mercury in the cistern; thus:—

1. By a so-called capacity correction which, duly noted and recorded on the scale by the maker, states the ratio of the interior area of the tube to that of the cistern; thus, capacity $\frac{1}{40}$. To apply this correction, there is always marked on the scale a certain height of the column which is correctly measured by the scale. This exact height is termed the *neutral point*; when the mercury sinks below this, the height read off will of course be too great, because the level of the mercury in the cistern will have risen above the zero in a proportionate amount; for the same reason, when the mercury rises above the neutral point, the reading will be too small, because the level of the mercury in the cistern will have fallen below the zero of the scale. The capacity correction is applied by taking the indicated fractional part of the difference between the height read off and that of the neutral point, and adding or subtracting it from the reading, as the case may be. Thus, suppose in the case of a barometer marked with a neutral point, and with a capacity correction of $\frac{1}{50}$, the mercury stands 1 inch above the neutral point, then $\frac{1}{50}$ of the difference the height read off and the neutral point, or, in this case, one-fiftieth or 0·02 inch, must be added to the observed reading.

2. In the Kew barometers the error is obviated by graduating the scale in nominal inches, which are shorter than true inches, from above downwards in proportion to the relative size of the diameter of the tube and cistern; the highest point on the scale, say 32 inches, being marked off correctly from a definite point on the cistern side. As in the ordinary Kew barometers these diameters measure about 0·25 and 1·25 inch respectively, the inches of the scale are shortened in the proportion of 0·04 inch to 1 inch.

3. Another device is to do away with the cistern altogether, and to employ a U-shaped tube, in which one arm is shorter than another, and open at one end. Both levels are read upon a scale, and the reading of the barometer is the difference in level of the mercury in the two legs. These are sometimes called siphon barometers, of which the ordinary wheel barometer is a common type; in this latter instrument the movements of the mercury are transmitted from a float on the mercury in the open tube, by means of a string, to an axis which carries an index moving over a dial plate as in a clock.

4. In what are called the Fortin barometers, or standard barometers, the necessity for capacity correction, or either of the other above-named devices, is avoided by giving the cistern a pliable base of leather, and capable of being raised or lowered by means of a screw *a* (fig. 121). The upper part of the cistern is made of glass, through which the zero of the scale can be seen as a piece of ivory, whose lower extremity is called the *fiducial point*, *b*. Before taking a reading, the level of the mercury in the cistern must be set exactly to this point, by raising or lowering the cistern base by means of the screw; since the fiducial point is the tip of the piece of ivory, and accurately corresponds, as a fixed point, to the zero of the scale, after the level of the mercury in the cistern has once been carefully adjusted to it, it is obvious that the height of the column of mercury then read will be an accurate measure of the atmospheric pressure.

Although in the majority of barometers the atmospheric pressure is measured by a column of mercury because of its high specific gravity, still, in some others, other liquids are employed, such as *glycerin*, which, having a lower specific gravity, is much more sensitive to variations in pressure. The specific gravity or density of mercury is 13·59, while that of glycerin is but 1·26; the atmosphere we know can support a mercurial column 29·92 inches high; therefore, it can equally support a glycerin column 27 feet high; or, in other words, a fall of 1 inch in a mercurial column is the equivalent of a fall of 10·7 inches in a glycerin instrument—the latter, in consequence of its greater range, being far more sensitive as an indicator. The advantage of the glycerin barometer is that it not only magnifies tenfold, as it were, the readings of the mercurial instrument, but the medium used, while undiluted, does not freeze at any known terrestrial temperature. Jordan's glycerin barometer, used at the *Times* Office, London, consists of a gas tube, five-eighths of an inch in diameter and 28 feet in height. As glycerin has a marked affinity for water, the glycerin in the cistern of this gigantic barometer is covered with a layer of paraffin oil.

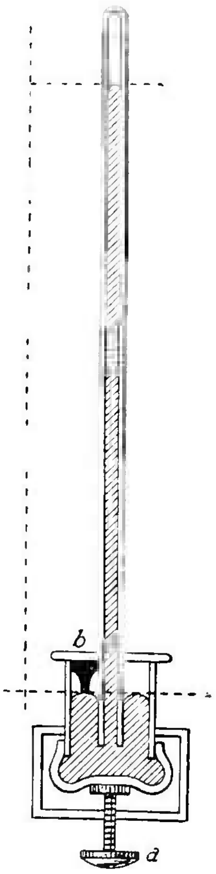


Fig. 121.

Water barometers have also been made, in which the column required to balance the atmosphere is 34 feet. These are obviously very sensitive, but unsuitable for general use, owing to the high freezing point of water, and the liability to condensation of its vapour.

In Callendar's *Compensating Open-Scale Barometer*, the liquid used is sulphuric acid. The readings of this barometer are independent of the temperature of the instrument, and give, without calculation or correction, the actual pressure of the atmosphere. The scale is nearly six times as open as that of a mercury barometer, so that the change of 0·01 inch or 0·2 millimetre in the length of the mercury column can, in this instrument, be read by the eye direct. It indicates both temperature and pressure, the expansion of the contained sulphuric acid being utilised for the purposes of an open-range thermometer.

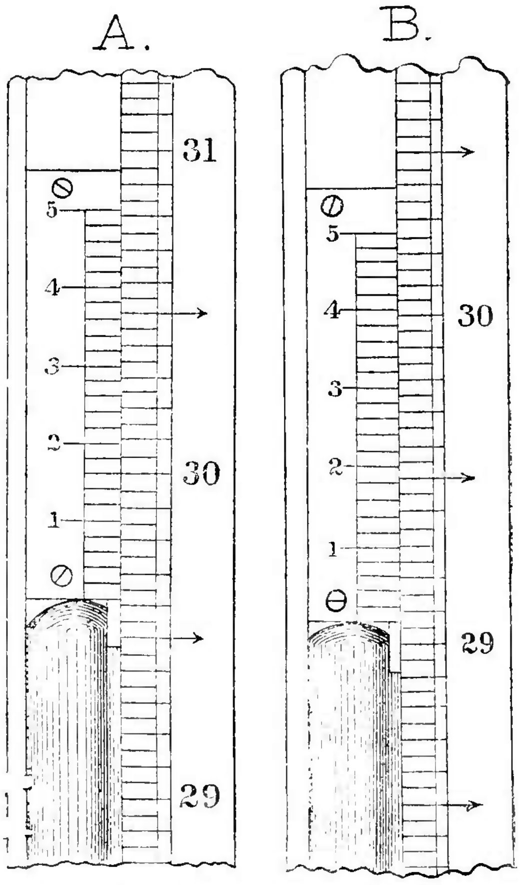
Besides mercurial, glycerin, water, and sulphuric acid barometers, familiar instruments in common use are *aneroid barometers*. These are small air-tight metallic boxes, from which the air has been displaced by peroxide of hydrogen, and so constructed that as the atmospheric pressure rises, so the metal box is forced in, and, helped by means of a strong spring, bulges out again when the pressure lessens. By an arrangement of levers, the movements of the metal are made to turn an index on a dial face, and are so exaggerated that the motion of the sides of the box to an extent of $\frac{1}{220}$ inch causes the index to move through 3 inches as marked on the dial. Watkins has invented an ingenious modification of the aneroid, by which a very considerably extended scale is afforded on a dial of some 5 inches in diameter. The pointer is drawn inwards towards the centre, with diminished pressure, and works on a scale engraved in spiral fashion, commencing with 31 inches at the outer margin of the dial, and ending with 27 inches near the centre; thus, an inch of mercury is here magnified to about 8 inches of scale, so that differences of level of 15 or 20 feet can be plainly distinguished, and the variations of atmospheric pressure in a squall of wind noted easily from minute to minute.

Aneroids are very sensitive and convenient, but liable at times to go hopelessly wrong, on which account they need to be periodically checked against a standard mercurial barometer. By a combination of a series of aneroid vacuum boxes, the movements of which by a lever are multiplied and recorded upon a revolving cylinder, so-called recording barometers have been made, and for observatory work serve a useful purpose, but are not absolutely accurate without being constantly checked against standard instruments.

Reading of Barometers.—The cases and scales of all good barometers are made of brass, because the coefficient of its expansion by heat is well known. These instruments should be hung perfectly vertical, not exposed to direct rays of the sun, or to artificial heat, and not exposed to accidental injury. An attached thermometer is always required to note the temperature at the time of taking the barometrical observation.

In all standard barometers there are in reality two scales: a principal or fixed scale, and a secondary or small movable scale, called a "vernier," which ensures greater accuracy in the reading. Each long line on the fixed scale is 0·1 inch, each short line is 0·05 inch. The vernier scale is so graduated that twenty-five of its divisions correspond to twenty-four of the half-tenth or 0·05 inch divisions on the fixed scale. Consequently, each division on the vernier is $\frac{1}{25}$th less than a half-tenth division on the fixed scale; and the vernier exhibits differences of $\frac{1}{25}$ of 0·05 inch, or $0·04 \times 0·05 = 0·002$ inch.

In taking a reading of a barometer, the first thing to do is to note the temperature of the instrument by means of the usually attached thermometer; next, adjust the mercury in the cistern to the fiducial point, if it be one made on Fortin's principle; then place the vernier so that its lowest edge is level with the top of the mercurial column, forming a tangent, as it were, to the mercurial meniscus. If the top of the mercury coincide exactly with one of the divisions on the principal scale, there is no need to use the vernier; but if it do not so coincide, the use of the vernier will accurately measure the excess of the mercury over the next lowest division on the scale. To do this, we must follow the vernier scale up, until we find one of its marks exactly corresponding with one on the fixed scale; call it x, and, as each of these represents 0·002 inch, we have $x \times 0{\cdot}002$ inch as the exact distance which the mercury column is over and above the next lowest mark to it on the principal scale. Thus, in example A (fig. 122) we find that the top of the mercury is just above 29·60 inches, but below 29·65; that is to say, neither of those readings give the absolutely correct height of the mercury. Following up the vernier, we find that its eighth line or mark is the first to exactly coincide with one on the principal scale; therefore, if we read that as meaning eight five-hundredths of an inch, or $8 \times 0{\cdot}002 = 0{\cdot}016$ inch, or the exact amount by which the top of the mercury column exceeds 29·60 on the fixed scale, we get, by the addition of these two numbers, 29·616 inches as the correct reading of this particular example. In the same way, example B reads 29·058 inches.



29·616. 29·058.

Fig. 122.

Corrections for the Barometer.—The reading having been thus accurately taken, it remains to apply certain corrections; these are (1) for capillarity, (2) index error, (3) for temperature, (4) for height above sea-level. The first two corrections are constant, and have to do with the actual instrument. *Correction for capillarity* depends on the size of the bore, and whether the mercury has been boiled in the tube or not. *Index error* is determined by comparison with a standard instrument. The capillarity and index errors are usually put together. The capillarity error is always additive; the index error may be subtractive or additive, but the two together form a constant quantity, and the certificates furnished by the Kew Observatory for the instruments verified there, and by most of the makers, include both corrections above-mentioned. *Corrections for Temperature.*—The error due to temperature is one which affects not only the mercury but also the brass of the scale, and in extremes of heat or cold may be considerable; this explains why it is so important to note the temperature before taking the reading. To secure uniformity of barometric records all nations have agreed to reduce their barometer readings to what they would have been had both the mercury and brass scale been at 32° F., or 0° C. All good barometers are made with brass scales, and for these the necessary temperature corrections are given in the following table:—

Temp.	27 inches.	28 inches.	29 inches.	30 inches.	31 inches.
30°	− 0·004	− 0·004	− 0·004	− 0·004	− 0·004
40°	− 0·028	− 0·029	− 0·030	− 0·031	− 0·032
50°	− 0·052	− 0·054	− 0·056	− 0·058	− 0·060
60°	− 0·076	− 0·079	− 0·082	− 0·085	− 0·087
70°	− 0·100	− 0·104	− 0·108	− 0·111	− 0·115
80°	− 0·124	− 0·129	− 0·133	− 0·138	− 0·143
90°	− 0·148	− 0·153	− 0·159	− 0·164	− 0·170
100°	− 0·172	− 0·178	− 0·184	− 0·191	− 0·197

Schumacher has suggested the following formula for temperature correction of mercury barometers with brass scales, and from which the above table has been prepared :—

h = observed height of barometer in inches.
t = temperature of attached thermometer (F.).
m = expansion of mercury per degree, viz., 0·0001001 of its length at 32°
s = linear expansion of scale, viz., 0·00001041 ; normal temperature being 62°.

$$-h\frac{m(t-32^\circ)-s(t-62^\circ)}{1+m(t-32^\circ)}.$$

Another rule is as follows :—As mercury expands $\frac{1}{9990}$ of its bulk for each degree F., (1) multiply the number of degrees *above* 32° by the observed height, and divide by 9990 : subtract this quotient from the observed height ; or (2) multiply the number of degrees *below* 32° by the observed height, and divide by 9990 : add this to the observed height.

Correction for Height above Sea-level.—As the mercury falls about $\frac{1}{1000}$ inch for every foot of ascent, this amount multiplied by the number of feet ascended must be added to the reading, if the place be above sea-level. For the British Isles, the mean sea-level at Liverpool has been selected by the Ordnance Survey as their datum. In places which are below sea-level,

	Barometer at Sea-level = 30 inches.						Barometer at Sea-level = 27 inches.					
Height in feet.	0° F.	20° F.	40° F.	60° F.	80° F.	100° F.	0° F.	20° F.	40° F.	60° F.	80° F.	100° F.
10	·012	·012	·011	·011	·010	·010	·011	·011	·010	·010	·009	·009
30	·037	·035	·034	·032	·031	·030	·033	·032	·030	·029	·028	·027
50	·061	·059	·056	·054	·052	·050	·056	·053	·051	·049	·047	·045
70	·086	·082	·078	·076	·072	·069	·078	·074	·071	·068	·065	·062
100	·123	·117	·112	·108	·103	·099	·111	·106	·101	·097	·093	·089
120	·148	·141	·134	·129	·124	·119	·133	·127	·121	·116	·112	·107
150	·185	·176	·168	·162	·155	·149	·166	·158	·152	·146	·139	·134
170	·209	·199	·190	·183	·175	·168	·188	·179	·172	·165	·158	·152
200	·246	·234	·224	·215	·206	·198	·221	·211	·202	·194	·186	·178
250	·307	·293	·280	·269	·258	·248	·276	·263	·252	·242	·232	·223
300	·368	·351	·336	·322	·309	·297	·331	·316	·302	·290	·278	·267
350	·429	·409	·392	·376	·360	·346	·386	·368	·352	·338	·324	·312
400	·489	·467	·447	·429	·411	·395	·440	·420	·402	·386	·370	·356
450	·550	·525	·503	·482	·462	·444	·495	·472	·452	·433	·416	·400
500	·610	·583	·558	·535	·513	·493	·549	·524	·502	·481	·462	·444
600	·731	·698	·668	·640	·615	·591	·658	·628	·601	·576	·553	·532
800	·970	·927	·887	·850	·817	·786	·873	·834	·798	·765	·735	·707
1000	1·208	1·154	1·105	1·059	1·017	·979	1·087	1·039	·994	·953	·915	·881
1250	1·502	1·435	1·374	1·317	1·266	1·218	1·352	1·292	1·237	1·187	1·140	1·096
1500	1·794	1·714	1·641	1·574	1·513	1·456	1·614	1·543	1·477	1·417	1·362	1·310

this correction will necessarily be subtractive, but such localities are few. If great accuracy is required, two disturbing elements must be taken into account: these are, the temperature of the air, and the actual air pressure at sea-level at the time of observation. For correcting for small altitudes the preceding table is modified from Scott's *Instructions in the Use of Meteorological Instruments.*

In the foregoing table corrections are given for two pressures at the lower station, namely, 30 and 27 inches. For intermediate pressures, the correction may be obtained by proportional parts. For heights exceeding those given in the table, the value at the sea-level, of a barometer reading at a station, the height of which is known, may be calculated from the following formula:—

$$\text{Log}\,\frac{h}{h'} = f \div \left\{60159\left(1+\frac{t+t'-64}{900}\right)\left(1+0{\cdot}00268\cos 2l\right)\left(1+\frac{f+52251}{20886861}\right)\right\}.$$

From a table of common logarithms the natural number corresponding to $\log\frac{h}{h'}$ is found; or $\frac{h}{h'}=n$, and $h=nh'$. In this formula—

h and h' = barometer reduced to 32° F. at the lower and upper stations respectively,
t and t' = the temperature of the air at the respective stations,
f = elevation of upper station in feet,
l = latitude of the place.

The above formula is merely an inversion of the well-known formula given by Laplace, in his *Mécanique Céleste,* for finding the difference of elevation between any two places by means of the barometer, which, adapted to Fahrenheit's thermometer and English feet and inches, is—

$$f = 60159\log\frac{h}{h'}\left(1+\frac{t+t'-64}{900}\right)\left(1+{\cdot}00268\cos 2l\right)\left(1+\frac{f+52251}{20886861}+\frac{x}{10443430}\right).$$

In this formula f is the difference of elevation between the two stations, and x is the height of the lower station above the sea-level.

In the last factor an approximate value must be used for f.

Measurement of Heights. — The barometer falls when heights are ascended, as a certain weight of air is left below it. The diminution is not uniform, for the higher the ascent the less weighty the air, and a greater and greater height must be ascended to depress the barometer 1 inch. This is illustrated by the following table, in which it will be seen that to lower from 31 inches to 30, 857 feet must be ascended, while to lower from 21 to 20, as many as 1276 feet must be ascended.

A great number of methods and rules for calculating heights, from the difference in barometric readings of any two places, have from time to time been suggested; and, by means of aneroids, are not difficult to carry out. A very simple rule for approximate determinations has been given by Strachan. Read the aneroid to the nearest hundredth of an inch; subtract the upper reading from the lower, leaving out or neglecting the decimal point: multiply the difference by 9: the product is the elevation in feet.

Example.

	Inches.
Lower station,	30·25
Upper ,,	29·02
	123
	9
Elevation,	1107 feet.

If the barometer at the upper station is below 26 inches, or the temperature above 70°, the multiplier should be 10.

Approximate Height due to Barometric Pressure.

Inches of Barometer.	Feet.	Inches of Barometer.	Feet.	Inches of Barometer.	Feet.
31·0	0	27·3	3,323	23·6	7,131
30·9	84	·2	3,419	·5	7,242
·8	169	·1	3,515	·4	7,353
·7	254	27·0	3,612	·3	7,465
·6	339	26·9	3,709	·2	7,577
·5	425	·8	3,806	·1	7,690
·4	511	·7	3,904	23·0	7,803
·3	597	·6	4,002	22·9	7,917
·2	683	·5	4,100	·8	8,032
·1	770	·4	4,199	·7	8,147
30·0	857	·3	4,298	·6	8,262
29·9	944	·2	4,398	·5	8,378
·8	1,032	·1	4,498	·4	8,495
·7	1,120	26·0	4,588	·3	8,612
·6	1,208	25·9	4,699	·2	8,729
·5	1,296	·8	4,800	·1	8,847
·4	1,385	·7	4,902	22·0	8,966
·3	1,474	·6	5,004	21·9	9,085
·2	1,563	·5	5,106	·8	9,205
·1	1,653	·4	5,209	·7	9,325
29·0	1,743	·3	5,312	·6	9,446
28·9	1,833	·2	5,415	·5	9,567
·8	1,924	·1	5,519	·4	9,689
·7	2,015	25·0	5,623	·3	9,811
·6	2,106	24·9	5,728	·2	9,934
·5	2,198	·8	5,833	·1	10,058
·4	2,290	·7	5,939	21·0	10,182
·3	2,382	·6	6,045	20·9	10,307
·2	2,475	·5	6,152	·8	10,432
·1	2,568	·4	6,259	·7	10,558
28·0	2,661	·3	6,366	·6	10,684
27·9	2,754	·2	6,474	·5	10,812
·8	2,848	·1	6,582	·4	10,940
·7	2,942	24·0	6,691	·3	11,069
·6	3,037	23·9	6,800	·2	11,198
·5	3,132	·8	6,910	·1	11,328
27·4	3,227	23·7	7,020	20·0	11,458

Observations of this kind have been much facilitated by the introduction of aneroids on which altitude scales are graduated, combined with an adjustable scale for temperature. The adjustment for the temperature of the air is applied by shifting the scale in accordance with the figures engraved on the outside of the instrument. The rim which holds the glass should be slightly raised, so as to be free from the locking-pin, and then turned until the figures corresponding to the air temperature are opposite to the pin, when the glass should be depressed so as to re-lock it. The making of an observation is simple. First determine, either by observation or by estimation, the air temperature likely to prevail during the observations; if this is done within 5° it will be sufficiently accurate. The scale must then be set to this temperature in the manner explained. The barometric readings at each place must be taken from the outer scale of feet, and the *difference* will give the difference of height between the two stations. The accuracy of the result will be increased if the observations are repeated more than once, and the average of the results taken.

Barometric Fluctuations.—Atmospheric pressure, as measured by the barometer, is subject to two classes of variation; the one is regular, the other is irregular. The regular or periodic variations are *diurnal* and *annual*, while the irregular or non-periodic variations are *cyclonic* and *anticyclonic*.

Barometric pressure will be low: (1) When the air is heated. (2) When the air is damp; because, when watery vapour mixes with dry air, the volume of the latter is increased, with the result that a volume of air which at 50° F., when dry, measures 1 cubic foot and weighs 546·8 grains, becomes, when saturated with moisture at the same temperature, 1·0121 cubic foot, with a weight of 550·9 grains; in other words, 1 cubic foot of the saturated air weighs but 544·3 or 2·3 grains lighter than it did when dry. (3) When the air from any cause has an upward movement, as in some varieties of wind.

Barometric pressure will be high: (1) When the air is very cold, and consequently dense. (2) When the air is dry. (3) When in any way an upper current sets in towards a given area, thereby compressing the strata beneath.

Accordingly we find an area of low pressure in winter in high latitudes over the North Atlantic and Pacific Oceans, where the temperature is abnormally high. Conversely, the regions of highest barometrical readings are situated over the continents, in high latitudes, and in localities characterised by abnormally low temperatures.

Diurnal variations are best marked in the tropics, where the range of pressure often exceeds 0·1 inch. There are two maxima and two minima; the first maximum is about 9 A.M., the second about 10 P.M. Condensation of the air after a cold night partly accounts for the forenoon rise, coupled with rapid evaporation, and consequently increasing tension of aqueous vapour. The evening maximum is partly due to a quick fall in temperature causing condensation, and possibly also to a saturated state of the air after the evaporation of the day. The first minimum is about 3 to 4 P.M., the second at 4 A.M. The first is mainly explained by the heating and expansion of the air at the hottest part of the day; the second is probably due to desiccation of the atmosphere resulting from condensation of, and withdrawal of tension of aqueous vapour by the nightly fall of temperature.

In this country the diurnal range is less, rarely exceeding 0·02 inch, but the maxima and minima occur about the same hours as in the tropics, and are probably dependent upon similar causes supplemented by constant shifting of the wind. In these islands the barometer falls usually with the south-west winds, and rises with the north and east; the former are moist and warm, the latter dry and cold winds.

Annual variations in atmospheric pressure are on a far larger scale than the daily ranges. In so far as concerns the dry air of the atmosphere, barometric pressure might be expected to be least in the summer and greatest in the winter of each hemisphere. But the production of aqueous vapour by evaporation being most active in summer, the pressure from its tension will be increased from this cause. As the aqueous vapour is transferred to the colder hemisphere, it is condensed into rain, and being thereby withdrawn from the atmosphere, atmospheric pressure is lessened; but the dry air which the vapour brings with it from the warm hemisphere remains, thus tending to increase the pressure. In the neighbourhood of the equator, where temperature and moisture differ little in the course of the year, the variation in the mean pressure from month to month is small (Buchan).

In Calcutta the average pressure in July is 29·538, and in January 30·022 inches, thus showing a difference of 0·484 inch. This large annual variation is caused jointly by the great heat in July, and by the heavy rains accompanying the south-west monsoon; while in January the barometer is high, owing to the north-east monsoon, by which the dry, cold, dense air of the continent is carried southward over India.

At places where the amount of vapour in the air varies little from month to month, but the variations of temperature are great, the annual variations of pressure are very striking. Thus, at Irkutsk in Siberia the pressure in July is 28·192 inches and in January 28·777 inches, the difference being nearly 0·6 inch. The great heat of Siberia during summer causes the air to expand and flow away in all directions, and the diminished pressure is not compensated for by any great increase of aqueous vapour tension. On the other hand, the great cold and small rainfall of that region during winter cause high pressures to prevail during that season. The same peculiarities are seen, though in a modified way, at Moscow, St Petersburg, and Vienna.

In Iceland, the Orkney Islands, and in some other parts of this country, the distribution of pressure is just the reverse of what obtains in Siberia, being least in winter and greatest in summer. The low winter pressures are due to the comparatively high winter temperatures causing an outflow towards adjoining countries, and to the large amount of moisture in the air, and the heavy rainfall which, by setting free the latent heat, still further augments and accelerates the outflow by the upper currents. The annual variation of pressure in the United Kingdom is most variable, but the maximum readings are usually about the end of May or early in June, while the minima are at the end of October or early in November.

Those irregular variations of barometric pressure which daily, monthly, and yearly occasion changes in wind and weather over more or less extensive areas of the earth's surface are broadly divided into the *cyclonic* and the *anticyclonic*, according as to whether they are associated with bad or good weather. In former years the value of the barometric reading was necessarily limited to the particular spot at which it was noted; but recently, as the result of increased facilities of communication between one place and another, it is possible to obtain simultaneous readings of the barometer at any given time at several places distributed over a wide area. Now, if these are recorded on a map, and lines be drawn between and connecting all places where the same pressure prevails, we obtain what is called a *synoptic chart*, made up of lines of equal barometric pressure, or *isobars*, as they are termed. This is what is actually done in all the chief meteorological stations, and experience has shown that these isobars commonly assume certain typical forms or shapes, which are again usually associated with certain kinds of weather. It is upon these data and facts that the modern methods of weather forecasting are based.

Isobars are drawn for each tenth of an inch, and tend to assume two primary and five secondary shapes (fig. 123). If they enclose an area of low pressure, forming a circle or an oval, they are described as cyclones. If, on the contrary, the isobars encircle an area of high pressure, they are described as anticyclones. These constitute the two primary types of isobars. The secondary shapes are five in number, being for the most part modifications of the primary types, or connected with either one or other of them; they are secondary cyclones, V-shaped depressions, wedges of high pressure, cols and straight isobars. The closeness of the isobars one to another, or the rapidity of changes of pressure, constitute what is called the "barometric gradient," and just as we measure and express a railway gradient as being 1 in 20, 1 in 100, and so on, so can we say that barometric gradients are so many thousandths of an inch in fifteen miles, or so many millimetres in one degree of the meridian. The steepness of the barometric gradients directly governs the velocity of the wind over any particular place, the wind's velocity being greatest at the localities of steepest gradient and *vice versâ*. In addition to this, if the wind's direction at each place be noted on a synoptic chart, it is found to be nearly parallel to the trend of the isobars, and tends to cross from the higher to the lower ones. This fact has found expression in what is known as Buys Ballot's law, namely, *that if you stand with your back to the wind, the lowest pressure lies to your left and in front.*

Cyclones.—An area of low pressure, and the whole system connected with it, is called a depression or cyclone, and in America "a low." As seen on a synoptic chart, cyclones are circles formed by concentric isobars, in which the outer lines mark a higher pressure than the inner ones; they constitute the most frequent arrangement of isobars in these latitudes. They usually travel from west to east, at the rate of about twenty miles an hour, and are invariably associated with bad weather. The *intensity* of a cyclone depends less upon the actual pressure or height of the barometer than upon the fact that the isobars are close together, and that the system is deep and moving quickly. The forces involved are due to the gradients or differences of pressure, and are greater the steeper the gradients. Hence a cyclone may be of a mild type, or be a gale or hurricane, according as to whether the gradients are gentle or steep. If we analyse the weather associated with a cyclonic disturbance, we find that the foremost portion of a cyclone area is always marked by stratiform clouds, moist heavy atmosphere, and the usual signs of coming rain, such as a pale moon, watery sun, dirty, gloomy sky. As the cyclone advances, a drizzling gradually changes into a driving rain, accompanied in the trough or situation of lowest pressure by squalls of wind. As the cyclone area shifts its position or moves onward, the rain moderates into showers, followed by a brighter sky with cumulus clouds and a sharp, brisk feeling in the air. If we study the barometer changes at different points in the path of a cyclone, it is at once obvious that in the fore part of the area of depression the barometer is everywhere falling, while in the rear part it is everywhere rising, and the turning-point, or line of lowest pressure, is what is called the trough. A cyclone may be

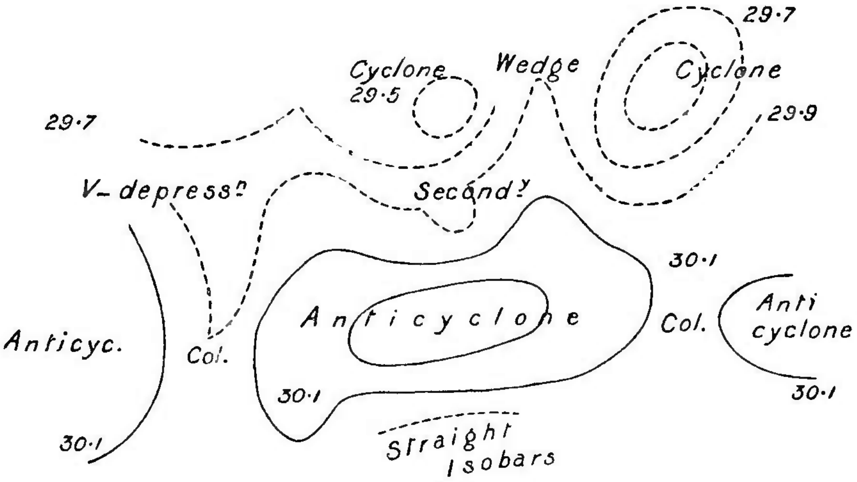


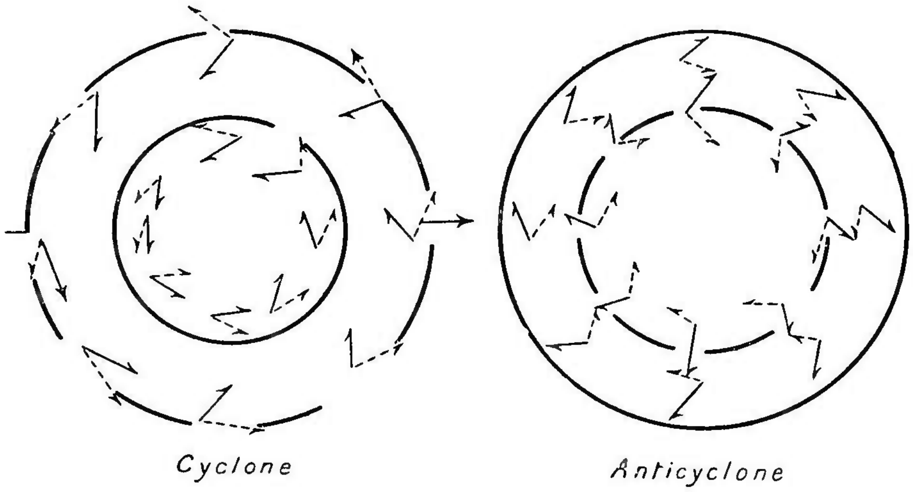
Fig. 123.

compared to a cup-shaped hollow, the isobars being simply contour lines. The extent or area of a cyclonic disturbance may vary from ten or twenty to some thousands of miles, covering even the whole Atlantic or the greater part of Europe. Cyclones are usually oval and not circular in form, their longest diameter being in these latitudes in a direction nearly W.S.W. to E.N.E. in the majority of cases. When the dimensions become great, especially if the system be much elongated, a cyclone frequently breaks up into two, three, or even more separate centres of depression. Large cyclones are, of course, much modified in both form and position by the variations of the deflecting force due to the rotation of the earth, and arising from difference of latitude. As a rule, the higher the latitude, the greater is the average size of cyclones. In the tropics, cyclones are usually smaller and circular. It is important, however, not to confound small cyclones with either waterspouts or tornadoes, which are too small to be much influenced by the rotation of the earth, besides which they are special phenomena of a distinct nature. The direction of the wind is, in all cyclones, obliquely across the isobars, and may be described as blowing spirally into the area of low pressure towards the centre, and from the central area in an upward direction. The particular angle at which the incurving of the wind takes place in a cyclone depends on the friction between the air currents and the earth's surface, the angle being smaller the greater the friction. Thus, according to Ley, the angle between the direction of the wind and the isobars is 29° for coast stations, and 13° for inland stations, thus showing distinctly the increased effects of friction on land. It has already been stated that cyclones in these latitudes for the most part move in an easterly direction; when a westward motion occurs, it is usually slow and seldom long-continued. The advance of a depression is commonly in a direction perpendicular to the line of steepest gradient, so that the highest pressure lies to the right; while also the temperature is highest to the right of its track. The rate of advance of a cyclone varies within very wide limits; on the whole, deep depressions move faster than shallow. The average rate of motion of translation of cyclones over Europe is from twenty to thirty miles an hour, while in America they travel commonly as rapidly as fifty miles an hour. So far as is known, cyclonic storms and weather seldom or never originate within five degrees of the equator, but this intermediate tropical belt is the scene of extremely violent hurricanes, which have a tendency to move in a westerly or north-westerly direction, and, moreover, appear to behave according to laws too complex to be given in detail here.

Secondary Cyclones are areas of low pressure formed by looped or incomplete circular concentric isobars with the lowest pressure in the centre. They have many weather features in common with primary cyclones, moving like them mostly from west to east. They frequently follow primary cyclones, and their bad weather is usually associated with calm, and stationary barometers.

V-shaped Depressions are angular intervals or areas with the lowest pressure in the interior, and frequently form between adjoining anticyclones, and are, as it were, a specialised form of cyclone, or even may form part of a cyclone. They have been aptly described as tongues of depression projecting from a cyclone situated to one side; in the northern hemisphere the point or tip is usually towards the south. The wind follows the universal law of gradients, being from south to south-west in front, and from west to north-west in rear of the trough. This latter line is given at once by joining the southern points of each successive isobar, and in practice is nearly always curved, the convexity being turned towards the east. As the V is usually moving towards the east, this trough line marks out the position of all the places at which the barometer, having fallen more or less, has just turned to rise. The weather experienced by an observer over whom one of these areas of depression drifts is from blue sky to cloud, later on rain with a falling barometer and south-west wind, then a squall, during which the wind jumps round to north-west, followed by a rapidly clearing sky and a rising barometer. Not only secondary cyclones but V-shaped depressions are in general most uncertain in their movements, and their occurrence is consequently very difficult to foretell. The extreme rapidity with which they travel at times, and the violence of the wind and rain developed within them, render them a source of great danger to both life and property. The peculiar thunderstorms of Central Europe and America are nearly always associated with V-shaped depressions.

Anticyclones.—These are areas of high pressure formed by more or less circular isobars, with the highest pressure in the centre. They differ from all other arrangements of isobars in tending to remain stationary and, also, to extend over large areas. The air is calm and cold in the centre, while on the borders the wind blows round the centre spirally outwards in the direction of the hands of the clock; thus on the east side the wind comes from the north, on the south from the north-east, on the west from the south-east, and on the north from the west. In describing the cyclonic system it was explained how the wind in the centre of that system was an ascending current; that wind circulation is compensated by an equivalent descending current in what is in all respects the opposite of a cyclone, namely, the anticyclone. The characteristic circulation of the air in this is, therefore, exactly the reverse of that in a cyclone: it blows in the same direction as the hands of the clock move, spirally outwards from the centre at or near the surface of the earth, and inwards towards the centre at the level of the highest clouds. In fig. 124 we give a diagram of the highest and surface currents in both a cyclone and an anticyclone; the solid arrows denote the surface winds, while the highest currents are given by the dotted arrows. In anticyclonic systems the barometric gradients are slight, and the normal wind circulation usually disturbed or disguised by accidental or local causes. The general weather features of an anticyclone are the exact opposite of cyclonic conditions, being in summer characterised by dry,


Cyclone

Anticyclone

Fig. 124.

quiet, bright weather, hot suns by day being followed by cool nights, except in the north-west quadrant of the system, where the nights are warm and often cloudy. Sea fogs are prevalent when the calm-centre overlies the sea; and in most cases much haze obscures the horizon. In winter, however, dense fogs sometimes accompany the calms of an anticyclone, and in parts of its periphery the sky may be densely clouded. If rain should fall, it is usually drizzling, not heavy. During winter, intense cold prevails in the centre and in the south-east and south-west quadrants of the area; in the north-east and north-west quadrants, at least in Western Europe, conditions are milder. Certain regions of the globe are remarkable for the existence of permanent and recurrent anticyclone systems. There is a permanent area of high pressure near latitude 30° north, called the Atlantic anticyclone, which varies in extent from month to month, attaining its greatest intensity in summer and least in winter. Another permanent area is that over the large land surface of Asia and Eastern Europe, in which the pressure is usually excessive during winter. It is the existence and more or less permanency of these two large areas of high pressure which combine to give a north-westerly gradient towards a stationary low pressure centre near Iceland, and to govern the motions of cyclones, which tend to skirt round their borders in an easterly direction. It is important to remember that, while an anticyclone system compensates a cyclone in the matter of transferring air from one level to another, there is no mutual relation between them in the sense of cause and effect.

Wedge-shaped Isobars usually point to the north and indicate areas of high pressure moving along between two adjacent cyclones. Though very usually associated with fine weather, it is only temporary because wedges of high pressure are never stationary, and are commonly followed by well-defined cyclonic areas. So far as weather is concerned, we may regard the two sides of the wedge as the rear and front of cyclones, and the wedge itself as a mere projecting tongue of an anticyclone. The wide end of the wedge is often associated with fog, and the narrow end with thunderstorms or showers.

Cols, or necks of comparatively low pressure, generally lie between two anticyclonic areas. Over them the weather is dull, gloomy, and stagnant, while in summer violent thunderstorms are frequently associated with them. Like the following, cols are essentially intermediate systems.

Straight Isobars are those without any curve, and may trend in any direction. This arrangement of isobars only marks the position of a barometric slope, and does not enclose any area of either high or low pressure. This form is essentially temporary and an intermediate arrangement of the atmospheric circulation or pressure which precedes the formation of a cyclone. The weather associated with straight isobars is too transitional to be characteristic, but very frequently is that of a hard sky, with a blustering wind and an inclination to rain, such as one experiences as to remark that "when the wind falls it will rain."

What are known as squalls, or puffs of wind of varying intensity, appear to be caused by the sudden breaking of the cold dense upper layers of air through lower and warmer layers lying underneath, condensing the vapour in the latter and causing them to ascend. In contrast to them are the various kinds of squall attributable to the sudden ascent of masses of warm air; examples of this phenomenon we know, as the familiar dust whirls on a dry road, or the dust storms, waterspouts, and tornadoes of the tropics. As in the case of cyclones and anticyclones, the question, What is the cause of these descending and ascending air currents? is one of some complexity, and has not yet received an adequate explanation.

It must not be forgotten that all the foregoing forms of isobars are at any time liable to break up, or at least pass into new forms, so that, although every part of every shape of isobars has a characteristic weather and sky appearance, still, owing to their often rapid breaking up, forecasting of weather is not always certain to come true. Cyclonic disturbances, for instance, are frequently diverted from their course by meeting a coast line or range of mountains, or even by the formation of areas of high pressure; so that their velocity is neither regular nor their direction of movement necessarily straight. On the other hand, experience shows that when advantage is taken of transatlantic and other meteorological observations telegraphed to a central meteorological office, synoptic charts can be prepared of such magnitude and detail as to render weather forecasting comparatively successful in a great percentage of cases. All meteorological phenomena are practically the products or results of the circulation or motion of a moist atmosphere, and consequently forecasting weather is nothing more than saying how and where certain air currents or eddies will move, or when new ones will form, and whether they will be gentle or violent. From the rapidity with which meteorological changes take place, the use of telegraphy is absolutely necessary if any success is to be attained in forecasting, and even this information can be only of use in some central office presided over by an experienced forecaster thoroughly conversant with the motions of low-pressure areas in his own country. It will be readily understood that in some countries forecasting is easier than in others. Thus, in the temperate zone, where most disturbances move from the west, those countries will be best suited for weather forecasting which lie to the east of a well-observed land area. For this reason Norway and Germany are better placed for weather forecasting than either France or England. Large areas of land and water mainly determine the great areas of high and low pressure, hence Great Britain being placed where it is, on the boundary, so to speak, between anticyclonic and cyclonic systems, renders the prognostication of weather peculiarly difficult in these islands, more particularly as their geographical position precludes an early knowledge of cyclones forming over the Atlantic. Moreover, just as an outlying rock is exposed to the wash of every sea, so is England exposed to the disturbing influences of every type of European or Atlantic weather, and has, in consequence, more unsettled weather than any other part of Europe.

Notation of Charts.—In order to simplify and condense as far as possible the notes placed on synoptic charts and meteorological returns, it is convenient to have a notation or uniform system of abbreviations. The one usually adopted is that given below.

Wind is represented by an arrow flying with it, thus: ↑ means S., → means W., ↓ means N., ← means E., and so on. The force of the wind is indicated by the number of barbs or feathers on the arrow, thus:— ∧ light breeze; ↑ fresh breeze; ↟ strong wind; ⇞ a gale; and ⊙ signifies calm.

Temperature and *Moisture*, being usually given as numerical results of instrumental observations, are omitted for the present. The remaining elements which go to make weather are described by letters and symbols as follows, a bar or dot under a letter denoting intensity.

b = blue sky: whether with clear or hazy atmosphere.
c = cloudy, but detached opening clouds.
d = drizzling rain.

f = foggy, ≡.
g = dark gloomy weather.
h = hail, ▲.
l = lightning, ⚡.
m = misty hazy atmosphere, ≡ or ∞.
o = overcast, the whole sky being covered with an impervious cloud.
p = passing temporary showers.
q = squally.
r = rain, continued rain, ●.
s = snow, ✳.
t = thunder, T
u = "ugly," threatening appearance of the weather.
v = "visibility" of distant objects, whether the sky be cloudy or not.
w = dew, ⌓.

The above notation, devised by Admiral Beaufort, has long been in universal use in this country. The following symbols have been added more recently, and are officially recognised by the various European meteorological institutions.

Thunderstorm,	Ꝁ	Strong Wind,	↗
Soft Hail ("Graupel"), .	△	Solar Corona,	○
Hoar Frost, . . .	⊔	,, Halo,	⊕
Silver-thaw ("Rauh-frost," "Duft"), . . .	V	Lunar Corona,	⦶
		,, Halo,	⊍
Glazed Frost ("Glatteis"),	∽	Rainbow,	⌒
Snow Drift,	⇸	Aurora,	♕
Ice Crystals,	←	Dust-haze ("Höhen-rauch"),	∞

In these symbols intensity is to be indicated by the exponents 0 and 2 attached to the symbols, thus,

✳^{0} means slight snow, ✳^{2} heavy snow.

BIBLIOGRAPHY AND REFERENCES.

ABERCROMBY, *Principles of Forecasting by means of Weather Charts*, Lond., 1885; also *Weather*, Lond., 1887; also *Instructions for observing Clouds* (with photographs), Lond., 1888. AITKEN, "On Dust, Fogs, and Clouds," *Trans. Roy. Soc. Edin.*, vol. xxx. i., 1883, p. 337.

BABBER, VON, *Hygienische Meteorologie*, Stuttgart, 1895. BLANFORD, *Instructions to Meteorological Observers in India*, Calcutta, 1876; also *The Climate of India*, Calc., 1889; also "On the Rainfall of Cherrapunji," *Quart. Journ. Roy. Meteor. Soc.*, July 1891, p. 146. BUCHAN, *Introductory Text-Book of Meteorology*, Lond., 1871; also "The Mean Temperature of the British Islands," *Journ. Scottish Meteor. Soc.*, vol. vi. N.S., 1882, p. 22.

DANIELL, *Meteorological Essays and Observations*, Lond., 1823. DICKSON, *Meteorology*, Lond., 1893. DINES, "On Wind-Pressure on an Inclined Surface," *Proc. Roy. Soc. Lond.*, vol. xlviii. pp. 233 and 257. DOVE, *The Law of Storms*, translated by Scott, Lond., 1862.

FITZROY, *The Weather Book*, Lond., 1863. FOX, *Ozone and Antozone*, Lond., 1873. FRANKLAND, E., "On Dry Fogs," *Proc. Roy. Soc. Lond.*, 1878.

GASTER, "On Fog, Cloud, and Sunshine," *Journ. Sanit. Institute*, vol. xv., July 1894. GLAISHER, *Hygrometrical Tables*, Lond., 1877. GUILLEMIN, *La Météorologie*, Paris, 1885.

Hann, *Allgemeine Erdkunde*, Tempsky, Prague, 1881; also *Handbuch der Klimatologie*, Stuttgart, 1883. Haughton, *Six Lectures on Physical Geography*, Lond., 1880. Hellmann, *Die Anfänge der meteorologischen Beobachtungen und Instrumente*, Berlin, 1889. Herschel, *Meteorology*, London, 1862.

Laughton, *Air Temperature, its Distribution and Range in Modern Meteorology*, Lond., 1879. Lemström, *L'Aurore Boreale*, Paris, 1886. Ley, *Aids to the Study and Forecast of Weather*, Lond., 1880. Lloyd, "Notes on the Meteorology of Ireland," *Trans. Roy. Irish Academy*, xxii., Science, 1854.

Mann, *Modern Meteorology*, Lond., 1879. Marcet, "Atmospheric Electricity," *Quart. Journ. Roy. Meteor. Soc.*, vol. xiv. p. 197, 1888. Marriott, "Moisture, its Determination and Measurement," *Journ. San. Institute*, vol. xv., July 1894. Mascart, *La Météorologie appliquée à la Prévision du Temps*, Paris, 1881. Mohn, *Grundzüge der Meteorologie*, Berlin, 1879. Moore, *Meteorology, Practical and Applied*, Lond., 1894.

Scott, *Principles of Forecasting by means of Weather Charts*, Lond., 1885; also *Elementary Meteorology*, Lond., 1887; also *Instructions in the Use of Meteorological Instruments*, Lond., 1892; also *Weather Charts and Storm Warnings*, Lond., 1887; also "Barometrical Conditions and Air Movements," *Journ. Sanit. Institute*, xv., July 1894. Sprung, *Lehrbuch der Meteorologie*, Hamburg, 1885. Symons, *British Rainfall*, published annually; also *Monthly Meteorological Magazine*; also *Pocket Altitude Tables*, Lond., 1880; also "Meteorological Instruments and Sanitary Work," *Journ. Sanit. Institute*, xv., July 1894.

Toynbee, *The Meteorology of the North Atlantic during August* 1873, Lond., 1878. Tyndall, *Heat, a Mode of Motion*, Lond., 1880.

Umlauft, *Das Luftmeer*, Wien, 1891.

Wild, *Uber Föhn und Eiszeit*, Bern, 1868. Williams, "Climate in Relation to Health and Geographical Distribution of Disease," *Journ. Sanit. Institute*, xv., July 1894.

CHAPTER XVI.

VITAL STATISTICS.

An accurate basis of facts, derived from a sufficient amount of experience and tabulated with the proper precision, lies at the very foundation of hygiene, as of all exact sciences. It is desirable, therefore, that all persons interested in sanitary science should know what data are at their disposal, how to collect them, and how to use safely the various facts placed before them. Probably no single cause has contributed more to the attention now paid to questions of Public Health than the careful collection of the statistics of births and deaths, and of the causes of death, which have been collected and published by the Registrar-General's Office during the past fifty years. These collections of figures and facts are usually spoken of as vital or health statistics, because they are so intimately associated with the various problems relating to the health and chances of life which the community enjoys. So valuable has been the work done, that we are now able to determine with some precision the causes and limits of mortality, and, by the study and analysis of the collection of facts known as vital statistics, to apply them as tests of the health of the communities to which they refer.

The chief vital statistics, bearing upon public health, relate in detail to past and present facts concerning populations, age and sex distribution, births, marriages, deaths, diseases, duration of the hours of occupation and general social conditions, such as the health of each class of the community as judged of by the expectation of life at given ages. Statistics of sickness, apart from mortality, have as yet not been attempted, chiefly on account of the difficulty in collecting the data with accuracy.

Population, as the natural basis of all vital statistics, necessarily demands preliminary consideration. Our knowledge upon this point in each place in Great Britain depends primarily upon the census returns which have been made regularly and with increasing care every ten years since 1801. The following table gives the results of each successive census, and shows the enormous increase in the population of England and Wales, and of London, in the present century :—

Year of Enumeration.	Population of England and Wales and in London in each Census.		
	England and Wales.	London.	Persons in London to 100 in England and Wales.
1801	8,892,536	958,788	10·78
1811	10,164,256	1,138,746	11·20
1821	12,000,236	1,378,853	11·49
1831	13,896,797	1,654,870	11·91
1841	15,914,148	1,948,293	12·24
1851	17,927,609	2,362,105	13·18
1861	20,066,224	2,803,847	13·97
1871	22,712,266	3,253,785	14·33
1881	25,974,439	3,815,544	14·69
1891	29,002,525	4,211,452	14·52

The chief data collected at each census are the total number of inhabitants in each area, the numbers living of each sex and at certain age-periods, and the numbers employed in certain callings. It will be at once obvious that the facts relating to the numbers living of each sex and age-periods and the numbers employed in certain callings can only be accurately known in actual census years, and making from them estimates for intermediate years. An interval of ten years between the takings of the census is now acknowledged to be too long, and it is probable that, if our population statistics are to remain in any way accurate, more frequent enumerations of the people will need to be taken, and even then certain inaccuracies are sure to exist, due chiefly to the still imperfect education of large numbers of householders and heads of families; these defects of information collected relate especially to occupations and ages. It is remarkable what a large number of people do not know their precise age; these persons generally giving their age in census returns in some multiple of ten. Another source of error and perplexity in all census returns is the too frequent wilful misstatements made by women, owing to their desire, for various reasons, to be thought between 20 and 25 years of age. This is shown by the fact that, in each successive census, the number of women returning themselves as between 20 and 25 is larger than the number of girls returned in the census of ten years before as between 10 and 15 years of age. The former being only the survivors, after the lapse of ten years of these latter, they should of necessity be fewer in number. The male sex is not altogether free from blame in the same matter, though the bias goes in the opposite direction. Thus, men of the poorer classes, who have passed the age of 60, constantly overstate their age for the sake of certain definite advantages, such as getting outdoor relief, or, if entering the poorhouse, gaining some special privileges not granted to their juniors. Some really old people often exaggerate their age in order to appear as centenarians.

In attempting to estimate the population of any given locality for any year intermediate between the collection of census returns, it is necessary to calculate the probable decrease or increase of the particular population by comparing the numbers of the latest enumerations. Thus, say a town had in 1881 a population of 35,626, and in 1891 one of 38,754, and it was required to know its estimated population in June 1896: it is only fair in such a case to assume that the 1896 population will be greater than the 1891, and, if we further assume that the increase will be at the same rate as between 1881 and 1891, by taking the difference between the 1881 and the 1891 populations and dividing by 10 we get the annual increase of population for that town. Inasmuch as the census is always taken in the first quarter of the year, and we require the population at the end of June 1896, an interval of $5\frac{1}{4}$ years will have elapsed since the last census; if, therefore, we multiply the annual increase of population, which in this example is $\frac{38{,}754 - 35{,}626}{10} = 312{\cdot}8$, by $5{\cdot}25$, we get an increase of 1642 to be added to the 1891 population, giving an estimated population of $38{,}754 + 1642$, or 40,396 for the middle of 1896.

The foregoing method of calculating an estimated population is fallacious, as it presumes the increase or decrease will be as in an arithmetical progression. The true law of population increase or its decrease is that of a geometrical progression, and is very suitably compared to the increase of a sum of money at compound interest. The increase in x years is derived from the increase in one year by multiplying 1 *plus* the annual rate of increase x times into itself If the increase in one year be 1·5 per cent., 1 becomes 1·015 in one year, and 1·015 multiplied x times into itself will give the increase in x years. To obtain, therefore, the annual rate of increase in x years, the *xth root*, and not the *xth part* of the x rate of increase, must be taken. If a population of 100,000 in 1891 becomes 101,000 in 1892, it is evident that the 1893 population will be greater than 102,000, for the yearly increase has now to be reckoned upon 101,000, not upon 100,000. If p be the population in any given year, say 1891, and r be the factor of annual increase (in this case $r = 1·01$), then in 1892 or in one year the population will become $p \times r$, in 1893 or in two years $p \times r^2$, and in n years $p \times r^n$. In the above instance the correct estimate for 1893 would be 102,010, for 1894 it would be 103,030, and so on. In mathematical language the increase is geometrical, not simply arithmetical, and on this assumption the Registrar-General calculates the estimated populations for London and other large towns, as well as for the whole country, for intercensal years. On this basis the calculations are more conveniently performed by logarithms in the following manner.

Taking the same example as above, in which a town had in 1881 a population of 35,626 and in 1891 one of 38,754, we find the logarithm for the 1891 population, or log 38,754 = 4·5883165, and deduct from it the logarithm for the 1881 population, or log 35,626 = 4·5517671; this gives 0·0365494, which is the logarithm of the decennial increase. Dividing this by 10 gives us 0·00365494, or the logarithm of the annual increase, and a quarter of this is 0·0009137, or the logarithm of the quarterly increase. By adding together the logarithm of the 1891 population and five times the logarithm of the annual increase and the logarithm of the quarterly increase we get the logarithm of the mid-year 1896 population, or 4·6075049, which by reference to a set of tables = a population of 40,504, or somewhat higher than the estimation made by that of a simple arithmetical progression.

On the other hand, supposing the census of 1891 to have given a lower figure than that of 1881, the population for any year subsequent to 1891 might be similarly calculated upon an assumption of a uniform decrease. Unfortunately, these assumptions as to a uniform increase or decrease of numbers are largely arbitrary or conjectural, and but rarely agree with the actual facts as found by the next census. Thus the population of London as estimated in 1891 by the Registrar-General was 4,441,993, but when actually enumerated by that year's census was found to be nearly a quarter of a million less, or only 4,211,452; that is, the rate of increase of population during the ten years 1882–91 had been much less than in the preceding decennial period. In a similar way the total population of England and Wales at the census of 1891 was found to show a rate of increase during the ten years 1882–91 of 11·65 per cent. as against 14·36 between 1872–81, giving in fact the lowest rate of increase recorded since the systematic taking of a census was begun in 1801. Had the 1882–91 rate of increase been the same as in 1872–81, the population at the last census would have been greater than it proved to be by more than 701,000.

The same thing was found to have occurred in regard to the populations of most of the large towns, with the result that their calculated death-rates had been returned too low. It is chiefly owing to errors in either under or over estimating the population that faulty estimates of the birth and death rates have occurred; so true is this, that any very excessively high or low birth or death rate is to many persons highly suggestive of the estimated population figure being wrong. The case of Liverpool in 1890–1 is interesting as illustrating this point. The death-rates were supposed, on the assumption that the population was increasing at the same rate as in the previous decade, to have fallen from 26·7 in 1881 to 23·6 in 1890; the truth, as discovered by the actual enumeration in 1891, being, that instead of increasing, the population had decreased, and that the death-rate, instead of falling to 23·6, had risen to 27·8. The only true remedy for these possible errors is a more frequent census.

The following table shows the difference between the estimated and enumerated populations of some large towns in 1891, as taken from the Registrar-General's returns, as well as the actual increase or decrease in their populations which had taken place in the period 1882–91.

Town.	Enumerated population at census of 1881.	Enumerated population at census of 1891.	Estimated population in middle of 1891.	Excess or defect of column 2 over column 3.	Actual increase or decrease of population.
Birmingham,	436,971	478,113	469,003	+9,110	+41,142
Blackburn,	104,014	120,064	125,874	−5,810	+16,050
Bolton,	105,414	115,002	117,034	−2,032	+9,588
Bradford,	194,495	216,361	246,101	−29,740	+21,866
Brighton,	107,546	115,873	125,539	−9,666	+8,327
Bristol,	206,874	221,578	235,171	−13,593	+14,704
Cardiff,	82,761	128,915	121,477	+7,438	+46,154
Derby,	81,165	94,146	103,269	−9,123	+12,981
Halifax,	81,117	89,832	82,998	+6,834	+8,715
Huddersfield,	86,502	95,420	101,080	−5,660	+8,918
Hull,	165,690	200,044	219,812	−19,768	+34,354
Leeds,	309,119	367,505	370,261	−2,756	+58,386
Leicester,	136,593	174,624	158,266	+16,358	+38,031
Liverpool,	552,508	517,980	620,443	−102,463	−34,522
Manchester,	462,303	505,368	506,325	−957	+43,065
Newcastle,	145,359	186,300	165,016	+21,284	+40,941
Norwich,	87,842	100,970	96,202	+4,768	+13,128
Nottingham,	186,575	213,877	252,217	−38,340	+27,302
Oldham,	111,343	131,463	151,158	−19,695	+20,120
Plymouth,	73,858	84,248	79,339	+4,909	+10,390
Portsmouth,	127,989	159,251	144,671	+14,580	+31,262
Preston,	96,537	107,573	106,141	+1,432	+11,036
Salford,	176,235	198,139	251,024	−52,885	+21,904
Sheffield,	284,508	324,243	338,543	−14,300	+39,735
Sunderland,	116,526	131,015	138,859	−7,844	+14,489
Wolverhampton,	75,766	82,662	84,277	−1,615	+6,896

As the Registrar-General has pointed out, the official method of calculating populations by the assumption of an equable rate of growth is only trustworthy in the case of very large communities, where any abnormal increase in one direction is sure to be counterbalanced by an abnormal decrease in another. It is hardly reliable for very small communities, where growth is very often most irregular and spasmodic.

A moment's reflection will show that many circumstances may help to quicken or slow the increase of a population. The increase in any given population may be either *natural* or *actual*. The former is merely the excess of births over deaths, while the latter is dependent upon the balance between births and immigration on the one hand, and deaths and emigration on the other. The facts revealed by the last census, in 1891, showed a decline in the natural increase of population for England and Wales; this was not due to any increased mortality, but rather to a decline in the birth-rate, which was low beyond precedent. For the whole country the actual increase, as shown by the last census, also showed a decline, due mainly to an excess of emigration over immigration during the last decennium. As a general rule, in towns the *actual* increase is greater than the *natural*, simply because there is a natural tendency for people to migrate from rural to urban districts; and with regard to such local migrations, at present we have no available or systematic record. It is well known that in times when trade is bad in certain localities, a considerable movement of the population occurs to other parts, and *vice versâ*.

Although not officially recognised by the Registrar-General, there are several methods of checking estimated populations, which, if used judiciously, are of great value. Amongst such are examinations of inhabited houses as ascertained from the rate-books, and then, assuming the density to remain the same, to multiply the number of inhabited houses by the average number of persons per house. Care, however, must be taken to allow for any marked change in the class of new houses built, whether containing fewer or more occupants than others, and, too, to allow for block buildings, flats and large hotels, all of which are liable to seriously affect statistical results. Another useful method for checking the calculation of a present population, suggested by Newsholme, may be derived from the birth-rate of a place. It is based on the assumption that the birth-rate remains the same for a series of years as it was found to be at the time of the last census. Thus, in Wandsworth, the average birth-rate for the decennium 1872–81 was 35·68 per 1000, and the number of births in 1881 was 7582, therefore, assuming that 35·68 was the number of births from one thousand of population, 7582 was the birth-rate of 212,500 people; or, $\frac{7582 \times 1000}{35\cdot 68} =$ 212,500. As a matter of fact, the actual census return for Wandsworth, in April 1881, was 210,434, an astonishingly close approximation of results.

Age and Sex Distribution.—This is sometimes spoken of as the constitution of a population, inasmuch as it shows the proportion in which males and females, and persons of different ages or of different callings enter into the composition of the community. These figures and facts are of course only obtained at each census, and generally may be taken to remain constant till the next census. The effect which these facts have upon mortality statistics will be explained later on; at present, allusion need only be made to the very marked difference which exists in the age distribution between the populations of town or urban and those of rural districts. The 1891 census gives for England and Wales the following age and sex distribution of the population per million persons of all ages :—

	English Urban Districts.			English Rural Districts.			Females to 100 Males.	
	Persons.	Males.	Females.	Persons.	Males.	Females.	Urban Districts.	Rural Districts.
All ages	1,000,000	479,268	520,732	1,000,000	498,131	501,869	109	101
0 to 5	122,524	60,906	61,618	122,521	61,045	61,476	101	101
5 ,, 10	115,343	57,428	57,915	121,504	60,859	60,645	101	100
10 ,, 15	109,405	54,149	55,256	115,639	59,133	56,506	102	96
15 ,, 20	103,429	49,865	53,564	97,405	52,204	45,201	107	87
20 ,, 25	95,551	44,260	51,291	80,155	39,782	40,373	116	101
25 ,, 35	157,413	74,520	82,893	134,266	65,608	68,658	111	105
35 ,, 45	117,719	56,781	60,938	107,193	52,375	54,818	107	105
45 ,, 55	85,188	40,353	44,835	88,420	42,999	45,421	111	106
55 ,, 65	53,264	24,175	29,089	67,106	32,685	34,421	120	105
65 ,, 75	29,658	12,721	16,937	45,658	22,090	23,568	133	107
Over 75	10,506	4,110	6,396	20,133	9,351	10,782	155	115

This table shows that, as compared with the country districts, in the towns of England and Wales there is a great excess of persons from 15 to 45 years of age, and a small proportion of children between 5 and 10 years of age. The probable explanation of these figures is the persistent immigration of young adults from the country to the urban areas in the one case, and the higher infantile mortality of the towns than of rural districts in the other. The proportion of females to males, of all ages, is much higher in towns than in the country, being 109 to 100 in the former, but only as 101 to 100 in the latter. These proportions are only manifest after the 10 to 15 age-period, when the girls begin to migrate into the towns as domestic servants. The migration of girls into towns is soon followed by that of boys, with the result that the unequal proportion of the two sexes in towns in the 15 to 20 age-period is considerably reduced, and continues to be so during all the more active working ages, or the period from the end of the 25th to the end of the 45th year of life. In the later years of life the disproportion between the sexes in the towns again increases, so much so that in the 55 to 65 years period the women are 20 per cent. more numerous in towns than the men, but only about 5 per cent. more numerous in the country. In the 65 to 75 period the excess is 33 per cent. in the towns and only 7 per cent. in the country; while in the over 75 years period the excess of women becomes 55 per cent. in the towns and only 15 per cent. in the rural districts.

The normal constitution of the population of England and Wales in 1891 was as follows :—

	All Ages.	0–5.	5–10.	10–15.	15–20.	20–25.	25–35.	35–45.	45–55.	55–65.	65–75.	Over 75.
Both Sexes,	1000	122	118	113	101	88	146	112	86	61	38	15
Males, .	489	61	59	57	51	42	70	54	42	29	18	6
Females, .	511	61	59	56	50	46	76	58	44	32	20	9

This increasing excess of females in the late-age periods, so far as it is common to both towns and country, is, of course, due to the fact that women are longer lived than men, that is, they survive when the men die off. The greater excess of women over men in towns than in the country is less easy of explanation. It may be due to the fact that men, as they get old, leave the towns, where the struggle for existence is so much the more keen, and retire into the country more rapidly than do the women; or it may be due to differences between the conditions of town and country life being more hostile to old men than to old women. Possibly both causes are at work. We know that for some reason or other urban life is exceptionally fatal to elderly men, and that towns offer, even to those in advanced age, more chances of comparatively easy work to women than to men; hence there is more inducement for women than for men to remain in the towns when they have grown old, especially as town life is much less healthy for men than for women. The practical importance of this question of age and sex distribution in vital statistics will be more apparent when we come to consider the value of death-rates.

Marriage-Rates.—These afford a valuable index of national prosperity, and incidentally throw an interesting light on the progress of elementary education. Marriages are usually stated in proportion to the actual population, or the number per 1000 living. This method is fairly reliable in the case of the same community in successive years, but not so for comparing different communities in the same year, because, owing to varying age and sex distribution, the number of marriageable persons must vary considerably in different communities. A more accurate method of estimating the marriage-rate for comparative purposes is to base it on the enumerated or estimated number of bachelors, spinsters, widowers, and widows living at marriageable ages.

The number of marriages registered in 1893 in England and Wales corresponded to a rate of 14·7 persons married per 1000 living. After 1886, when the marriage-rate was 14·2, which is the lowest on record, there was a gradual recovery for five years, the rate in 1891 reaching 15·6; in 1892, however, the rate declined to 15·4, and it further fell to 14·7 in 1893. The decline in the marriage-rate corresponds usually with a fall in the value of British exports, and with the amount per head of population cleared at the Bankers' Clearing House, and also with a fall in the price of wheat; this latter was reduced in 1893 to 11·5 per cent. below the previously lowest on record, or that of 1889. These coincidences are in direction, but not in degree. This decline in the marriage-rate is not confined to England, as a similar decline is shown in other European states; this fact is suggestive of other causes being at work than mere commercial prosperity.

The marriage-rate is always higher in large towns than in rural districts, probably because a large number of young people resort to populous districts, where, owing to the presence of large trades and manufactures, higher wages can be secured, and there they marry. The statistics as to ages at marriage are not perfect, but there is evidence that the mean age at marriage has been gradually rising since 1873. The mean ages of those married in 1893 were 28·51 years for men and 26·23 years for women. The mean age of bachelors who married was 26·55, of widowers 44·61, of spinsters 25·04, and of widows 40·64 years. Further evidence that marriage is now deferred to a somewhat later period of life than formerly is afforded by the decline in the proportion of under-age marriages. In the earlier years of civil registration the proportions of those who married before 21 years of age were less than 50 in 1000 for men, and less than 150 in 1000 for women. These proportions increased steadily until in 1874 they reached their maximum, namely, 84 per mille for men and 227 for women; since then they have gradually diminished, the figures for 1893 standing at 56 for men, and 181 for women.

The age at marriage, especially the age of the women, is an important factor in controlling the fecundity of marriages, because childbearing is limited practically to between the 16th and 45th years of life. The parents of nearly half the children born are under 30 years of age; if no women married before 30, the births would be reduced to about two-thirds of their present number, and if the marriage age were postponed to 35, the births would fall to one-third of their present number, and the population would rapidly decline. For not only would the number of births in each generation diminish, but also the interval between the births of successive generations would lengthen, the length of life remaining the same (Farr). It is questionable whether early marriages are really any more fruitful than later ones, but, even supposing their fertility be identical, the number of children in the late marriages is less, because the generation is longer, and from the fact that many who would have been parents have died before reaching the later age of marriage. In this country the average number of births to a marriage is about 4·5. The census report of 1891 shows that the condition as regards marriage of the population of the United Kingdom was as follows :—

Civil Condition.	United Kingdom.		Proportions per 1000 Living.					
	Males.	Females.	England and Wales.		Scotland.		Ireland.	
			Males.	Females.	Males.	Females.	Males.	Females.
Single,	11,619,047	11,751,611	620	596	663	631	696	641
Married,	6,055,017	6,146,253	345	329	304	290	265	262
Widowed, .	640,507	1,520,487	35	75	33	79	39	97

The latest returns available, or those of 1893, indicate that the men who signed the marriage register with marks instead of writing their names were in the proportion of 50 in 1000, while the similarly illiterate women were 57 in 1000. With the progress of elementary education there has been a continuous diminution in the proportions of both men and women unable to write their names; the proportions in 1893, as compared with those in 1892, showing a reduction of 10·7 per cent. for men, and of 13·6 per cent. for women.

Birth-Rates.—The Births and Deaths Registration Act of 1874 compels every birth to be registered within forty-two days of its occurrence. The number of births per 1000 persons living, or birth-rate as it is called, averaged 31·9 in the ten years 1883–92, in England and Wales, the highest rate of 36·3 ever recorded in this country having been reached in 1876, and the lowest 30·2, in the year 1890. For the year 1894 it was 29·6. The birth-rate naturally varies greatly in different towns or localities, being higher in towns and during times of commercial prosperity, and of course lower in rural districts and during periods of trade depression. Bad trade and bad harvests also diminish the number of marriages, and consequently lower the number of children born.

The birth and marriage rates are readily found by a simple proportion sum; thus, if the population of a town be 13,621, and the number of births and marriages during the year are respectively 441 and 215, then $\frac{441}{13,621} \times 1000 = 32{\cdot}3$ birth-rate per 1000, and $\frac{215}{13,621} \times 1000 = 15{\cdot}7$ marriage-rate per 1000. This method of stating the ratio of births, marriages, or deaths in one year, as per thousand persons living in a place, is the most usual and convenient, but occasionally it may be necessary to compare these rates for shorter periods, say weeks, months, or quarters; in which case it is done in the following way. Suppose it is required to know the birth-rate during $\frac{1}{n}$ part of a year, then—

$$\frac{\text{Number of births during the period in question}}{\text{Population in the middle of the year}} \times n \times 1000 = \text{birth-rate of}$$

period in question. Taking the preceding example, and required the birth-rate during one week or $\frac{1}{52{\cdot}17747}$ part of a year, during which period ten births have taken place; we get $\frac{10}{13,621} \times 52{\cdot}17747 \times 1000 = 38{\cdot}3$, or birth-rate.

When comparing one community with another, to be strictly fair the birth-rate should be calculated on the total population only after it has been reduced to a common or normal constitution as regards sex, age, and marriage. This is best secured by calculating the birth-rate on the number of women between twenty and forty years of age who constitute the great majority of childbearing mothers. More males appear to be born than females, in the proportion of 104 to 100. The number of illegitimate children born is diminishing; formerly it was as much as 5 per 1000; in 1893 the proportion was as low as 1·3 per 1000 persons living, or 42 per 1000 births. This illegitimate birth-rate varies much in different districts; thus, the registration counties in which the proportion of illegitimate to total births was highest, were, the North Riding of Yorkshire, Herefordshire, Shropshire, Cumberland, Westmoreland, and North Wales.

There is reason to believe that in France and some foreign countries the production of children is deliberately restricted in relation to the possible maintenance of them at home; with the result that the total populations are diminishing. In this country we have no need to discourage the expansion of the population, for our colonies are in need of more inhabitants, and our industries of more work-people. In fact it is the absence of such restrictions on population in Great Britain which has enabled us to establish our colonial empire and extend the British nation all over the world. It is as much a mistake to suppose that the inhabitants of a country are in proportion to their food as it is to think that the productions of a country are in proportion to the number of its inhabitants. The truth is, the population that a country sustains does not depend exclusively on the amount of subsistence existing in it at any one time, but rather that the produce of a country is limited chiefly by the number and character of its inhabitants, and the more numerous, cultured, and civilised they are, the greater will be the products of their industry. Unfortunately, population is often out of the place where it is wanted or could be most productive; but at no time can it be said that the population of any country is excessive or out of ratio with means of subsistence. In Great Britain the means of subsistence have increased faster than the numbers of the people; for, while the population has doubled, the value of capital has more than trebled itself. Thus, at 3 per cent. per annum, compound interest, capital doubles itself in twenty-four years. A birth-rate of 3 per cent., which is near the actual present rate in England and Wales, would imply, in the absence of deaths, that the population would be doubled in the same period. But as the death-rate is 1·9 per cent. of population, the real increase per 100 at the present birth-rate is 1·1, or 0·011 per unit. Now $p=\mathrm{PR}^n$, where, as in compound interest, p is the amount when increased, or principal + interest; P is the principal or original population; R is 1 + the rate of increase per unit or r, that is, $\mathrm{R}=1+r$; n is the number of years. It is required to know the time necessary to double the population. In this case, $p=2$, and $\mathrm{P}=1$. Then if $p=\mathrm{PR}^n$, $2=1\times\mathrm{R}^n=\mathrm{R}^n=(1+r)^n$, or $2=(1+0{\cdot}011)^n$, or $(1{\cdot}011)^n=2$. Therefore, $n \log 1{\cdot}011=\log 2$, and $n=\dfrac{\log 2}{\log 1{\cdot}011}=\dfrac{0{\cdot}3010300}{0{\cdot}0047512}=63{\cdot}4$ years.

The population, therefore, doubles itself in about sixty-four years, a much longer period than capital takes to double itself, and money capital may be taken as representative of subsistence or other working materials.

Each member of the population, when the balance between expense of subsistence and wages earned through life is worked out, represents enormous wealth. And as for any need to restrict the production of children, as advocated by Malthus, for fear of over-populating the world, it is as uncalled for as it is mischievous; and amounting as it does to a policy of depopulation, it means the gradual reduction of this country, in the presence of the great continental nations, to the level of a second-rate power.

Apart from this aspect of the question, to the sanitarian, the Malthusian doctrine, which assumes that the fewer the people the happier they will be, is of very serious and far-reaching import. If sanctioned or encouraged, it would involve practically the relaxation of all efforts to improve the public health, while all efforts to remove insanitary conditions and obviate unhealthy employments would necessarily be regarded as attempts to evade an inevitable and, from the Malthusian point of view, a beneficial law. Possibly few would carry the doctrine so far as to propose the actual destruction of life, but its advocates are logically bound to welcome a high death-rate as being *prima facie* favourable to a reduction of numbers. Even this idea is fallacious, for we shall see later on that the births almost invariably increase when the mortality increases, and where the mortality is greatest there the population is multiplying most rapidly (Newsholme).

Death-Rates.—By the Births and Deaths Registration Act of 1874 all deaths must be registered within five days of their occurrence. In 1893 the deaths registered in England and Wales were in a proportion of 19·2 to 1000 persons living. This rate was 0·2 per 1000 higher than the rate in the preceding year, but was identical with the mean annual rate in the ten years 1883–92. In 1894 the death-rate dropped to 16·6 per 1000 living, or the lowest on record. The death-rate is obtained in exactly the same way as that for births: by multiplying the actual number of deaths from all causes into 1000, and dividing the product by the population; this is known as the general or gross death-rate. In a similar way, as explained above for calculating the weekly or quarterly birth-rate, so is the annual death-rate for the week, month, or quarter obtained.

Thus, take a town with a population of 20,000 and the deaths in any week being 8, the annual death-rate for that week will be 21, or $\frac{8}{20{,}000} \times 52{\cdot}17747 \times 1000 = 20{\cdot}87$. These so-called weekly death-rates are convenient for reports, but are not reliable data on which to compare the relative conditions of places, as much of the mortality often depends upon epidemics, weather, and other causes of a temporary nature. These death-rates, as published for each week by the Registrar-General, must therefore not be regarded as actual rates, but rather as annual rates per 1000, representing the number who would die supposing the same proportion of deaths to population held good all through the year. Their chief value is for contrasting mortality rates of any given place at corresponding periods of some previous year. The Registrar-General makes his death-rates for each quarter refer to the thirteen weeks most nearly corresponding with the natural quarter; and the quarterly population is obtained by multiplying by thirteen the population of one week. The value of the general death-rate has been much criticised on the ground that it is much influenced by movements of the populations, by the presence of large institutions, such as hospitals, by the age and sex distribution of the population, and by the birth-rate. All this is quite true, but still, if due correction be made, it is probably in the case of large populations the most trustworthy test we have of relative vitality. The corrections most advantageously applied to general death-rates are : (1) for non-resident, or migratory people ; (2) for sex and age distribution.

The correction for a migratory population is most difficult to apply, as it is not easy to trace and control the facts relating to visitors and immigrants. In the case of watering-places and favourite residential towns, corrections in this direction are most important, and are largely made by the officials from materials obtainable from the sub-registrars ; but, even under the best supervision, considerable disturbance and fallacies to the statistics occur. Closely allied to the consideration of migration is the effect which public institutions, such as poorhouses or hospitals, exert on local death-rates, as the disturbance arising from them is due to migration into them from neighbouring districts. To meet this difficulty, the rule is to deduct the deaths of those inmates drawn from outside areas, at the same time adding the deaths of proper inhabitants of the place which may have occurred in other institutions outside the district. In this connection reference may be made to the statistical table A., given in Appendix XII. Each sanitary authority in London is supplied quarterly by the Registrar-General with particulars of death of their inhabitants in outlying districts, so that the deaths in all these cases may be apportioned to their proper districts. Unfortunately, such accuracy does not pertain to rural districts, but it is to be hoped, in course of time, even this will be done.

All general death-rates require to be corrected for sex and age distribution.

Sex.—The death-rate among males in England and Wales during 1893 was 20·3, and that among females 18·1, per 1000 living of the corresponding sex. Out of equal numbers living there were 1117 deaths of males to 1000 of females, as compared with an average proportion in the decennium 1883–92 of 1122 to 1000. As a class, females live longer than males, the death-rate among the males being uniformly higher than among females, except at the ages between ten and twenty years; both death-rates, however, are decreasing, owing to the great saving of life in the earlier years of age. Since females live longer than males, it follows that if two towns were in an equally healthy state, but that one of them contained a larger proportion of females than the other, the one with the lower proportion of females would have the higher death-rate.

Ages.—The following table shows the mean annual death-rates in England and Wales, during recent years, per thousand persons living, at each age-period :—

Age Groups.	All Persons.			Males.			Females.		
	1871–80	1881–90.	1891–93.	1871–80.	1881–90.	1891–93.	1871–80.	1881–90.	1891–93.
0– 5,	63·4	56·8	58·5	68·5	61·6	63·7	58·4	52·0	53·3
5–10,	6·5	5·4	4·7	6·7	5·4	4·7	6·3	5·3	4·7
10–15,	3·7	3·1	2·7	3·7	3·0	2·6	3·7	3·1	2·8
15–20,	5·4	4·4	4·1	5·3	4·3	4·1	5·5	4·4	4·1
20–25,	7·1	5·6	5·2	7·4	5·7	5·4	6·8	5·5	5·0
25–35,	9·0	7·6	7·2	9·4	7·8	7·4	8·6	7·4	7·0
35–45,	12·7	11·5	11·8	13·8	12·4	12·8	11·6	10·6	10·8
45–55,	17·8	17·3	18·4	20·1	19·4	20·8	15·6	15·1	16·0
55–65,	31·8	31·6	34·5	34·9	34·7	37·9	28·7	28·5	31·2
65–75,	65·0	65·4	71·0	69·7	70·4	75·8	61·0	60·4	66·2
75–85,	143·1	138·6	147·7	150·8	146·6	155·3	135·4	130·6	140·2
Over 85,	311·9	288·3	288·0	327·4	305·8	301·2	296·4	270·8	274·8
All ages,	21·4	19·2	19·5	22·7	20·3	20·6	20·1	18·1	18·4

The above table clearly shows that there is a great tendency to death among young persons; this liability to die reaching its minimum from between ten to fifteen years of age, and afterwards steadily increasing throughout life. In this latter respect there was a remarkable increase of mortality at the advanced ages in 1890–91, due to the prevalence of epidemic influenza.

It follows, therefore, that a town, a large proportion of whose inhabitants were at the most viable age, would have a lower death-rate than a town equally healthy, but in which the ages of the people were less favourable to long life ; just as it would be if the one town had a much larger population of females than the other.

Corrected Death-rates.—In order to neutralise the errors in death-rates arising from sex and age constitution of the population, the Registrar-General has devised a method by which they can be corrected. This method, based primarily upon the death-rate of each sex at different ages throughout England and Wales, provides a series of factors by which the recorded death-rates of the great towns can be each multiplied so as to make them comparable with that of England and Wales. By the use of these factors the recorded gross death-rate of any of these towns can be lowered or raised to what it would be if the age and sex distribution of that particular town were the same as that of England and Wales generally. This new rate is called the *corrected death-rate.* The factor employed is practically the expression of the ratio which the recorded death-rate bears to an empirical (arbitrary) *standard death-rate* calculated on the hypothesis that deaths at each age-period were at the same rate as in England and Wales during the decennium 1881–90, the death-rate at all ages in England and Wales during that period having been 19·15 per 1000. Owing to the proportions of persons of low mortality being excessive in most towns, their recorded death-rates are too low, and in consequence the factor for their correction is in most cases above unity, the only exceptions for last year being Norwich and Plymouth.

The table below gives these factors for the chief towns as issued by the Registrar-General in 1895, along with their recorded and corrected death-rates per 1000 living in 1894.

Towns, in the order of their Corrected Death-rates.	Standard Death-rate.	Factor for Correction for Sex and Age Distribution.	Recorded Death-rate, 1894.	Corrected Death-rate, 1894.	Comparative Mortality Figure, 1894.
Cols.	1.	2.	3.	4.	5.
England and Wales,	19·15	1·0000	16·59	16·59	1000
England and Wales, less the 33 Towns,	19·45	0·9845	15·78	15·54	937
33 Towns,	17·71	1·0813	18·12	19·59	1181
Croydon,	18·37	1·0424	13·19	13·75	829
Portsmouth,	18·73	1·0224	15·15	15·49	934
Leicester,	17·64	1·0855	14·65	15·90	958
Derby,	17·36	1·1031	15·01	16·56	998
Brighton,	18·94	1·0110	16·41	16·59	1000
West Ham,	17·75	1·0788	16·17	17·44	1051
Plymouth,	19·70	0·9720	18·30	17·79	1072
Norwich,	19·99	0·9579	18·74	17·95	1082
Bristol,	18·33	1·0447	17·26	18·03	1087
Cardiff,	17·16	1·1159	16·22	18·10	1091
Hull,	18·23	1·0504	17·36	18·23	1099
Halifax,	17·20	1·1133	16·48	18·35	1106
Huddersfield,	16·47	1·1627	15·80	18·37	1107

Towns, in the order of their Corrected Death-rates.	Standard Death-rate.	Factor for Correction for Sex and Age Distribution.	Recorded Death-rate, 1894.	Corrected Death-rate, 1894.	Comparative Mortality Figure, 1894.
Cols.	1.	2.	3.	4.	5.
Nottingham,	17·81	1·0752	17·24	18·54	1118
Swansea,	17·53	1·0924	17·04	18·61	1122
London,	17·97	1·0656	17·76	18·93	1141
Gateshead,	17·83	1·0740	17·66	18·97	1143
Bradford,	16·73	1·1446	17·00	19·46	1173
Sheffield,	17·22	1·1120	17·77	19·76	1191
Leeds, .	17·28	1·1082	17·87	19·80	1193
Birkenhead,	17·42	1·0993	18·06	19·85	1197
Newcastle,	17·58	1·0892	18·29	19·92	1201
Blackburn,	17·05	1·1231	17·89	20·09	1211
Birmingham,	17·33	1·1050	18·59	20·54	1238
Bolton,	16·90	1·1331	18·79	21·29	1283
Oldham,	16·72	1·1453	18·61	21·31	1285
Burnley,	16·67	1·1487	18·70	21·48	1295
Wolverhampton,	18·30	1·0464	20·70	21·66	1306
Sunderland,	18·25	1·0493	20·78	21·80	1314
Preston,	17·42	1·0993	20·81	22·88	1379
Manchester,	16·90	1·1331	20·42	23·14	1395
Salford,	17·03	1·1244	21·00	23·61	1423
Liverpool,	17·26	1·1094	23·85	26·46	1595

If the corrected death-rate in each town be compared with the death-rate at all ages in England and Wales, taken as 1000, it gives a number known as the *comparative mortality figure*, as shown in the last column of the preceding table. These figures may be expressed in another way, by saying that after correction has been made for differences of age and sex distribution, the same number of people that gave 1000 deaths in England and Wales in 1894 gave 958 in Leicester, 1193 in Leeds, and 1379 in Preston. Or we can say that in 1894 the death-rate for the whole of England and Wales was 16·59; and the recorded death-rate for Blackburn is 17·89, with its factor for correction as 1·1231. Then $17{\cdot}89 \times 1{\cdot}1231 = 20{\cdot}09$ as the corrected death-rate for Blackburn, and $\frac{20{\cdot}09}{16{\cdot}59} \times 1000 = 1211$ as its figure of comparative mortality.

Infantile Mortality.—The calculations of infant and child mortalities demand special remark; particularly as it is by no means uncommon to find them worked out on the population, or on the number of deaths at all ages. The proper, the most simple and most accurate way is rather to utilise the birth returns, and calculate out the ratio of deaths of infants under one year to the number of actual births in the latter half of the preceding year and the former half of the current year. The greatest care should be given to child mortality, or the death-rate of those under five years of age, as it constitutes an important and instructive index of health conditions. In 1894 the infantile death-rate or proportion of deaths of infants under one year of age to registered births in England and Wales was 137 in 1000. In 1893 it was 159 per 1000 births, or higher than in any year since 1870, when the proportion had been 160 in 1000. The average mortality of infants from all causes in the four decennia ending with 1890 has been in the proportions of 154, 154, 149, and 142 respectively to 1000 births. The rate differs widely in different counties and towns; the general rule being that the rate is lowest in purely agricultural, and highest in the mining districts, and in those with textile industries. For the past ten years three towns in particular have been especially bad in this respect; they are Preston, Burnley, and Leicester, the infantile mortality of which during the ten years 1884–93 has been 229, 215, and 207 per 1000 births respectively. The following table gives the number of survivors after a lapse of 3, 6, and 12 months out of 100,000 births respectively in three agricultural counties (Herts, Wilts, and Dorset); in five mining or industrial counties (Stafford, Leicester, Lancashire, West Riding, and Durham); and lastly, in the three selected towns of Preston, Burnley, and Leicester. The figures are based upon the returns for the years 1891–2 and 1893.

Age.	Of 100,000 born, the Numbers Surviving at each Age.			Annual Death-rates per 1000 living in each successive Age-period.		
	Three Rural Counties.	Five Mining and Manufacturing Counties.	Three Selected Towns.	Three Rural Counties.	Five Mining and Manufacturing Counties.	Three Selected Towns.
At birth,	100,000	100,000	100,000	211	330	378
,, 3 months,	94,760	92,110	90,896	75	155	238
,, 6 ,,	93,144	88,605	85,628	60	126	181
,, 12 ,,	90,306	83,126	78,245	...	...	...

It will be seen from these figures how high is the mortality among young children in these particular towns and industrial counties, as compared with the rural counties; put into round numbers, it means that for 10,000 deaths in the agricultural counties there would be 26,000 in the towns in each case out of 100,000 children born alive.

The chief causes of infantile mortality, common to every locality, are briefly: premature birth, congenital defects, hereditary tendencies, inexperience and neglect of mothers, industrial conditions, improper food, and overlaying. Infant mortality is more particularly influenced by the prevalence of epidemic diarrhœa, and by epidemics of measles or whooping-cough. A high infant death-rate does not necessarily imply a high tendency to death among the rest of the population, as it is often high in towns that have a low general death-rate; thus Leicester has had an infantile death-rate for the ten years 1884–93 of 207 per 1000 births, but during the same period its general death-rate has been only 20·3 per 1000 living. It is always high in districts where female labour is largely employed in manufactures.

Combined Death-rates.—A very frequent source of error in vital statistics is made in calculating the mean death or other rate of two populations or communities; these are often spoken of as *combined death-rates.* The error usually arises from failing to take into account the proportion which the two populations or groups bear to one another. Thus, suppose two towns each contain 30,000 inhabitants, and have respectively mortalities of 22 and 16, their mean or combined death-rate would be $\frac{22+16}{2}$ or 19. But suppose one of the towns have 42,000 inhabitants and the other 18,000, and have respectively the above mortalities, their combined death-rate will then not be the mean of their two separate death-rates, but as follows:—

One town of 42,000 people with a death-rate of 22 per 1000 = 924 deaths.
,, ,, ,, 18,000 ,, ,, ,, 16 ,, = 288 ,,

or 60,000 people give 1212 deaths,

and $\frac{1212 \times 1000}{60,000} = 20{\cdot}2$, the true combined death-rate per 1000.

Influence of Birth-rate on Death-rate.—With regard to the influence of the birth-rate upon the death-rate much controversy has prevailed. To a great extent this has been unnecessary, and has arisen from a misconception as to the true meaning of the relation between the birth and death rates. Practically, the birth-rate affects the death-rate only in so far as it alters the age constitution of the population. If we imagine a population in which there has been a high birth-rate for one or more years, it is clear such must contain a larger proportion than usual of young children, and inasmuch as the death-rate of young children is higher than that of all others except the aged, the general death-rate of that population will be raised; but this condition is to a large extent counterbalanced by the fact that a high birth-rate implies the presence in that particular population of a large proportion of persons of the childbearing age, that is, of an age-period when the mortality is unusually low. So, again, if the high birth-rate be continued for any length of years, it means not only a large proportion of children and of persons at reproductive ages, but also of young adults, among whom a low rate of mortality also prevails. In the same way a continuously low birth-rate may bring about a low death-rate. A striking illustration of this kind is afforded by the case of Aston Manor, which enjoys a very low death-rate, and where the age constitution of the population per 1000 at the last two censuses was as follows:—

Age-Periods,	0–5.	5–10.	10–15.	15–25.	25–35.	35–45.	45–55.	Over 55.
Census of 1881,	157	131	110	191	156	113	74	68
,, 1891,	127	123	119	204	162	113	68	74

In this town the enormous reduction in the child population, and relative increase of ages between fifteen and thirty-five or those of lower mortality, is wholly due to a continuous decline in the birth-rate during the last fifteen years, which has shown itself in a reduced death-rate, and more palpably in the fact that, though the population has increased between 1881 and 1891 from 53,842 to 68,639, the demand for school accommodation has been stationary. Thus far the change in the constitution of the population has had an apparently favourable influence on the death-rate, but, if it continue to operate, it will lead to an accumulation of persons over forty-five years of age, and be followed by a steady rise in the death-rate, however excellent the sanitary condition of the district may be; when the authorities doubtless will be as eager as they are now unwilling to have the recorded death-rate "corrected."

The real influence of the birth-rate upon the death-rate, therefore, is not one which can be well expressed as a low birth-rate causing a low death-rate, or a high birth-rate producing a high death-rate, but rather that the average age of a population governs the death-rate, and that the lower the mean age of the living, the lower should be the death-rate, and, by inference that the death-rate really controls the birth-rate, because the lower it is, the more chance is there of there being a large proportion of persons at the child-producing ages. If a high death-rate follows a high birth-rate, it reasonably suggests an excessive infantile mortality; very often low death-rates and low birth-rates co-exist, but it must not be supposed that the one is always necessarily caused by the other.

Relation of Density to Mortality.—The influence exerted by density of population on mortality and death-rates has long been recognised. The density may be either expressed as so many persons to a square mile, or as acres to a person, or we may state the distance which would separate each individual from his next neighbour if the whole population were spread as uniformly as possible over the surface of the country. The gradual increase of density of population in this country at each successive census is shown in the following table:—

Date of Census,	1801.	1811.	1821.	1831.	1841.	1851.	1861.	1871.	1881.	1891.
Persons per square mile,	153	174	206	238	273	307	344	390	445	499
Acres per person,	4·20	3·67	3·11	2·69	2·34	2·08	1·86	1·64	1·44	1·29
Proximity in yards,	153	143	132	123	114	108	102	96	90	85

The late Dr Farr found that the mortality increases with the density of a population; not in direct proportion to the density, but as the twelfth root. This rule, however, is of very limited practical application, as many variable conditions are involved. According to Ogle, this influence of density does not affect the mortality unless there be more than four hundred persons to the square mile. Newsholme regards the number of persons per room as the most reliable index of density; and shows that in 1889 the vital statistics of the 20,000 inhabitants of Peabody Buildings, with a density of 750 per acre, compared favourably with those of London generally (average density 49 per acre) as regards infant mortality, total death-rate, and death-rate from diarrhœa and enteric fever; though there was a higher mortality from phthisis, scarlet fever, diphtheria, measles, and whooping-cough.

The practice of building back-to-back houses so prevalent in Yorkshire and Lancashire, and without provision for through ventilation, illustrates very clearly the evil effects of crowding populations, and has been well sifted by the reports of Barry and Gordon Smith to the Local Government Board in 1888. Increased density of population gives rise to filth conditions, to the more rapid spread of infectious diseases, phthisis, accident, and other evil conditions, the outcome of co-existent poverty and occupation. It is probably by and through these, rather than from mere overcrowding, that density of population in any way influences the death-rate of a community.

Urban and Rural Mortality.—Closely connected with the influence of density of population upon mortality is the question of the respective death-rates in urban and rural districts. The following table gives the death-rates for town and country districts.

The death-rate is evidently diminishing in both urban and rural areas, but more rapidly in the former than in the latter, so that the difference between them grows less. The increased excess of the urban over the rural death-rate in 1893, as compared with the rates in 1891 and 1892, was in part due to the high mortality from diarrhœa, a disease affecting town in greater degree than country populations. The rates in 1891 and 1892, however, in the rural districts had been unusually high, doubtless on account of epidemic influenza, thus reducing the difference between the urban and rural rates, so that in 1893 the ratio of urban to rural mortality only reverted to its normal figure.

Year.	Persons to a Square Mile in England and Wales.	Annual Deaths to 1000 Persons living in			Deaths in Town Districts to 100 Deaths in Country Districts, in equal Numbers living.
		England and Wales.	Town Districts.	Country Districts.	
1851–60	325	22·2	24·7	19·7	124
1861–70	365	22·5	24·8	20·2	126
1871–80	416	21·4	23·1	19·8	122
1881–90	470	19·2	20·3	18·1	117
1891	499	20·2	21·9	18·5	114
1892	504	19·0	19·5	18·5	108
1893	510	19·2	20·6	17·8	116
1894	514	16·6	17·4	15·9	109

As Newsholme has pointed out, the true difference between urban and rural mortality is greater than is shown in the preceding table, if due allowance be made for age and sex distribution. There is in the town districts a much larger proportion of females, a larger proportion of adults of both sexes in the prime of life, and a much smaller proportion of very aged persons. "There is a slight counterbalancing influence of a large number of infants in towns, but these, as we have already seen, are followed by an increase of young adults, and, therefore, apart from any excess of infant mortality, ought not to raise the general death-rate." The extent of the correction required on these accounts may be gathered from an example. In 1893 the urban death-rate was 20·2; the rural death-rate 17·4. Owing, however, to the great differences of age and sex distribution of the respective populations, the urban death-rate ought, with equal healthiness, to have been nearly 12 per cent. lower than the rural death-rate, instead of being, as it was, 16 per cent. above it. The figures for 1894 are much more satisfactory.

Causes of Death.—It is not sufficient to know the death-rate of a community; it is necessary to know and inquire what rates the different causes of death give when the deaths are distributed to their several classes. Although the death-rates obtained from registrars are principally derived from certificates signed by either doctors or coroners, and, as such, should be clear statements of the precise cause of death, still even now the cause of death in many cases is both vague and ill-defined. Each year, however, shows improvement in this direction, with the result that the registration of causes of death is becoming more and more accurate and complete. Some idea of the mortality in England and Wales from the several classes of diseases during the last few years will be gathered from the following table:—

Causes of Death.	Rate per Thousand living.									
	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
Zymotic diseases, .	3·116	2·531	2·679	2·702	2·133	2·456	2·541	2·706	2·785	3·165
Parasitic diseases,	0·039	0·030	0·036	0·030	0·025	0·024	0·024	0·023	0·021	0·020
Dietetic diseases, .	0·058	0·060	0·061	0·064	0·063	0·067	0·081	0·083	0·079	0·088
Constitutional diseases,	3·431	3·310	3·370	3·213	3·166	3·223	3·374	3·339	3·168	3·210
Local diseases,	9·618	10·007	10·040	9·867	9·643	9·394	10·364	10·807	9·801	9·536
Violence, . .	0·656	0·634	0·634	0·652	0·622	0·614	0·653	0·670	0·651	0·675
Developmental diseases, .	1·586	1·614	1·638	1·578	1·569	1·550	1·611	1·690	1·624	1·593
Ill-defined and not specified causes,	1·160	1·019	1·064	0·968	0·891	0·893	0·900	0·899	0·853	0·883
All causes, .	19·66	19·20	19·52	19·07	18·11	18·22	19·54	20·21	18·98	19·17

Some of these groups of causes of death are deserving of closer analysis.

The Zymotic death-rate, or death-rate from special febrile diseases, is an important fact to be noted among all communities, as it furnishes a very popular standard as to their general healthiness. But it will be readily understood that it is liable to great fluctuations according to the greater or less prevalence of one or other of those diseases, with the result that a so-called mean zymotic death-rate is often of little value. Thus, say in a given community the zymotic death-rate be excessive owing to the epidemic prevalence of the two zymotic diseases, measles and whooping-cough. Owing to these diseases not being either usually or truly dependent upon defective sanitary conditions, their excessive prevalence, as evidenced by an increased zymotic death-rate, furnishes less clue as to the health condition of the community than would an equally high zymotic mortality rate owing to such diseases as diphtheria or enteric fever, which are more directly the expression of faulty sanitary states.

Of late years the zymotic death-rate has shown a steady tendency to fall; in 1894, for England and Wales, it was 1·76 per 1000 living; but so far the best endeavours of sanitarians in this country have not been able to get the death-rates of the chief diseases of this class below the following rates per 1000 living:—

Zymotic Diseases.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
Small-pox, .	0·083	0·104	0·010	0·018	0·036	0·001	0·001	0·002	0·015	0·049
Measles, .	0·419	0·533	0·436	0·602	0·347	0·518	0·439	0·436	0·460	0·374
Scarlet fever,	0·402	0·233	0·218	0·282	0·226	0·235	0·242	0·171	0·190	0·235
Typhus, .	0·012	0·012	0·009	0·008	0·006	0·005	0·005	0·005	0·003	0·005
Enteric fever, .	0·236	0·175	0·184	0·185	0·172	0·176	0·179	0·168	0·137	0·229
Simple continued fever,	0·028	0·024	0·022	0·018	0·015	0·015	0·013	0·011	0·008	0·009
Whooping-cough,	0·425	0·481	0·470	0·404	0·436	0·430	0·478	0·468	0·455	0·342
Diphtheria,	0·186	0·164	0·149	0·160	0·171	0·189	0·179	0·173	0·222	0·318
Influenza,	0·003	0·005	0·003	0·003	0·003	0·002	0·159	0·574	0·534	0·325
Cholera,	0·030	0·011	0·019	0·017	0·008	0·012	0·014	0·011	0·150	0·045
Diarrhœa,	0·978	0·492	0·899	0·727	0·455	0·648	0·606	0·469	0·505	0·954
Erysipelas, .	0·079	0·073	0·055	0·067	0·058	0·043	0·048	0·043	0·050	0·065
Puerperal fever,	0·091	0·089	0·076	0·088	0·085	0·065	0·068	0·068	0·080	0·102

Of the so-called *Parasitic Diseases* the greater number are attributed in the Registrar-General's returns to thrush. The deaths from diseases of this class in 1893 were fewer than in any previous year on record. The deaths

Causes of Death.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
Thrush,	0·032	0·025	0·029	0·024	0·019	0·019	0·019	0·018	0·016	0·015
Alcoholism,	0·047	0·049	0·051	0·052	0·051	0·055	0·070	0·071	0·063	0·073
Rheumatic fever,	0·101	0·107	0·092	0·095	0·096	0·079	0·084	0·088	0·086	0·104
Rheumatism,	0·032	0·032	0·032	0·035	0·033	0·032	0·033	0·037	0·037	0·030
Cancer,	0·563	0·572	0·590	0·615	0·621	0·656	0·676	0·692	0·690	0·711
Phthisis,	1·827	1·770	1·739	1·615	1·568	1·573	1·682	1·599	1·468	1·468
Diabetes, .	0·055	0·056	0·059	0·063	0·063	0·062	0·065	0·066	0·068	0·070
Convulsions, . .	0·854	0·808	0·831	0·778	0·736	0·756	0·749	0·763	0·701	0·701
Diseases of nervous system,	1·824	1·823	1·858	1·806	1·772	1·715	1·745	1·748	1·622	1·612
Diseases of circulatory system,	1·506	1·613	1·647	1·666	1·695	1·664	1·757	1·826	1·684	1·630
Diseases of respiratory system,	3·342	3·737	3·641	3·626	3·502	3·309	4·120	4·474	3·884	3·536
Croup,	0·176	0·156	0·134	0·143	0·129	0·114	0·109	0·091	0·076	0·071
Dentition, .	0·183	0·171	0·178	0·152	0·150	0·153	0·158	0·160	0·144	0·136
Diseases of liver, .	0·362	0·360	0·358	0·337	0·316	0·311	0·302	0·294	0·274	0·276
Other digestive diseases,	0·599	0·563	0·617	0·596	0·586	0·630	0·652	0·651	0·641	0·791
Diseases of urinary system,	0·442	0·444	0·450	0·446	0·445	0·441	0·451	0·468	0·449	0·451
Diseases of parturition, . .	0·070	0·075	0·065	0·061	0·063	0·061	0·080	0·097	0·097	0·098
Diseases of organs of locomotion,	0·092	0·092	0·092	0·091	0·085	0·084	0·079	0·075	0·065	0·060
Diseases of skin, .	0·067	0·064	0·066	0·063	0·063	0·059	0·062	0·063	0·066	0·068
Accident and negligence,	0·567	0·549	0·540	0·558	0·528	0·528	0·565	0·574	0·553	0·576
Homicide,	0·012	0·011	0·011	0·013	0·011	0·010	0·010	0·011	0·010	0·011
Suicide, .	0·076	0·074	0·082	0·080	0·082	0·076	0·077	0·085	0·088	0·087
Ill-defined causes,	1·160	1·019	1·084	[illegible]	0·891	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

due to *Dietetic Diseases* are mainly the result of intemperance, and returned under the head of Alcoholism. The annual death-rates per 1000 living from the chief causes of death, other than the zymotic, in England and Wales, during recent years is given in the preceding table.

The foregoing tables indicate that, in regard to certain well defined diseases, the death-rate has changed in the direction of increase or decrease. The increase in mortality is manifest in respect of cancer, diabetes, diphtheria, influenza, suicide, and diseases of the circulatory and respiratory systems. It is probable that some real increase has occurred in respect of nervous diseases also, possibly due to improved methods of diagnosis and greater care in certification of cause of death. There has been a true increase in diphtheria in the last few years, especially in urban districts. Puerperal fever has apparently increased, but it is not improbable that this is due to more correct certification, arising from the systematic inquiry now made by the Registrar-General in respect of doubtful entries. Measles and whooping-cough show a high average mortality, with little tendency to decrease, but these diseases have no demonstrated relation to insanitary conditions, and as yet have not been seriously combated either by hospital isolation or disinfection.

A decrease is manifest in the mortality from small-pox, scarlet fever, diarrhœa, typhus, enteric fever, simple continued fever, thrush, phthisis, convulsions, croup, and ill-defined causes. The reduction in regard to the first five is real, and mainly attributable to improved sanitation. Phthisis has been undoubtedly lessened by better drainage and ventilation, but improved diagnosis is probably responsible for the transfer of some cases to the category of other respiratory diseases. The gradual disappearance of simple continued fever, croup, convulsions, and ill-defined diseases as causes of death may be explained by better diagnosis and better certification, but nearly all these cases have involved transference to other headings, and are not true reductions in mortality.

Other influences which have an important bearing upon the mortality of certain diseases are sex, age, and occupation. The mortality among women appears to be higher than among males for such diseases as rheumatism, anæmia, chlorosis, erysipelas; while for affections connected with childbirth, it is, of course, limited to the female sex. On the other hand, men die more than women when affected with such diseases as syphilis, diabetes, rickets, typhus, meningitis, and hydrophobia.

The influence of age upon mortality rates is very marked in certain diseases. Thus, phthisis or consumption is at its lowest prevalence between the ages of 5 and 12, but increases up to 47 years of age, after which it lessens. Small-pox mortality is highest in the first and twenty-fifth years, while diarrhœa, whooping-cough, measles, and diphtheria all have their highest death-rates during the first few years of life. Cancer is a disease which appears rarely to affect the young, but tends to increase after 28 years of age. Diseases connected with the heart and circulatory system increase in their mortality rates from birth upwards. The total death-rate, and the death-rates from affections of the nervous system, lungs, and bladder, all appear to be at their lowest between the tenth and fifteenth years of life.

Occupation.—The more recent investigations of Ogle and Arlidge have thrown considerable light upon the influence which occupation has upon mortality. Some callings are much less favourable to health than others; some again, while being relatively healthy, are dangerous. The chief circumstances which render certain employments more or less hurtful to health are, bad ventilation and overcrowding of work-rooms; exposure to weather, or extremes of heat and cold; inhalations of vapours, gases, or metallic, mineral and organic dust; overstrain and mental anxiety; also temptations to intemperate habits. Many difficulties and fallacies underlie all comparative statistics of class mortalities, unless due allowance be made for the age at which such employments are followed, as well as the question of the class of person actually engaged, and the importance of differentiating between employer and employed. Thus, a death-rate of 10 per 1000 among factory girls aged 15–25 in a town where the general death-rate was 22 would be very high, since that for females at that age-period is about 5. This precaution is sufficient when, in the absence of anything specially unfavourable to health in the occupation, any excessive mortality must be ascribed to insanitary surroundings or irregular habits. As Farr says, "it would be obviously unfair to expect that all trades could be rendered equally healthy; and when a certain amount of danger to life or unhealthiness is unavoidable, the death-rate should also be compared with that of some other group of workers in the same or similar industry, thus giving a practicable as well as an ideal standard."

Again, the healthiness or unhealthiness of an occupation may be obscured by the fact that those who follow the several industries do not start on equal terms as regards health. A weak, weedy lad will not become a navvy, but a tailor or shopman by preference. The occupations demanding great muscular strength and activity to some extent, then, consist of picked men. So, again, there are some callings only attainable late in life, while, on the other hand, some are only suited to young persons, who after a few years seek more lucrative employments. In all these cases the mean age at death is delusive. Most females follow their employments only until by marriage they cease to be self-supporting, consequently, the mean age at death of female clerks, domestic servants, and shop assistants is valueless. To give that of ladies' maids as 36 and of nurses as 60, or to say that the mean age at death of a judge is 68 and that of a solicitor is 50, is merely an abuse of statistics.

The following table shows the comparative mortality and death-rates for two age-periods of various occupations, as gathered from Ogle's figures for the three years 1880–1–2, which is the latest period for which an analysis has been made. In his larger table Ogle gives the death-rate per 1000 living at five age-periods, but of these the groups between the 26th and 46th birthdays are the largest, and show the influence of occupation most markedly. Before 25 the influence of occupation has not had time fully to develop, and after 65 the influence of retirement comes into play.

The comparative mortality figure is derived in this way. During 1880–1–2, when this table was constructed, there were in England and Wales 1000 deaths per 64,641 males aged 25–65, of whom 41,920 were under and 22,721 were over 45 years of age. The comparative mortality figures are the number of deaths that would have occurred in the several occupations out of 64,641 males, distributed according to age, as in England and Wales. For instance, 41,920 butchers aged 25–45, and 22,721 aged 45–65, with a death-rate respectively of 12·16 and 29·08 per 1000, gave 1170 deaths. Thus the figure 1170 represents the mean mortality of butchers between 25 and 65 as compared with the mortality of all males of similar ages in England and Wales, which is 1000. It is of interest to note that the death-rate of more than three-fifths of the industries is below the mortality figure for "all males." The standard furnished by "all males," however, is a very unsatisfactory one, as it includes an enormous number permanently enfeebled in health and not engaged in any definite occupation.

Occupation.	Mean Annual Death-rate per 1000 living.		Comparative Mortality Figure.
	Age 25–45.	Age 45–65.	Age 25–65.
All males,	10·16	25·27	1000
Occupied males,	9·71	24·63	967
Unoccupied males,	32·43	36·20	2182
Males in selected healthy districts,	8·47	19·74	804
Inn and hotel servants,	22·63	55·30	2205
General labourers in London,	20·62	50·85	2020
Costermongers and hawkers,	20·26	45·33	1879
Cornish miners,	14·77	53·69	1839
Potters and earthenware manufacturers,	13·70	51·39	1742
Filemakers,	15·29	45·14	1667
Watchmen, porters, and messengers,	17·07	37·37	1565
Licensed victuallers and innkeepers,	18·02	33·68	1521
Chimney-sweeps,	13·73	41·54	1519
Cabmen and omnibusmen,	15·39	36·83	1482
Brewerymen,	13·90	34·25	1361
Hairdressers,	13·64	33·25	1327
Professional musicians,	13·78	32·39	1314
Bargemen and watermen,	14·25	31·13	1305
Carters and carriers,	12·52	33·00	1275
Cutlers and tool and needle-makers,	11·71	34·72	1273
Plumbers, glaziers, and painters,	11·07	32·49	1202
Glass-blowers,	11·21	31·71	1190
Butchers,	12·16	29·08	1170
Law clerks,	10·77	30·79	1151
Medical men,	11·57	28·03	1122
Cotton operatives in Lancashire,	9·99	29·44	1088
Wool and worsted operatives,	9·71	27·50	1082
Printers,	11·12	26·60	1071
Tailors,	10·73	26·47	1051
Chemists and druggists,	10·58	25·16	1015
Tobacconists,	11·14	23·46	1000
Commercial travellers,	10·48	24·49	996
Blacksmiths,	9·29	25·67	973
Builders and bricklayers,	9·25	25·59	969
Bakers and confectioners,	8·70	26·12	958
Corn millers,	8·40	26·62	957
Insurance agents,	9·04	25·03	928
Artists, sculptors, and architects,	8·39	25·07	921
Shoemakers,	9·31	23·36	921
Tanners and fellmongers,	7·97	25·37	911
Watch and clockmakers,	9·26	22·64	903
Plasterers and whitewashers,	7·79	25·07	896
Coal miners,	7·64	25·11	891
Grooms and private coachmen,	8·53	23·28	887
Drapers and warehousemen,	9·70	20·96	883
Barristers and solicitors,	7·54	23·13	842
Booksellers and stationers,	8·53	20·57	825
Carpenters and joiners,	7·77	21·74	820
Fishermen,	8·32	19·74	797
Grocers,	8·00	19·16	771
Schoolmasters and teachers,	6·41	19·98	719
Agricultural labourers,	7·13	17·68	701
Farmers and graziers,	6·09	16·53	631
Gardeners and nurserymen,	5·52	16·19	599
Clergy, priests, and ministers,	4·64	15·93	556

In the preceding table the selected occupations are given in the order of the greatness of their mortality, as shown by the comparative mortality figure.

Inn-servants, inn-keepers, and brewers all have an excessive mortality, chiefly due to intemperance, but a large proportion of this class must be of temperate habits, as the comparative mortality figure for recognised intemperate persons is, according to Neison, 3240. Publicans and inn-keepers show also the highest mortality from gout and urinary diseases, with the exception of occupations dealing with lead. Plumbism as well as alcoholism would appear to be a cause of some forms of heart disease, as diseases of the circulatory system are most fatal among brewers, publicans, costermongers, cabmen, fishermen, painters, plumbers, filemakers, and potters. Nervous diseases give rise to a high mortality among those addicted to intemperance, and appear to be most fatal in the same occupations as are associated with a marked mortality from alcoholism. The same is the case with diseases of the liver; while suicide also has a fairly close relation to intemperance.

Respiratory diseases, especially phthisis, cause a high mortality among the debilitated, and those exposed to the weather, to impure air, and to certain forms of dust. For these reasons we find a high mortality figure among costermongers, tailors, drapers, cutlers, filemakers, potters, printers, wool and cotton workers, and in some miners, such as the Cornish miners. Coal miners, as a class, have a relatively low mortality figure, probably due to the fact that coal mines are well ventilated, and that the nature of the employment excludes weakly persons. Lead-poisoning is prevalent among printers, earthenware makers, painters, plumbers, glaziers, and filemakers. The two latter callings show also an extremely high mortality from renal diseases. The high mortality of printers is due less to plumbism than to phthisis. Butchers show a high mortality, which is apparently due to excessive indulgence; the same remark applies to commercial travellers. The shopkeeper class have a relatively low mortality; among them grocers suffer much less than drapers from phthisis and respiratory diseases, but more from diseases of the circulation, and slightly more from alcoholism and suicide. The clergy enjoy the lowest mortality, being closely pressed in this respect by gardeners, farmers, and agricultural labourers; the latter appear to suffer much from phthisis and respiratory diseases. Farmers have a somewhat high mortality from gout, alcoholism, and liver disease. Fishermen appear to have a low mortality from diseases of the nervous and respiratory systems, but suffer largely from accidents.

Sickness Rates.—Our information on this point is somewhat unsatisfactory, as the materials are wanting for a complete study of the amount of illness in the community. What statistical evidence we have is drawn from the experience of friendly societies, certain industrial organisations, the police, the navy, and the army. All these, however, are more or less selected bodies, and cannot be regarded as fairly representing the general population. The following figures have been obtained from, and are based upon, the experience of certain friendly societies, more particularly the Manchester Unity of Oddfellows and the Foresters.

These figures indicate that after mid-life the average duration of each illness increases, and with it the "expectation of sickness" and the proportion of number of cases of illness to each death. On the basis of these data it may be calculated that, inasmuch as in 1893 there were in England and Wales 569,958 deaths, there were 1,598,882 constant sufferers from sickness, and nearly 2,000,000 sufferers from such illness as would require medical relief, or throw the members of friendly societies on their funds. The economical loss to the community represented by this amount of sickness is enormous; and, assuming that a large proportion of it is preventible, the necessity of still further improving the sanitary condition of the people is manifest.

Ages.	Number of Years of constant Sickness corresponding to one annual Death.	Annual average amount of Sickness per head, in weeks.	Average duration of each Illness, in weeks.	
			Males.	Females.
10–20	2·47	0·75	3·43	3·30
20–30	2·53	0·93	3·80	3·90
30–40	2·17	1·00	4·74	5·20
40–50	2·45	1·80	5·58	5·80
50–60	2·64	2·60	7·80	7·00
60–70	4·00	4·36	9·54	9·50
70–80	5·53	7·50	12·12	12·60
Over 80	4·80	10·50	10·00	11·00

Statistical Evidence of the Health of Communities.—In attempting to judge the health of a community by statistical evidence, the greatest importance is attached to the following points, namely, the total corrected death-rate, the zymotic death-rate, and the infant mortality. All these have been discussed, and the various sources of error connected with them explained. Equally significant with the zymotic death-rate and the infant mortality is the phthisis death-rate, which, if excessive, indicates dampness of soil, unhealthy work-rooms, or overcrowding of tenements. The death-rate from respiratory diseases, other than phthisis, is also important. But, besides these, certain other evidence is usually considered, mainly as a test of the mean or average longevity of the population. This evidence consists of facts relating to what is known as "the mean age at death," "the probable duration of life," and "the expectation of life."

The *mean age at death* of a population is the sum of the ages at death divided by the number of deaths. It is no good test of the relative healthiness of populations unless due corrections be made for age and sex distribution. As Farr says, a population of ensigns might show a mean age at death of 22, and a population of generals over 48, but the latter population would not be more healthy than the former, it would merely consist of persons of a different age. A high birth-rate may reduce the age, though the health of the community may be extremely good. If the birth-rate be high, there will be in consequence a greater proportion of infants or young children in the population. These, we know, have a relatively high death-rate, with the result that the average age of death will be proportionately reduced. In this country the mean age at death averages 42 for males and 45 for females. Farr has shown that it is nearly equivalent to the reciprocal of the death-rate *minus* one-third of the difference between the reciprocal of the death-rate and that of the birth-rate; or two-thirds the reciprocal of the death-rate *plus* one-third that of the birth-rate. Suppose the death-rate to be 1 in 46, and the birth-rate 1 in 29, we have $\frac{46 \times 2}{3} + \frac{29}{3}$ $= 40 \cdot 3$ as the mean age at death.

The *probable duration of life* is practically the age at which exactly half of any given number of children born alive will have died; or, in other words, there are equal chances of their dying before and after that age. It is sometimes spoken of as the equation of life, or *vie probable* of French writers. All these terms are more or less unfortunate, as there is a probability for every possible duration of life. Regarded strictly as defined above, the probable duration of life is of no great value as a test of longevity; it can only be obtained from what is called a life-table, and as so determined for England and Wales, gives the probable duration of life for each male 47 years, and for each female 52 years. The probable duration of life is often confounded with another statistical expression, called the *mean duration of life*, which is the probable or likely duration of life from birth, and, by French writers, called the *vie moyenne*. If we imagine an absolutely stationary population, that is, one in which age and sex distribution does not change, then, starting from birth, the mean duration of life would be identical with the mean age at death, and with the expectation of life as determined by means of life-tables. But such a stationary population is rare, and in an ordinary community, whose numbers are constantly being disturbed by migration or other causes, the mean duration of life really signifies the present age in years *plus* the probable duration of life after having attained a given age, and which is more commonly called the mean after lifetime, or expectation of life. For comparative purposes, it is often more convenient to employ the term mean duration of life as indicating the expectation of life at birth; but if it is required to remove the disturbing influence of infant mortality, then the mean after lifetime, or expectation of life at a later age, must be taken. This expression, expectation of life, must not be taken to imply that any individual may reasonably *expect* to live a given number of years, because it has no true relation to the most probable duration of the lifetime of any given person. It merely shows the *average* number of years which a person, at a given age, lives, and in that sense constitutes the true measure of the chances of living which a mixed community has. Its estimation is made by means of what is called a life-table, and which is nothing more than a table constructed from census figures on the basis of the number living and the number dying at each age. Such a table shows how many out of, say, 1,000,000 persons supposed to be born at the same time will survive at the end of each year or term of years. The same table will also show the sum of the number of years which they live, and if this sum of these years be divided by the number living at any given age, the result will be the expectation of life for that given age.

Life-tables.—Farr called a life-table a *biometer*, because it really represents "a generation of individuals passing through time," and measures the probabilities of life and death of this generation at birth, and of survivors at each successive age-period, until the whole generation is extinct.

In order to construct a life-table it is necessary to have (1) particulars from a census return of the number, age, and sex distribution of a population; (2) returns of deaths for one or more years among this same population, grouped in the same ages or age-periods as have been adopted for stating the census population. A separate table is required to be constructed for each sex, and for this reason the death returns must be distinct for the two sexes.

A life-table can be constructed for either annual or quinquennial intervals; in most tables an annual interval is adopted for the first five years, and after that five-year periods are taken. The first step is to ascertain from the census returns the mean population, or the number of lives at risk at the centre of each year of life, and the number of deaths in the corresponding years of life. By dividing the former into the latter we obtain the rate of mortality per unit of population, better known to actuaries as the *central* *death-rate*, because it represents the rate at which people are dying in the centre of a given year. Let this be expressed per 1000, and call it D. These deaths may be assumed to be evenly distributed over the whole age-period, so that half the deaths will occur in the first portion of the period, and the other half in the second portion; and the ratio of the final to the initial population is $\frac{1000 - \frac{1}{2}D}{1000 + \frac{1}{2}D}$, which, when simplified, becomes $\frac{2000 - D}{2000 + D}$. This ratio is practically identical with the probability of living through one year, or p_x equals $\frac{\text{number of survivors at end of year}}{\text{number living at beginning of year}}$.

For the construction of a hypothetical life-table, let us suppose that the mortality among infants in a given population is 100 for every 1000. It will be at once evident that, if there be 1,000,000 babies born and living at the commencement of a given year, these will be reduced to 900,000 in the course of the year, and this number will commence the second year. Presuming that the data show that the death-rate among children in the second year of life is as high as 50 per thousand living, then applying the foregoing formula, we get $\frac{2000 - 50}{2000 + 50}$ or $\frac{1950}{2050}$ or 0·951219, and the 900,000 children at the beginning of the second year are reduced to 900,000 × 0·951219, or 856,097 at the beginning of the third year. In the same way, knowing the death-rates for the third, fourth, and fifth years of life, the actual numbers of children surviving at the end of those age-periods is calculated. Suppose now, by the end of the fifth year only 650,000 survive out of the original million, and we propose to continue constructing the life-table for quinquennial or five-year periods in place of annual intervals. The calculation is practically the same, substituting for the death-rate of each year the death-rate for each quinquennium. Presume the death-rate among persons aged 5–10 years to be 7, then applying the formula for the reduction of the population during this five-year period, we get $\left(\frac{2000 - 7}{2000 + 7}\right)^5$ or 0·965632, and at the end of this quinquennium, or by the end of the tenth year, the 650,000 will be reduced to 650,000 × 0·965632 = 627,660. This calculation can be repeated for each five-year period until there are no more survivors left.

Such an ideal life-table will consist of a series of columns, in the first of which will be entered the various years of life or age-periods headed by the symbol x.

The second column would be marked D, or as it is sometimes written m_x. The entries in this column would be obtained by dividing the deaths during each year or age-period by the corresponding mean population, and represent the rate of mortality.

From the entries in the second column, those of the third or p_x column would be obtained. These represent the probability of living one year for each age or age-period, as calculated from the formula $p_x = \frac{2000 - D}{2000 + D}$.

The next column, l_x, is obtained by multiplying the number living at the immediately preceding year by p_x. The entries in this column will represent the number surviving at each successive age, or in other words l_x represents the number who reach the precise age x.

The next column required in a life-table is one showing the mean number living in each year of life, and technically called P_x. Thus the mean number living in the tenth year $= \frac{l_9 + l_{10}}{2}$.

The next column in the table is known as the Q_x column. The number opposite any age in this column is the sum of all the numbers in the P_x column from that age to the end of the table, that is, until all the lives become extinct; and it shows, therefore, the aggregate number of years which the persons at each age in the table will live.

The last column is that marked E_x; in it, opposite each age, is placed the mean after lifetime, or expectation of life at each age. This is obtained from the formula $E_x = \frac{Q_x}{l_x}$.

The following table represents the headings of a typical life-table, prepared in accordance with the foregoing principles; it will serve to show a complete view of the results obtainable from a life-table. Each year of age should be inserted to make it complete, but in order to economise space, the intermediate years have been omitted. The table is practically an epitome of Farr's English Life-Table, No. 3, for Males, published in 1864.

Age or Age-Period. x.	Annual Mortality per Unit at Age x. D or M_x.	Probability of Living one Year from each Age. p_x.	Number Born and Living at each Age. l_x.	Mean Population in each Year of Age. P_x.	Years of Life Lived at Age x and upwards. Q_x.	Mean After Lifetime at each Age x. E_x.
0	0·18326	0·83212	511,745	456,820	20,426,138	39·91
5	0·01369	0·98640	370,358	367,672	18,410,252	49·71
10	0·00563	0·99438	353,031	352,007	16,608.936	47·01
15	0·00519	0·99482	344,290	343.415	14,866.429	43·18
20	0·00832	0·99171	333,608	332,231	13,169,656	39·48
25	0·00920	0·99084	319,442	317,892	11,536,677	36·12
35	0·01105	0·98901	288,850	287,229	8,492,601	29·40
45	0·01554	0·98458	253,708	251.763	5,774,489	22·76
55	0·02485	0·97644	209,539	206,984	3,447,708	16·45
65	0·04698	0·95410	150,754	147,315	1,631,508	10·82
75	0·10391	0·90122	75,777	72,012	491,685	6·49
85	0·21966	0·80208	16,877	15,151	63,030	3·73
95	0·42035	0·65265	833	678	1,806	2·17
105	...	...	4	3	5	...

Besides the preceding life-table, several others have been constructed, the more important being: "The Healthy Districts Life-Table," prepared by Farr on the basis of the mortality during the five years 1849–53 in sixty-three selected districts which showed, during the decennium 1841–50, a mean annual death-rate not exceeding 17 per 1000 persons living. This table expresses very accurately the actual duration of life among the clergy and other classes of the community living under favourable circumstances.

The "Upper Class Experience Table," constructed by Ansell from data collected by him as to men of the upper and professional classes.

The "Healthy Males Table," based on the experience of the principal insurance offices.

The "Clerical Experience Table," based on data respecting over 5000 clergymen living between 1760 and 1860.

The "New English Life-Table" by Ogle, and constructed on the death-rates of 1871–80.

The "Brighton," "Manchester," "Glasgow," and "London" Life-Tables, prepared by the medical officers of health of those respective towns on the basis of the census of 1891 and death-rates of recent years.

The following table gives a portion of Ogle's "New English Life-Table," as issued in 1885 :—

Age.	Males.		Females.	
	Survivors at each Age out of 1,000,000 Born.	Expectation of Life in Years.	Survivors at each Age out of 1,000,000 Born.	Expectation of Life in Years.
0	1,000,000	41·4	1,000,000	44·6
1	841,417	48·1	871,266	50·1
2	790.201	50·1	820,480	52·2
3	763,737	50·9	793.359	53·0
4	746.587	51·0	775,427	53·2
5	734,068	50·9	762.622	53·1
10	708,990	47·6	738.382	49·8
15	696,419	43·4	724,956	45·6
20	680,033	39·4	707,949	41·7
25	657,077	35·7	684.858	38·0
30	630,038	32·1	658,418	34·4
35	598,860	28·6	628,842	30·9
40	563,077	25·3	596,113	27·5
45	522,374	22·1	560,174	24·1
50	476,980	18·9	520,901	20·7
55	424,677	16·0	477,440	17·3
60	365,011	13·1	422,835	14·2
65	297.156	10·6	356,165	11·4
70	222,056	8·3	277,225	9·0
75	144.960	6·3	190,566	6·9
80	77,354	4·8	108,935	5·2
85	30,785	3·6	47,631	3·9
90	8,015	2·7	14.225	2·9
95	1,183	2·0	2,533	2·2
100	82	1·6	225	1·6

Having stated the data on which a life-table is based, and described the method of its construction, we are in a position to study the life history of the persons to which it has reference. The essential points for such a study are the three following:—

(*a*) *The probability of living a given period for each age-period* in the two sexes separately. This is commonly written p_x, and equals, as we have already seen, $\frac{\text{number of survivors at end of period}}{\text{number living at beginning of period}}$. Thus, by the above New English Life-Table, at birth the probability of a male child living one year is $\frac{841,417}{1,000,000}$ (the certainty of surviving to the end of the first year of life being taken as unity), and therefore the probability of his dying during the year is $\frac{1,000,000 - 841,417}{1,000,000} = 0·158583$. At 25 the probability of a male living five years, by the same life-table, is $\frac{630,038}{657,077}$, and the probability of his dying during the quinquennium being $\frac{657,077 - 630,038}{657,077}$, or $\frac{27,039}{657,077} =$ 0·04115; and so on.

(*b*) *The number of survivors out of* 1,000,000 *children born* of each sex, at each succeeding year, or quinquennial period of life, until the whole number becomes extinct by death. The above table starts with a million boys and a million girls assumed to be born at the same time, and shows how many survivors there would be at each successive period. Thus, of 1,000,000 males born, 476,980 are still alive at the end of fifty years from birth; and of 1,000,000 females born, 520,901 survive to the same age.

(*c*) *The expectation of life*, or mean after lifetime, of males and females at the end of each given period. To find the expectation of life at any age x, the rule is, add together the years of life lived through by the whole of the life-table population after that age, and divide by the number of survivors at that age, or $E_x = \frac{Q_x}{l_x}$. Suppose it is required to find the expectation of life for males at the age 35, on the basis of Ogle's English Life-Table. If we refer to that table, and add together the numbers surviving at each age later than 35, we obtain the figure 3,133,710, which is the number of complete five-year periods lived through by the whole of the life-table population after 35 years of age. These five-year periods equal 15,668,550 years, and as this number of years is lived by 598,860 males, the number of complete years lived by each male is 26·16 years. This result is known as the "curtate expectation of life."

In the above remarks we have confined our attention to the complete quinquennia of life, and have not taken into account that portion of lifetime lived by each person in the quinquennium of his death. In some instances this may be only a few months or days, in others one or more years; but it may be assumed with a fair degree of accuracy, taking one person with another, that the duration of life in the quinquennium of death will be half such a period, that is, 2·5 years. If we add this 2·5 to the curtate expectation of life, the complete expectation of life is obtained. Thus, the complete expectation for males at $35 = 26{\cdot}16 + 2{\cdot}5 = 28{\cdot}66$ years. In life-tables where the age-periods are given in single years of life, the addition to be made to the curtate expectation will be 0·5 year. Usually, only the complete expectation of life is given in life-tables.

If reference be made to Farr's table or the earlier English life-table given on page 787, it will be readily seen that the seventh or last column is obtained in the same way, and that the mean future lifetime of any person can be obtained by the formula $\frac{Q_x}{l_x}$.

From what has here been explained, it will be gathered that life-tables can be constructed for individual towns as well as districts or countries, provided the necessary facts are available. And owing to the important conclusions which may be drawn from it, a local life-table must henceforth be regarded as indispensable to every medical officer of health. As Tatham has said, it is to him what the two-foot rule is to the mechanic. "In a word, the life-table is the one and only means by which the vague expressions 'more or less' of the sanitarian can be reduced to an exact comparative standard." Although the most recent life-table for the whole of England and Wales is that for the decennium 1871–80, known as Ogle's "New English Life-Table," that for 1881–90 not being yet published, still we have available for comparison four local life-tables based on the death-rates for 1881–90, namely, those for Manchester (Tatham), Brighton (Newsholme), Glasgow (Russell), and London (Shirley Murphy). These recent tables are of the greatest interest as showing the immense difference in the expectation of life in large and crowded manufacturing centres, in the metropolis, and in a typical seaside health resort of magnitude. Reference should be made to all these tables by those desirous of constructing similar local tables for themselves, as details are therein given for which space is not available in a general work of this kind.

A comparison between the old and new life-tables for England and Wales shows that there is a greater expectation of life under the new table up to 19 years of age for males, and 45 for females. After these ages the improvement appears to be less, possibly due to a greater death-rate under new conditions amongst the elderly people; but this is so much counterbalanced by the saving in life during the earlier years, that the total number of survivors up to about 70 for males and 90 for females is greater under the new table than in the old. The mean after lifetime at birth for both sexes is about 43½ years in this country; while the probable duration of life lies between 45 and 50 for males, and between 50 and 55 for females.

The following comparative tabular statement gives the expectation of life at the end of each five years of life, and for each sex in London, Manchester, Glasgow, and Brighton, as worked out by their recent life-tables (1881–90), as well as for England and Wales (1871–80).

Ages.	Males.					Females.				
	England and Wales.	London.	Manchester.	Glasgow.	Brighton.	England and Wales.	London.	Manchester.	Glasgow.	Brighton.
0	41·35	40·66	34·71	35·18	43·59	44·62	44·91	38·44	37·70	49·00
5	50·87	50·77	45·59	46·97	52·87	53·08	54·42	48·06	48·27	56·92
10	47·60	47·22	42·75	44·32	49·12	49·76	50·95	45·43	45·44	53·15
15	43·41	42·88	38·78	40·51	44·67	45·63	46·65	41·50	41·59	49·07
20	39·40	38·70	34·62	36·90	40·55	41·66	42·45	37·33	38·00	44·76
25	35·68	34·70	30·69	33·29	36·51	37·98	38·34	33·38	34·60	40·48
30	32·10	31·80	27·08	29·60	32·67	34·41	34·95	29·73	29·88	36·39
35	28·66	27·39	23·76	26·06	29·02	30·90	30·69	26·30	28·06	32·48
40	25·30	25·22	20·68	22·44	25·60	27·46	26·80	22·99	23·45	28·71
45	22·07	21·00	17·80	19·54	22·36	24·06	23·80	19·79	21·61	25·07
50	18·93	18·75	15·06	16·35	19·33	20·68	20·65	16·74	17·50	21·79
55	15·95	15·31	12·49	13·99	16·48	17·33	17·34	13·91	15·60	18·48
60	13·14	13·00	10·16	11·40	13·67	14·24	14·50	11·35	12·88	15·26
65	10·55	10·59	8·15	9·38	10·96	11·42	11·78	9·11	10·69	12·19
70	8·27	8·30	6·48	7·50	8·69	8·95	9·00	7·25	8·00	9·32
75	6·34	7·20	5·11	6·25	6·64	6·97	7·79	5·76	6·45	6·97
85	3·56	5·50	3·16	3·30	3·33	3·88	5·70	3·76	3·62	3·72

It is interesting to note from this table that at each age and for each sex the expectation of life in London exceeds that in Manchester and Glasgow, but is less than that of Brighton. The expectation of life for males at birth at Brighton is shown to be 43·59 as compared with 34·71 years in Manchester, and 41·35 years in England and Wales. In other words, it was 20·4 per cent. higher in the seaside health resort than in the industrial centre, and 5·1 per cent. higher than in the country at large. Similarly for females the expectation of life at birth in Brighton was 49·00 years as compared with 38·44 in Manchester, and 44·62 years in England and Wales, an excess in favour of Brighton of 21·5 and 8·9 per cent. respectively.

When speaking of the general English life-table, 1871–80, it was pointed out that the share in the gain of life of recent years was not uniform for each age-period. The local life-tables for Manchester and Brighton, 1881–90, show that this experience is shared by these towns with the rest of the country. That the expectation of life has not improved for ages beyond 20 in males and 45 in females is usually explained by the two following hypotheses:—(1) That, owing to the saving of life in the earlier years of life, a saving which has been especially in zymotic diseases and phthisis, there has been a larger number of weakly survivors, who would under the former conditions have been carried off by these diseases. It is extremely doubtful whether there is any real evidence in support of this view that the operation of the law of the survival of the fittest has been impeded, with results unfavourable to the health and vigour of adult life. It is not unlikely that the weeding out of weakly lives, caused by the greater mortality among weakly children suffering from an infectious disease, is almost entirely counterbalanced by the greater number of children made weakly in former times by non-fatal attacks of an infectious disease. In regard to phthisis and tubercular diseases, it is reasonable to suppose that much at least of the deteriorating effect of the survival of tubercular persons is counterbalanced by the large number of persons who are prevented by improved sanitary and social conditions from becoming tubercular.

(2) The increased strain of modern life is supposed by many to explain the increasing death-rate among adults. It is doubtful whether such increased strain exists in the community as a whole. The majority of the population belong to the wage-earning classes, and it is beyond dispute that the moral, physical, and financial condition of the masses is infinitely better now than fifty years ago.

We are disposed to think that much of the failure of the later ages to participate in the improved expectation of life is due to the effects of increasing "urbanisation" and the associated increase of manufacturing and indoor occupations, with a decline in agricultural and outdoor pursuits and callings. To these considerations may be added that we are, so far as sanitation is concerned, in a transition period; the benefits from the Public Health Acts of 1871, 1875, and 1891 not having been fully reaped, even yet. Possibly in another twenty years the improved conditions of life will have endured sufficiently long to enable their full force and value to be determined and felt; for the present we must suspend judgment, and leave "the complete solution of the problem to a time when the statistical experience of our country is more mature."

In the absence of proper life-tables, the late Dr Farr showed that the mean duration of life, or mean after lifetime, could be approximately calculated from the birth and death rates by the following formula, in which B = birth-rate and D = death-rate, while x = the expectation of life at birth.

$$x = \frac{2}{3} \times \frac{1000}{D} + \frac{1}{3} \times \frac{1000}{B}$$

Say a town has a birth-rate of 32 and a death-rate of 28 per 1000, then applying this formula, we get $\frac{2000}{3D} + \frac{1000}{3B}$ or $\frac{2000}{84} + \frac{1000}{96} = 34$, as the mean expectation of life at birth under those conditions.

Willich gives another formula, in which x = the expectation of life at any age a, between 25 and 75 years, then: $x = \frac{2}{3}(80 - a)$, and applying this, say for calculating the expectation of life at 53 years of age, we get $\frac{2}{3}(80 - 53) = x$ or 18 years.

Life-Capital.—If we apply the figures of a life-table to the existing or estimated population of a community in groups of ages at a given period, we obtain the aggregate future lifetime of each of those populations, or, as it has been appropriately called, the life-capital of the community in that particular period or year (Tatham). Taking Manchester as an example, as we have available for that city a life-table based upon the most recent facts as gained at the last census, we are able to construct the following table :—

Ages.	Expectation of Life.		Population.		Life-Capital.	
	Males.	Females.	Males.	Females.	Males.	Females.
0,	34·71	38·44	31,796	32,539	1,103,639	1,250,799
5,	45·59	48·06	28,622	29,444	1,304,877	1,415,078
10,	42·75	45·43	27,756	28,699	1,186,569	1,303,795
15,	38·78	41·50	25,960	27,580	1,006,728	1,144,570
20,	34·62	37·33	23,460	26,700	812,185	996,711
25,	30·69	33·38	22,632	22,695	694,576	757,560
30,	27·08	29·73	18,188	21,051	492,531	625,846
35,	23·76	26·30	17,550	18,675	416,988	491,152
40,	20·68	22·99	13,724	14,167	283,812	325,699
45,	17·80	19·79	11,648	12,861	207,334	254,519
50,	15·06	16·74	9,275	10,576	139,681	177,042
55,	12·49	13·91	7,522	9,188	93,950	127,805
60,	10·16	11·35	3,422	4,346	34,767	49,327
65,	8·15	9·11	2,820	3,550	22,983	32,340
70,	6·48	7·25	1,541	2,796	18,118	20,271
75,	5·11	5·76	819	1,381	4,185	7,954
85 and upwards,	3·16	3·76	69	144	218	541
All ages,	...	...	246,804	266,392	7,807,441	8,979,009
Total,	...		513,196		16.786,450	

These figures have a direct and an important bearing on the vital statistics of the community to which they apply; and this may be shown in either of two ways. In the first place $\frac{\text{life-capital}}{\text{population}}$ = average life-capital or future lifetime of each member of the population; and, in the second place, since mean population is equal to years of life expended in a year, $\frac{\text{population} \times 100}{\text{life-capital}}$ = proportion per cent. of life-capital expended in a year.

On the basis of these calculations we can construct the following table in reference to the city of Manchester :—

Average Life-Capital of the Population.			Proportion per cent. of Life-Capital expended in a Year.		
Persons.	Males.	Females.	Persons.	Males.	Females.
32·70	31·63	33·77	3·057	3·161	2·953

This table is in reality the application of the Life-Table for Manchester to the existing population of that city. It shows that so long as the age constitution remains as at the last census enumeration, and the death-rates at the various ages continue as in the decennium 1881–90, the average life-capital of the population of Manchester, taking young and old together, is 32·70 years; and that under the same conditions the ordinary expenditure of this capital per annum is 3·057 per cent.

If now we calculate for any period the number of deaths which should have occurred in each age-group at the rates of 1881–90, and compare them with the deaths which actually occurred during the period, the differences between the two sets of figures will be the numbers of lives saved or lost by the fluctuations of mortality in the given period; and by means of the resulting figures we can ascertain the gain or loss of life-capital due to these fluctuations of mortality. The gain or loss of life-capital depends not simply on the *number* of lives saved or wasted, but on the value of those lives to the community. Thus, say in a given community it is found that 262 lives under 5 years of age have been lost, each being worth from a life-table 38·3 years, while 422 lives between 5 and 65 years of age have been gained worth only 22·87 years each. It is at once obvious that there will have been in this case an actual loss to the particular community of 383 *years of future lifetime.* This is a consideration of the very greatest importance, and adds new force to the contention that the infantile death-rate is one of the best tests of sanitary condition. Not only is it such a test, but a heavy death-rate among children represents an enormous waste of the life-capital of the population.

The method here indicated in a simple form is capable of considerable extension and application, particularly if life-tables for given cities, towns, or large areas be prepared. From them it would not be difficult to compute the average years of life that will be lived between any specified ages. For instance, if 20 to 65 be taken as the working period of life, we can calculate how many years of working life will, on an average, be lived by children now under 5, between 5 and 10, &c. In this way we could estimate what may be called the working life-capital; and in the same way we could calculate the number of years of working life-capital gained or lost in any year or series of years. Considerations of space render it impossible to follow out here all the possible and practical uses to which life-tables readily lend themselves. It is sufficient to have indicated some of the most important and striking of these uses, and to have shown that, in a properly prepared life-table for its district, the sanitary authority possesses a powerful instrument for statistical investigation. By its aid we can learn how much of the best and most useful part of human life is wasted owing to the life conditions of the community, and we can also use it as a measure of future sanitary progress or regress.

Statistical Methods, and Tabulation of Mortality Facts.—The elements of statistical inquiries are individual facts, or so-called *numerical units*, which, having to be put together or classed, must have precise, definite, and constant characters. For example, if a number of cases of a certain disease are to be assembled in one group with a definite signification, it is indispensable that each of these cases should be what it purports to be, an unit not only of a definite character, but of the same character as the other units. In other words, an accurate diagnosis of the disease is essential, or statistical analysis can only produce error. If the numerical units are not precise and comparable, it is better not to use them. A great responsibility rests on those who send in inaccurate statistical tables of disease; for it must be remembered that the statist does not attempt to determine if his units are correct; he simply accepts them, and it is only if the results he brings out are different from prior results that he begins to suspect inaccuracy.

These items or numerical units being furnished to the calculator, are by him arranged into *groups;* that is to say, he contemplates the apparently homogeneous units in another light, by selecting some characteristic which is not common to all of them, and so divides them into groups. To take the most simple case:—A certain number of children are born in a year to a given population. The children are the numerical units. They can then be separated into groups by the dividing character of sex, and then into other groups by the dividing characters of "born alive" or "still-born," &c.

Or, a number of cases of sickness being given, these numerical units (all agreeing in this point, that health is lost) are divided into groups by diseases, &c.; these groups, again, are divided into others by the character of age, &c., and in this way the original large group is analysed, and separated into minor parts.

This group-building seems simple, but to properly group complex facts, so as to analyse them, and to bring out all the possible inferences, can only be done by the most subtle and logical minds. The dividing character must be so definite as to leave no doubt into which group an unit shall fall; it must be precise enough to prevent the possibility of an unit being in two groups at the same time. The rule is of the greatest importance, and many examples could be pointed out of error from inattention to it.

Statistical results are now frequently expressed by graphic representations, a certain space drawn to scale representing a number. The most simple plan is that of intersecting horizontal and vertical lines.

Two lines, one horizontal (axis of the *abscissæ*) and the other vertical (axis of the *ordinates*), form two sides of a square, and are then divided into segments, drawn to scale—vertical and horizontal lines are then let fall on the points marked; the axis of the ordinates representing, for example, a certain time, and the axis of the abscissæ representing the number of events occurring at any time. A line drawn through the points of intersection of these two quantities forms a graphic representation of their relation to each other, and the surface thus cut can be also measured and expressed in area if required, or the space can be plotted out in various ways, in columns, pyramids, &c. In the same way circles cutting radii at distances from the centre drawn to scale are very useful; the circles marking time (in the example chosen), and the radii events, or the reverse. Such graphic representations are most useful, and allow the mind to seize more easily than by rows of figures the connection between two conditions and events.

For the medical officer of health a systematic and simple method of keeping his statistical facts is of the first importance. This is particularly the case in regard to the tabulation of the causes of death. He may append to his annual report a table of the deaths at all ages and from all causes on the model of the Registrar-General or of those given in Appendix XII. as required by the Local Government Board. But for practical purposes connected with public health, and for weekly or monthly issue, a simpler form is often preferable. Individual ingenuity will readily be able to draw up a suitable table, which should be divided into a few well-marked age-periods, as infancy, early and late childhood, adolescence, early and late adult life, and old age, each of which has its several dangers to health, and social or industrial conditions. These periods would be, under 1 year, 1 to 5, 5 to 10, 10 to 20, 20 to 40, 40 to 70, and over 70.

Care should be taken to give all the zymotic diseases, phthisis and the preventable diseases generally in detail; under diphtheria may be grouped croup and any fatal cases of so-called putrid sore throat, but in the present day, with increased facilities for bacteriological observation, the errors in diagnosis of these cases should be reduced to a minimum; in any case where doubt exists, a short explanatory note in the column of remarks should be given. So also "cholera" when reported in the absence of an epidemic, "cholera infantum," and the so-called "dysentery," except in the case of persons returning invalided from the tropics, are best grouped together under the heading of "diarrhœa and enteritis." Where possible, tubercular phthisis should be distinguished from the non-tubercular, but in most cases phthisis will be found most conveniently noted as a single item, while "all other respiratory diseases" may constitute a second heading. Scrofula may be included under the general term of phthisis and tuberculosis. Syphilis should, when possible, be separately noted and efforts made to trace and clear up ambiguous cases where there is reason to suspect that this disease is the original cause of death. This is especially important in regard to the congenital form, as the reported mortality from it does not represent the truth, many cases being returned as "marasmus," "tabes," &c.

Diseases of the heart, kidneys, and liver, except cancer, may be bracketed in a comprehensive class of "diseases of the internal organs," with the omission of separate headings for so-called "dropsy" and "jaundice," these latter really being only symptoms and without importance to questions of public health. Cancers of all kinds and parts should form a single and separate group, so also should puerperal fever. Diseases of the nervous system must form a distinct heading, but it is advisable to exclude "teething" and "convulsions" from it, unless it is clear that they are not the pathological expression of gastro-intestinal derangement, the result of improper feeding. These causes of death constitute a serious source of error in infantile mortality returns, but a tactful medical officer of health can often, by judicious inquiry, obtain sufficient information to correct such returns, so as practically to allocate them to their proper position under the heading of "improper or defective feeding of infants."

Some excellent statistical forms for public health purposes have been suggested and drawn up by the Society of Medical Officers of Health. The tabular form given on page 796 has been prepared and modified from one in use in Germany by the health officials of that country. From its remarkable compactness and comprehensiveness, it appears to us to be well worthy of adoption in this country, and might serve as a basis for a scheme of international vital statistics.

Value of Statistical Series and Averages.—We have now discussed the chief kinds of statistical material generally at the disposal of the sanitarian, but before closing the subject it is necessary to indicate the chief sources of fallacy in statistics, and the general limits within which they may be used.

In an ideal mass of statistics the facts must (1) be all correctly observed; (2) they must be of the same kind and order; (3) they must be all localised both in regard to time and place; (4) they must be sufficiently numerous to give correct averages, and extend over sufficient length of time. It will be at once obvious that these various essentials are not easy to obtain. It has already been explained that while it is easy enough to ascertain correctly the numbers of a people during the census year, it is less simple to do so during intermediate years. Similarly, differences of degree or intensity, causation or virulence of diseases, render their comparison, by reducing their statistics to the same order and kind, extremely difficult. So, too, the importance of localising statistics, both in respect of time and place, is made clear by pointing out the absurdity of attempting to construct a particular disease-rate for some health resort from the deaths of persons occurring there from that special affection. The fourth essential for an ideal statistical series is well expressed in the mathematical statement that the error diminishes as the square root of the number of observations; in other words, the smaller the total number of facts the larger will be the relative percentage of errors

Month.	Births.			Deaths.			Ages of the Dead.												Causes of Death.															Uncertificated Deaths.	Death-Rate per 1000 on the Estimated Monthly Population.	Mean Estimated Population for the Year.
							0–1 Year.		2–5 Years.										Zymotic Diseases.							Other Prevalent Diseases.					Violent Deaths.					
	Male.	Female.	Total.	Male.	Female.	Total.	Legitimate.	Illegitimate.	Legitimate.	Illegitimate.	6–15 Years.	16–20 Years.	21–30 Years.	31–40 Years.	41–50 Years.	51–60 Years.	61–75 Years.	Over 75 Years.													Accident.	Suicide.	Homicide.			
January,																																				
February,																																				
March,																																				
April,																																				
May,																																				
June,																																				
July,																																				
August,																																				
September,																																				
October,																																				
November,																																				
December,																																				
Totals,	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		
	– per 1000 of the Population.			– per 1000 of the Population.																																
	Illegitimates.						Per cent. of the Deaths.																													
	M. – –	F. – –	T. – %				Per thousand of the Population.																													
	of the Births.																																			

Observations or Additional Particulars :—

displayed by them, and the larger the number of facts collected the smaller will be the margin of error.

There being a number of facts, each of which can be expressed by a numerical value, an *average* or *mean number* is obtained by adding all the numerical values and dividing by the number of facts. The mean or average is really a number which lies between the highest and lowest of a series of numbers, and has a definite dependence upon the whole of the series. The terms, mean and average, are often used synonymously ; regarded mathematically, there are several kinds of means. Thus, the simple average, or *arithmetic* mean of four numbers, such as a, b, c, d, is conveniently written as $\frac{a+b+c+d}{4}$, but their *geometric* mean would be $\sqrt[4]{a\,b\,c\,d}$, while their *harmonic* mean stands thus : $\frac{4}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}$, and their *quadratic* mean is—

$$\sqrt{\frac{a^2+b^2+c^2+d^2}{4}}.$$

Of course, if the terms of the series of numbers are unequal, then the quadratic mean will be the highest, next the arithmetic, and then the geometric and harmonic means; but if all the terms of the series are equal, then their means are equal too. The chief practical question in vital statistics is not so much either the value of a true or pure average, or arithmetical mean, or even the probable value of a fixed quantity, but rather the probable value of an *average* or variable quantity ; the question being in most cases, how far the mean is a trustworthy approximation to the true value sought. Its degree of approximation may be determined by working out the mean and probable errors ; the smaller the latitude of error the more trustworthy the series from which the mean number is drawn.

The *mean error*, that is, the divergence of the individual terms of the series from its mean, is conveniently performed in the following way : (1) find the mean of the series, then find the mean of all the observations *above* the mean, and subtract the mean from it ; this gives the mean error in excess ; (2) find the mean of all the observations below the mean, and subtract it from the mean ; this gives the mean error in deficiency. Add the two quantities, and take the half ; this is the mean error. It will be at once obvious that the greater the mean error the greater is the need for the series to be extended, in order to compensate for the unreliability of each term of the series ; and that the value of any series of observations increases with their number and with their equality.

The *probable error* of a mean result may be conveniently obtained by application of the following rules as given by Jevon :—

1. Draw the mean of all the observed results.
2. Find the excess or defect, that is, the error, of each result from the mean.
3. Square each of these reputed errors.
4. Add together all these squares of the errors.
5. Take the square root of the sum.
6. Divide the square root by the number of results.
7. Multiply the quotient by 0·67449, or by $\frac{2}{3}$.

Thus, suppose of the series 21, 32, 27, 25, 18, 33, whose mean is 26, we want to know the probable error of that mean. Now, the apparent errors of each number of the series from the mean are 5, 6, 1, 1, 8, 7 ; their squares are 25, 36, 1, 1, 64, 49; and the sum of the squares is 176. The nearest square root in whole numbers of this sum is 13, and this, divided by 6, or the number of the series, gives 2·16, which, multiplied by the factor 0·67449, yields 1·45 as the probable error of the mean of the series.

This calculation of the probable error may be described in another way, by saying that it is the error of mean square multiplied by the mathematical constant 0·67449.

The error of mean square is the quadratic mean of the apparent errors, or the result of dividing the square root of the sum of the squares of the apparent errors by the number of terms.

To compare two or more similar groups together, the probable error of each may be first ascertained, then the relative values of each will be as the reciprocals of the squares of the probable errors; that is $\frac{1}{(pe)^2}$, where (pe) is the probable error. Thus, if we have two groups, A and B, A having a probable error of 10 per cent. and B one of 2 per cent., the value of A will be $\frac{1}{10^2} = \frac{1}{100}$, and the value of B will be $\frac{1}{2^2} = \frac{1}{4}$, or the group B will have a value 25 times as great as A.

The relative values of two or more series are also as the square roots of the numbers of units of observation. So also, by increasing the number of observations in any inquiry, the value (or accuracy) increases as the square root of the number.

Thus a group of 10 observations is to a group of 100 as $\sqrt{10}$ to $\sqrt{100}$, or as 3·16 to 10.

In many cases the method by successive means is very useful. This consists in taking the mean of the mean numbers successively derived from a constantly repeated series of events (say the mortality to a given population yearly). Supposing, for example, the annual mortality in England to be, in successive years, 22, 23, 21, 26, 23, 21, 22, 28, 22, 21 per 1000 living, the successive means would be—

$$\frac{22+23}{2} \quad \frac{22+23+21}{3} \quad \frac{22+23+21+26}{4},$$

and so on, until the numbers are so great as to give every time the same result. It is useful to calculate the successive means in both the direct and inverse order, viz., from first to last, and then from last to first, *i.e.*, putting the two last together, then the three last, &c., so as to see if the variation was greater at the end of a series than at the beginning. The degree of uncertainty is then the mean variation between the successive means.

A plan almost the same as this has been used; a certain number of facts being recorded, the sum is divided into two, three, or more parts, and it is then seen whether the results drawn from the lesser groups agree with that drawn from the larger group and with each other. If there is any great difference of results, the numbers of the lesser groups are not sufficient. In the instance given above, the mean of the ten years is 22·9; the mean of the first three years is 22; of the second three years is 22·33; of the third three years is 24. The term of three years is therefore far too short to allow a safe conclusion to be drawn. The mean of five years again is 23, and of eight years is 22·8, numbers which are much nearer each other and the mean of the whole ten years.

What is known as Poisson's formula is very frequently employed to determine the liability to error in vital statistics. Thus, say 500 persons are sick with a certain disease, and 165 of them, or 33 per cent., have died, and it is required to know whether these numbers are sufficiently great to say that this mortality rate is approximately constant and reliable for the particular disease in question; or whether the figures are too small to accept this death-rate as correct.

Poisson's formula says if $\mu =$ the total number of observations, made up of m in the direction of recovery, and n in the direction of death, then $m + n = \mu$; and that the true proportion of each group to the whole number of cases will be in the proportions represented by the formula $\frac{m}{\mu} \pm \frac{2\sqrt{2 \times m \times n}}{\mu^3}$. In the case cited, the probability of recovering is represented by $\frac{m}{\mu}$ or $\frac{67}{100}$ and of dying by $\frac{n}{\mu}$ or $\frac{33}{100}$.

The possible error is expressed by the second part of the formula $\frac{2\sqrt{2 \times m \times n}}{\mu^3}$, and the smaller will be the value of this possible error the larger the total number of cases, or μ.

Applying this portion of the formula, we get $\frac{2\sqrt{2 \times m \times n}}{\mu^3} = \frac{2\sqrt{2 \times 67 \times 33}}{\mu^3}$ $= 0{\cdot}1330$ to unity, or 13·3 per cent., as the probable error—a figure which is very high, and suggestive of the view that the number of cases is too few for us to accept the mortality rate of 33 per cent. as found, as being approximately correct.

The application of averages or means, when obtained, it will be seen, are of great importance, but only when founded on a sufficient number of cases. There is always a danger of attaching too much value to means or averages, forgetting how great a range there may be above and below them, and it is by reminding us constantly of this that calculations of the mean and probable errors, as well as the use of Poisson's rule, are so useful.

In addition to averages, it is always desirable to note extreme values, that is, the two ends of the scale of which the average is the middle. To use Guy's pointed expression, "averages are numerical expressions of probabilities; extreme values are expressions of possibilities."

BIBLIOGRAPHY AND REFERENCES.

ANSELL, *Statistics of Families*, Lond., 1874.

BLOCK, *Traité de Statistique*, Paris, 1878. BRISTOWE, "The Mutual Relations of the Birth-rate and Death-rate," *St Thomas's Hospital Reports*, vol. vii., 1876.

DE CHAUMONT, *Lectures on State Medicine*, Lond., 1875. DE MORGAN, *An Essay on Probabilities, and on their Application to Life Contingencies and Insurance Offices*, Lond., 1838.

FARR, *Vital Statistics*, a Memorial Volume of selections of writings, edited by Noel Humphreys for the Sanitary Institute, Lond., 1885; also *English Life-Table, No. 3*, Lond., 1864.

GUY, Article on "Medical and Vital Statistics," in the *Encyclopædia of Anatomy and Physiology*, Lond., 1849.

HUMPHREYS, "The Value of Death-rates as a Test of Sanitary Condition," *Journ. Statistical Soc. Lond.*, Dec. 1874; also "The Recent Decline in the English Death-rate," *Idem*, June 1883.

Jevons, *Principles of Science:* Chap. xvii. on the "Law of Error."

Laycock, *Principles and Methods of Medical Observation and Research*, Lond., 1864. Longstaff, "The Recent Decline in the English Death-rate." *Journ. Statistical Soc. Lond.*, June 1884; also on "The Seasonal Prevalence of Continued Fevers in London," *Trans. Epidem. Soc. Lond.*, 1885.

Milne, Article on "Human Mortality," in the 8th edition of the *Encyclopædia Britannica.*

Neison, *Contributions to Vital Statistics*, 3rd ed., Lond., 1857. Newsholme, *The Elements of Vital Statistics*, Lond., 1889—this contains a good bibliography; also *The Brighton Life-Table*, Brighton, 1893.

Radicke. *On the Importance and Value of Arithmetical Means*, published by New Sydenham Society, 1861. Ransome, *On some of the Numerical Tests of the Health of Towns*, Lond., 1863; also "On the Form of the Epidemic Wave, and some of its Possible Causes," *Transac. Epidem. Soc. Lond.*, 1881–2; also "On the Vital Statistics of Towns," *Manchester Statistical Soc.*, 1888. Registrar-General, *Annual Reports* for successive years; also *Census Reports.* Rumsey, *On some Fallacies of Vital Statistics*, Lond., 1875.

Simon, *Public Health Reports*, edited by Seaton and republished by Sanitary Institute, 1887. *Statistical Reports of the Army and Navy* for successive years.

Tatham, *Manchester Life-Tables*, Manchester, Blacklock & Co., 1893; also *Report on the Health of Greater Manchester*, 1891–3, Manchester, 1894.

Walford, *On the Number of Deaths from Accident and Violence in the United Kingdom and some other Countries*, Lond., 1881. Welton, "The Effect of Migration in Disturbing Local Rates of Mortality," *Journ. Soc. of Actuaries*, vol. xvi., 1871. Willoughby, "Figures, Facts, and Fallacies," *Sanitary Record*, 1884.

CHAPTER XVII.

OFFENSIVE TRADES.

CERTAIN businesses frequently come under the notice of the medical officer of health as giving rise either to nuisance, or as proving injurious to the health of the community. While the actual number of these so-called offensive trades is considerable, and the facts as to their being a frequent source of nuisance are beyond dispute, it must be admitted that the evidence regarding their prejudicial influence upon the health of either workmen engaged in them or upon surrounding populations is imperfect. Be this as it may, their possible powers for evil are so great that their supervision constitutes one of the most important duties of the sanitary authority; and a knowledge of the chief sources of nuisance likely to arise in each business or group of businesses is imperative upon the sanitary officer. Ballard, to whose exhaustive report on effluvium nuisances, made to the Local Government Board in 1876–7, we are mainly indebted for information on this subject, classifies the offensive trades as follows:—

(1) The keeping of animals.

(2) The slaughtering of animals.

(3) Other branches of industry, in which animal matters or substances of animal origin are principally dealt with.

(4) Branches of industry in which vegetable matters are principally dealt with.

(5) Branches of industry in which mineral substances are principally dealt with.

(6) Branches of industry of mixed origin in which mineral, vegetable, and animal substances are dealt with.

Keeping of Animals.—Offence most usually occurs from the keeping of either cows, horses, or pigs, and the question of nuisance in connection therewith arises mainly in towns. The sources of nuisance from the keeping of these animals are (*a*) the storing of grains or other food-stuffs; (*b*) emanations from their dung; (*c*) fouling of the air in or around sheds, stables, or styes; (*d*) soakage of urine into the ground from imperfect paving.

Few cow-sheds are adequately ventilated, and when we remember that the cow passes daily large quantities of semi-liquid manure, much urine and flatus, the difficulties in the way of keeping cow-sheds sweet in smell are enormous. In addition to this, grains are constantly stored in towns as food for cows. These grains are in a wet state, and unless freed from liquid rapidly generate a sour odour from acetous fermentation. The only remedy for these defects is to provide large airy cow-sheds, with impermeable floors, an ample supply of water, racks and partitions made of iron, and walls lined with glazed tiles. The general regulations in force as to cow-keeping will be more fully referred to in the next chapter, when considering the legislation relating to milk-supplies.

The keeping of stables and mews in proper order presents daily difficulties to the sanitary authorities of towns, especially when the floor above is used as a habitation. Similar objections are likely to arise in connection with stables as with cow-sheds. The chief source of nuisance is the storage of dung in heaps where it is liable to ferment, and when disturbed to give off watery vapour highly charged with ammonia. Horse-dung should be either removed daily, or stored in open iron cages near the stable door. Ammoniacal emanations may be controlled by damping the manure with dilute sulphuric acid, which in no way will decrease its commercial value as a fertilising agent.

As regards the keeping of pigs, the Public Health Act, 1875, sec. 47, states that pigs must not be kept in towns so as to be a nuisance, and the Public Health (Lond.) Act, 1891, sec. 17, prohibits pigs being kept in the metropolis so as to be either a nuisance or within 40 feet of a street. Pig-styes, in all places, should be situated at a considerable distance from dwelling-houses; they should have impermeable floors, with a proper slope, and be provided with a gutter communicating with the drain by a trapped opening. The "wash" and other materials evolving effluvium should be kept in air-tight vessels.

The keeping of poultry in large towns is often a source of nuisance, especially among the poor, who frequently endeavour to keep fowls either in the cellars of their houses or in very small back yards. The only effectual remedy is to forbid the keeping of poultry in towns altogether.

Slaughtering of Animals.—While the general state of the law in regard to slaughter-houses and knackeries is considered in the next chapter, it is necessary in this place to briefly mention those features of these businesses which are liable to be sources of offence or nuisance. Places for the slaughtering of animals are either private or public (abattoirs). In this country the greater number are private establishments, but it is hoped that the time is not far distant when private slaughter-houses will be abolished, as experience indicates that neither the public health nor the sale of diseased flesh can be efficiently safeguarded except by a system of abattoirs.

The chief difficulties in connection with slaughter-houses and knackeries arise from the filthy way in which the live animals are kept before slaughter, or owing to putrid carcasses or other material being allowed to remain on the premises, or from garbage and refuse. "The place where cattle are kept and fed for several days before killing is technically called a 'lair,' but where they are temporarily detained before slaughter is called a 'pound ; but in small businesses the one shed or place serves for both lair and pound."

If strictly defined, a knacker is properly a horse slaughterer, but he also kills old and diseased animals other than horses, and commonly receives carcasses of animals which have died of disease or violence as well. In addition to the sources of nuisance common to slaughter-houses also, the chief causes of offence in knackeries arise not from the slaughtering, but from subsidiary trades—bone-boiling, flesh-boiling (for fat extraction or cats' meat), manure-making, &c., &c.—which are usually carried on at knackeries in order not to waste the materials.

The ordinary slaughter-man or butcher disposes of the "offal" or débris readily. The blood is either used for making "black puddings," when mixed with fat and condiments, or it is sold for pigs' food, or it is defibrinated and utilised in Turkey-red dyeing, or it is sent to the maker of blood albumin. The fat goes to the fat-melter; the hides of cattle go to the tanner, the feet to the tripe-boiler, and sheep-skins to the fell-monger. The first stomach of cattle and sheep is cleaned for human food (tripe); the second stomach is usually sold as food for dogs or pigs; the heart is used for human food; the liver and lungs are occasionally so destined, but more commonly are given to animals. The small intestines go to the gut-scraper, the small intestines of pigs being used for sausage skins; and the large intestines are used for human food. The intestinal contents are sold for manure.

In knackeries, all the soft parts are stripped from the skeletons of the animals; the bones, in turn, being utilised for boiling, like all the rest of the carcass.

The general principles for preventing nuisances arising from slaughter-houses and knackeries are summarised in the rule—observe strict cleanliness. The premises must be conveniently situated, well lighted, ventilated, drained, and surrounded by a wall to conceal from the view of neighbours all the operations going on within. The floors should be impervious, smooth, suitably guttered, and sloped towards the drains. The lower six feet of the walls should be covered with some impervious smooth material, which can be thoroughly washed with a hose and brush. Wherever possible, iron should be substituted for woodwork. Proper receptacles, with well-fitting lids, should be provided for conveying all garbage from, and also where possible for conveying offensive matters to the works.

Utilisation of Blood.—Blood is utilised for either (*a*) making albumin, (*b*) making manure, or for (*c*) Turkey-red dyeing: all these businesses may be the source of nuisance.

In the making of blood albumin, the blood is received into shallow pans, allowed to coagulate, the clot separated and the serum desiccated. In this trade the blood must be fresh, hence there is rarely any nuisance connected with it; moreover, the business is commonly in connection with large public abattoirs, in which space and cleanliness are adequately secured. If complaints do arise, they are due to old material (clots, &c.) retained on the premises until putrid, and to a general unpleasant smell proceeding from the yards, difficult to remove except by the most scrupulous cleanliness. When not directly used for manure-making, all blood-clot should be placed in proper air-tight receptacles and burnt. No dung or other heaps should be permitted on the premises. The clot-room and drying-room are best lighted and ventilated from above; if possible, the air should be drawn off by a fan into a furnace flue.

Blood manure is commonly made by mixing blood-clot with impure sulphuric acid. The mixture is dried, powdered, and mixed with other materials, such as superphosphate, and finally dried either in the air or artificially. Nuisance may arise during the mixing of the acid, or during the drying by artificial heat. These operations should be conducted in a covered chamber, from which the acid vapours can be conducted into a flue or into water.

In Turkey-red dyeing of cotton a substance termed alizarin and derived from the coal-tar product, anthracene, is used to obtain the characteristic colour. Bullock's blood is used to fix the alizarin on the cotton, by the coagulation of its albumin. As the blood is always more or less putrid during the whole of the process, a constant smell exists in and about the dye-works. The nuisance may be obviated by the observance of scrupulous cleanliness, and by conducting the operation in a closed chamber provided with a suitable flue to carry off the offensive vapours under and into a fire connected with a high chimney.

Boiling of Tripe, Trotters, Flesh, &c.—The preparation of these materials as articles of food are a constant source of annoyance. Tripe is the first stomach of the ox or sheep. It is usually emptied of its contents at the slaughter-house, subsequently washed and scalded, and finally deprived of its villous membrane by being scraped with a knife or revolving brush. The tripe is then boiled, either in a boiler or in a pan having a steam-jacket. When cooked it is hung up to drain and cool. The fat is collected for soap-making, and the liquor run off into the drains.

Ox-feet and sheeps' trotters are sometimes boiled in conjunction with tripe. They are first roughly dressed, any adherent skin being removed (and set aside for glue-making), and boiled, the fat being collected from the surface and used for making "neat's foot oil." If not intended for food, ox-feet are very carefully prepared so as to avoid waste. The skins are stripped off and treated with lime-water for glue-making; the hoof is split open and the small deposit of fat found at the ends of the two long bones carefully set aside for "neat's foot oil" making. The hoofs are then washed and boiled; then finally set aside for the comb or button-maker. The small bones are used for manure, the long ones for knife-handles, and the liquor either run off into the drain or carefully skimmed for any oil it may contain. Many sheeps' trotters are too putrid for conversion into food; these are limed and then disposed of for manure. It is chiefly from the boiling of these offensive trotters that the main nuisances arise in connection with these industries.

In knackers' yards arrangements usually exist for boiling the flesh of horses and other animals which, while unfit for human food, can be utilised for making cats' meat or grease. The chief sources of nuisance in these places arise from (1) general filthiness of the premises, and want of reasonable care; (2) accumulation of materials, such as carcasses, bones, hoofs, horns, blood, skin, fat, and hair; (3) seething materials being removed from the boilers, thrown on the ground and emitting noxious smells while they cool; (4) fumes from the boiler in action, or while being emptied.

These nuisances can be obviated usually by the construction of suitable premises, with boilers so constructed with hopper-lids or other appliances that vapour from them will be drawn up the chimney. The cooling of the meat should be either rapidly carried out in cold chambers, or else be done in properly closed sheds from which the vapours can be readily carried to a flue or chimney. All waste material should be packed in air-tight buckets, and a sufficient staff of workers maintained to prevent excessive accumulations of work.

Bone-boiling is peculiarly offensive, as the vapours generated appear to travel long distances. A further offence arises from the fact that recently boiled bones, when heaped together, evolve an offensive steam possessing a strong musty ammoniacal odour. In this business, as in some of the others already mentioned, there would be less nuisance if the operations were conducted in steam-jacketed pans in place of pans on which the fire plays direct. The other general principles of nuisance prevention in this trade are practically identical with those already enunciated for tripe and trotter boilers.

Gut-Cleaning.—This trade is practically identical with gut-spinning and the preparation of sausage skins. Gut-scraping or cleaning is largely done by women. The small intestines of pigs and sheep are first washed and cleaned of their contents; they are then softened by soaking in cold salt water for from three to five days; they are then scraped on a bench by a wedge-shaped piece of wood. The repeated scraping gradually detaches all the interior soft parts, which pass along to go out of the cut end. Finally, only the peritoneum and a little of the muscular structure of the gut is left;

this is then thrown into water. If required for sausage skins, the gut is then simply placed in salt.

For making catgut, lengths of the scraped gut are sewn together with needle and thread; these, after being steeped in a weak solution of carbonate of sodium for a week, are then spun by means of a spinning wheel, the thickness of the catgut depending on the number of strands of gut in it. The catgut is usually bleached by exposure for two or three days to the fumes of burning sulphur in a special chamber, after which it is dried by being stretched over pegs in the open air, but protected from sun and rain.

Ballard says, "speaking generally, gut-scraping and gut-spinning establishments are the most intolerable of nuisances wherever they may chance to be located." The annoyance from these businesses is often mainly due to their being carried on in places quite unsuited for the purpose. The premises should always be provided with proper stone tables and other appliances; the storage of material for any length of time should be forbidden, and what material there is should be kept in properly covered and non-absorbent receptacles. The liquor should be deodorised with chlorinated water. The floors, walls, and general principles of construction of premises used for gut-scraping should be on the same lines as already indicated for slaughter-houses. No accumulation of stinking material should be permitted for a moment, and there should be proper vessels for conveying material to and from the place. The cleansing of these establishments must be frequent and thorough; for nothing will prevent a nuisance unless continuous care be exercised to keep the places clean, and never to allow filth to accumulate.

Fat-Melting, Dip-Candle-Making.—In these associated trades the materials used are kitchen stuff, dripping, fat, waste-meat, and inferior stuff obtained from the boiling down of bones and scraps at knackeries, tripe and glue-boiling works, &c., &c. The fat and grease "is melted either in pans (*a*) heated by an open fire, or (*b*) in pans which are steam-jacketed, or (*c*) by free steam and sulphuric acid."

Tallow is either beef or mutton fat or a mixture of them prepared and melted by one or other of the above means. Lard is pig's fat similarly treated. "Moulds" are candles shaped in moulds, and made from mutton suet. "Dips" are inferior candles made by dipping a wick into a melted fat made from inferior tallow.

In these businesses the sources of nuisance are (1) the storage of the fats; (2) melting the fat; (3) ladling the fat out; (4) storage of residues, technically called "greaves"; (5) general filth. As Ballard says, "The method of preventing nuisance commences at the slaughter-houses. As soon as the fat is removed from the animals it should be laid on racks, and it should not be packed until quite cold and hard." The residue or greaves is usually sold for manure, or, if of a better kind, as food for animals. The chief nuisance arises in the "rendering" or boiling of the fats. The fresher and sweeter the materials used the less is the danger of nuisance during the melting. The great secret in preventing nuisance at this stage is the avoidance of burning the materials, or even raising them to a high temperature. Practically, the temperature need not exceed 120° F. Owing to the residues having to be pressed in order to squeeze out all the fat, a nuisance often arises during the process; but by conducting the operation under cover, or in a special boxed-in apparatus, or in a chamber provided with a special flue, this source of offence can be avoided. In general terms, the principles of preventing nuisance from these trades are the same as those mentioned in the sections on tripe-boiling, &c., &c. In towns the only method of rendering permissible should be by free steam, or in steam-jacketed pans. Melting over an open fire should be forbidden; and unless fat-melters will adopt proper precautions, they should be compelled to remove from populous districts.

"General cleanliness, the use of good material, melting at a low temperature, and the use of steam and acid to melt the fats are the cardinal points to be attended to with a view to conducting this business without nuisance."

Soap-Making.—The ordinary neutral fats may be chemically regarded as salts, in which glycerin is the base and a fatty acid is the acid. Soap-making or saponification is the chemical action resulting from the interaction of an alkali (soda or potash) with a neutral fat (tallow), the glycerin or base being displaced and its place taken by the alkali. Soaps are divided into two classes, "hard" and "soft," according to their physical characters. Hard soap has soda for its base, while soft soap has potash as its base.

Soaps are made from fats of all kinds and from rosin (colophony) in combination with fats. The business of soap-making has a sanitary interest, not so much on account of the soap itself as of the fats and grease from which it is usually made, and the melting of which is often a nuisance.

The soap is usually made in large pans, set in brickwork, in which the fat or oil or both is placed, and heated either by fire or better by free steam discharged into the pans, or by steam contained in pipes surrounding the pan. To the melted fat caustic lye is gradually added, until the materials have been introduced in proper proportions to form soap. By the addition of common salt the soap floats insoluble and nearly dry on the top of the liquor. This latter is either run off, or the soap drawn off from the top. After further treatment with alkali and heat, the soap is run into frames in which it sets in suitable bars or shapes.

Soft soap is made on a similar principle as hard soap, the chief differences being that potash is used instead of soda, and that linseed, cotton, whale, or other oil is used in place of tallow or other grease.

The chief offensiveness in soap-making arises from the manipulation of the fats and oils. Some of these latter when heated are peculiarly unpleasant. Nuisance from these causes can be obviated by conducting the melting at the lowest possible temperature, by using pans or boilers with properly fitted lids, and connected with the chimney by a pipe or flue; or, if necessary, by carrying the vapours under and into the fire or into water. The lid of the pan should have a door through which the boiling can be superintended. In other words, the precautions demanded are identical with those required for fat-boiling.

Bacon-Curing.—Frequently this is a most offensive trade, owing to the smell generated by the singeing of the hairs of the pig. After the pig has been killed, it is "scalded" and washed, and then scraped to remove the hair, without singeing; but sometimes the hair is singed before scalding. The stench from the burning hair is very objectionable, and is often unnecessarily aggravated by leaving the carcass still smoking on the premises. A bucket of cold water thrown over it stops the smell at once.

Other sources of nuisance are the fumes from the smoking chambers where the bacon is dried, and also the brine, in which the bacon has been steeped, being retained on the premises and allowed to decompose. The mode of avoiding this latter nuisance is obvious.

The chief remedy is to so conduct the business in closed chambers that the fumes from the burnt hair and hot steaming carcasses shall be burned or condensed, or both, and then discharged through a furnace into a high chimney.

The preparation of bacon from imported American pork may at times be an annoyance, owing to the warm liquor, in which the pork is steeped, undergoing putrefaction, and being discharged into drains. The process employed consists in first steeping the pork for about twelve hours in water to extract the excess of salt, then drying it in a hot, closed room, warmed by charcoal fires, and subsequently exposing it to a current of air.

Fell-Mongering and Leather-Making.—A fell-monger is one who prepares skins for the leather dresser. The skins may be either fresh or old (foreign). The fresh skins are beaten with a mallet to free them from dirt, and then soaked and washed in water. The skins are afterwards limed in order to remove the hair. This process finished, the skins are hung up; and when the hair or wool can be readily detached it is removed by hand. When denuded of hair, the skins are called "pelts." The pelts are thrown into a pit containing milk of lime, and from this pit go direct to the leather dresser. Foreign skins, being dry and hard, first require soaking. The hair is not removed from them by liming, but by the "tainting" process, or that in which a certain decomposition occurs which loosens the wool; at this stage the hair or wool is readily removed by hand.

In fell-mongering "the chief nuisance is the storing of large quantities of skins, none of which are absolutely free from adhering portions of flesh, but the other operations can all be done without the creation of nuisance. It is true that large quantities of skins undergoing the 'tainting' process smell, but the smell seldom extends beyond the sheds."

Leather-making consists of two chief stages, "tanning" and "currying." Tanning is essentially a chemical preparation of the skin, or a conversion of the raw putrescible hide into an imputrescible and more or less flexible material known as leather. Currying is the treatment of the leather by means of fatty and other matters, by which it is rendered more soft, supple, waterproof, and generally improved in appearance.

Tanning consists in treating the "pelts," after removal of the lime by washing, with bark or some substance containing tannin. The chief substances used are oak bark, divi-divi (a South American bean), chestnut extract, hemlock extract, valonia (acorn cups from the Levant), mimosa bark, catechu, kino, sumach, &c., &c. The ground tan is placed in pits made of cement, stone, or brick; these being arranged in series so that the skins are passed through successively stronger tan liquors. After removal from the tan-pits, the leather is hung on poles in lofts to partially dry; from these poles it is transferred to heaps or piles on the floor to "sweat" a little. Subsequently the leather is scraped, oiled, and rolled to improve texture and surface, and is often coloured. Some hides are "shaved" or reduced in thickness by splitting. "Soft leather, such as glove kid, are not tanned, but 'tawed,' in which process treatment with alum and salt is the chief means employed."

In the currying processes the leather undergoes further steeping, heating, stretching, and drying. After this it is oiled; various kinds of oil are used, such as whale, castor, cod-liver, linseed, &c., &c.

The sources of nuisance from tanneries are various. The chief arise from solid waste, hair, bits of flesh, fat, skin, &c., as well as from the débris from the bottom of the lime and tan-pits. In the preparation of certain superior kinds of leather the pelts are placed in so-called cleaning pits, which contain dung or urine. These liquors have usually an abominable odour, and unless the process is performed in a suitable shed, so constructed that the contaminated air passes into either a tall chimney or through a fire, a nuisance is certain to be created. To these possibilities of offence must be added the possibility of the presence of arsenic in skins which have been roughly cured abroad. Wash-water from these skins, treated with arsenic and lime, readily generates sulphuretted hydrogen, sulphide of arsenic, and subsequently arsenious and sulphurous acids. The dangers from these poisons are best obviated by adding salts of iron, which form insoluble arseniates.

The remedies for the chief sources of complaint in respect of fell-mongeries and tanneries follow lines more or less indicated for other trades of this kind. The first essential is the construction of premises adapted to the business. The more carefully they are so adapted to the work the less likelihood is there of a nuisance arising. All pits should be water-tight, and the floors around smooth, impermeable, properly sloped, and well guttered. The walls of the buildings should be of hard smooth material, so that they do not absorb dirt, and can be frequently washed. The whole of the premises should be freely open to the air and light. The conveyance of all offensive skins and other débris to and from the tan-yard should always be in covered carts. A plentiful supply of water should be at hand, with a hose, as well as ample conveniences for the workpeople to wash themselves.

Glue-Making.—This important article is obtained by boiling bones (after the fat has been extracted), hoofs, horns, scraps cut off during the preparation of skins for leather, scraps of leather, parchment, &c.; in fact, from nearly every kind of waste animal tissue. "These various materials are first limed and the lime afterwards well washed out with water. The matters are then boiled, the fat being skimmed off the top, and the warm liquid glue run into shallow troughs and allowed to solidify. The solidified mass is then cut up into slices."

The character of the materials used in this business readily suggest the possible nuisances which may arise. The effluvium from the boiling process, in particular, is often most offensive; to this must be added the smell which emanates from the débris from the vats, after the glue has been drawn off, and commonly called "scutch." If this "scutch" be allowed to accumulate, the resulting odour is intolerable. The sooner it is barrelled and removed the better. In order to remove fat from it, the "scutch" is treated with hot water, or cold water with steam, and the fat skimmed off, the residue being pressed in coarse canvas to extract the least remnant of grease. The cake is used for manure. If kept dry and under cover, "scutch" will keep inoffensive for some time, but if allowed to accumulate in the open air it soon becomes offensive.

Nuisance may result from accumulations of raw material before use; this can be obviated by stacking and covering each layer of a few inches thick with lime; above all things, it must be kept dry. To avoid smell from the boilers, the vapours should be conducted under and into a fire and burned, or into a scrubber where it would be washed and condensed. It should always be conducted finally into a tall chimney.

Artificial Manure-Making.—This is a very large trade, and utilises an enormous quantity of material which otherwise would be wasted. The artificial manures are known by such terms as "blood manure," "bone manure," "superphosphate," "poudrette," &c., &c. The materials used in the making of these artificial manures are of the most varied kind, and include:—the débris of knackers' yards, offal from tanneries, tripe and trotter boilers, glue-works, scutch, shoddy, hair, bones, bone-ash, night-soil, coprolites, fossil remains, animal charcoal, soot, gypsum, burnt tar, and certain salines, such as sulphate of ammonia, common salt and nitrate of soda.

During the process of manufacture, impure sulphuric and hydrochloric acids are largely used. These acids are stirred up with the dry material until a thick paste-like mass is produced, the consistence of which varies. "Superphosphate" is prepared from a mixture of mineral phosphates and ground bones, treated with sulphuric acid. "Poudrette" is the name of a manure in the form of a dry powder, prepared from night-soil treated with sulphuric acid.

It is obvious that the general atmosphere of works devoted to businesses of this kind is always more or less impure. Nuisance is often complained of before the materials reach the works, owing to the stench caused during their conveyance there. This can be obviated by their being brought as far as possible in a fresh state, and always contained in air-tight receptacles. The highly irritant vapours which arise in the mixing and manipulation of the materials should invariably be either condensed and run into the drains or be carried to tall chimneys provided with efficient furnaces, while the whole of the operations should be conducted within large, airy, but closed buildings.

Oil-Cloth and Linoleum-Making.—Oil-cloth is made of coarse canvas, which is first coated with size and afterwards covered with a coating of very thick paint, laid on with a trowel and well worked in. Both sides of the canvas are treated in this way; and when one layer is dry, additional ones are similarly treated. Finally, the pattern is printed on. In place of size, frequently blood and lime are used. The drying is usually conducted in rooms artificially heated to 180° F.; and during this stage of the process very offensive vapours are given off.

Linoleum consists really of finely powdered cork mixed with linseed oil, and rubbed up into a kind of cement with rosin and kauri gum. "These ingredients are heated together in a steam-jacketed pot, provided with stirrers and an air-tight lid, a pipe from which conducts the vapours into the furnace." After being rolled this cement is ready for use, about 46 ℔ being mixed with 56 ℔ of the ground cork. Colouring matter is added, and after further mixing the compound is rolled out into sheets, and finally applied to the canvas made of jute. Only one surface of the canvas is thus covered, the other surface being protected by a layer of "backing," made of size and pigment or varnish.

In this business there is some danger of explosion, both during the powdering of the cork and when the cork and cement are mixed. The cement may take fire spontaneously, and also the fine dust floating in the air is liable to ignition.

Similar nuisances may arise in both these trades, and are due to the vapours given off by the hot oil. In the drying-rooms of oil-cloth factories it is hardly possible to breathe after the cloths have been drying for some hours, and the vapours often extend over considerable distances. The only remedy is to propel the vapours by means of a fan into the furnace, the process being greatly assisted by previously passing them through water.

India-Rubber Making.—In this manufacture and in vulcanising, offensive odours of sulphur compounds are caused, intermingled with those of tar-oils, &c. The crude rubber is boiled, washed, and incorporated with sulphide of antimony or sulphur. It is subsequently vulcanised by either the American process, which is chiefly mechanical, or by the English process, in which naphtha is used as a solvent. Ballard gives the processes concerned in creating nuisance to be (1) the boiling of the rubber; (2) the use of naphtha; (3) the discharge of steam from the vulcanisers; (4) the drying of sheets of vulcanised india-rubber upon steam-chests after washing them, the process giving an odour of burning rubber.

The means to be adopted to prevent these nuisances are,—to conduct the boiling operations in covered vessels, to use a ventilating fan, and to pass the effluvia through a heated furnace.

Varnish-Making and Oil-Boiling.—Varnishes may consist of (1) "drying oils," which become hard and resinous by oxidation in the air; (2) of oil varnishes made of a resin and a drying oil; (3) of compounds of gums, resins, &c., in a volatile liquid, which by evaporation leave the precipitated solids as a glassy coating. The principal resins used are copals, dammar, animi, and kauri, &c. All oils have not the same properties as drying oils, linseed oil being the most important of the commercial drying oils. This valuable property of drying or oxidising is increased by exposure to the air in a thin film; by heating, or, as it is called, boiling; by the addition of "driers" or substances which hasten desiccation by parting with some of their own oxygen, or acting as carriers of atmospheric oxygen; the chief of these are sulphate of zinc, peroxide of iron, and protoxide of lead. The two latter are true oxidisers, while the first acts by assisting the separation of vegetable albumin and other substances which hinder the drying.

The actual processes employed in these businesses are practically those of melting and fusion. The vapours given off are very pungent and irritating, affecting the eyes and causing headache, malaise, nausea, and vomiting. The essential agent in these offensive and far-reaching vapours is acrolein, which is a product of the decomposition of glycerin. It is a light, volatile liquid of low specific gravity, with a boiling point of about 120° F.

The only effective method of preventing nuisance is to have the pot in which these materials are heated covered with a hood, from which a pipe, provided with a fan, conducts the vapour into a fire. The nuisance is usually so great that a special hot coke fire, connected with a high chimney, should be provided to destroy these vapours.

Paper-Making.—Paper is now made from a variety of substances, such as waste paper, old rags, hemp, old ropes, straw, wood made into pulp, canes, bamboo, and esparto grass. The collection and storage of old rags and waste material of this kind is a constant source of menace to the public health, and constitutes an important sanitary question. Apart from this, they may heat and ignite spontaneously through slow combustion.

The preliminary preparation of rags and paper for paper-making consists of dusting them in an "agitator." After this they are cut into small pieces by hand and again dusted; after which they are boiled with carbonate of soda or caustic soda, or a mixture of both. Next they are bleached either by chlorine in a closed chamber, or by the alternate application of bleaching liquid and acid. Their subsequent treatment does not differ from that of esparto grass.

Esparto grass, after a preliminary cleaning by picking out of impurities, is boiled with a caustic alkali in a closed boiler into which steam is forced under pressure. The resulting liquor is always very foul, and if not turned into the nearest stream is run into a store tank. From this, by subsequent evaporation and incineration of the residue, soda is recovered, and constitutes a valuable economical operation. From the esparto or rag pulp, paper is eventually made by a series of mechanical procedures which do not suggest sanitary questions.

It is the esparto liquid which is the chief source of nuisance and offence. It has the colour of strong tea, is alkaline, strongly reducing, and emits a most offensive odour. It should never be permitted to be run into any stream or ditch near habitations. Annoyance commonly arises from the vapours given off during the boiling processes and from the mass of pulp while cooling. But the recovery of the soda usually leads to a greater nuisance, partly from the vapours yielded by the evaporation, but still more from the pungent empyreumatic fumes produced by the ignition of the residues from the store tanks.

All vapour should be conducted by a flue into a tall chimney, while the fumes produced during incineration should be conducted under and into furnace fires.

Some sanitary dangers exist in the employment of poisonous colouring agents for paper, but their effects are less apparent in the actual industrial processes than upon children and others handling or sucking the finished article. The use of poisonous colouring matters needs to be absolutely forbidden, as being both dangerous and unnecessary.

Manufacture of Alkali.—This industry has been the subject of special legislation, more particularly with reference to the gases and acid fumes which are produced. Improvements in apparatus for washing the issuing gases have materially reduced the prevalence of nuisances from this cause; moreover, the administration of the Alkali Act being supervised by special inspectors has largely removed this matter from the domain of the sanitary officer.

Apart from this, however, the industry in certain special features directly concerns the sanitary authorities, owing to nuisances which arise from what is known as "tank waste." To appreciate the nature of these possible nuisances, it is necessary to refer briefly to the materials used in the actual manufacture of alkali.

These materials are common salt, sulphuric acid, limestone, and coal. The salt is decomposed by sulphuric acid and heat, resulting in the production of sulphate of soda with liberation of fumes of hydrochloric acid. The sulphate is mixed with limestone and coal and heated, the ultimate product being a mixture of unburnt carbon, sodic carbonate, and calcium sulphide; the former gives the whole mass a black colour, hence the name of "black ash." If this black ash be treated with water, the sodic carbonate is dissolved out, leaving a residue known as "tank waste."

The main "source of nuisance from these waste heaps is the soluble matter which is a sulphuretted compound of calcium of indefinite composition, but which is mainly composed of sulphide of calcium, partly converted by oxidation into hyposulphite of calcium, and holding in solution with it a considerable but indefinite quantity of sulphur." If these waste heaps, from rain or any other cause, become moistened, they are liable to emit large volumes of sulphuretted hydrogen which are a constant nuisance and offence. In recent years some success has attended efforts made to so utilise the waste that the sulphur contained in these heaps may be extracted by appropriate chemical treatment. The processes adopted, in theory, should not produce any nuisance, but practical experience shows that sulphuretted hydrogen is not unfrequently evolved, with the result that the control and management of these mounds of black ash waste in the vicinity of alkali works still constitute a frequent source of anxiety to sanitary authorities in whose districts they are situate.

Other Trades associated with the Generation of Irrespirable Gases.—In addition to the foregoing there are a number of other businesses which possess the common feature of generating more or less of certain gases which are not only offensive to the smell, but which produce readily or immediately great irritation of the respiratory passages. Among industries of this kind we may mention more particularly the manufacture of oxalic acid from sawdust, the distillation of wood for the purposes of obtaining wood naphtha and pyroligneous acid, the making of coal gas, the distillation of tar, the manufacture of carbolic acid, the making of sulphate of ammonia and sal-ammoniac from the ammoniacal liquor of gas-works, the making of sulphuric acid and salt, the manufacture of chloride of lime and of glass, tin burning and the making of tin-plates, copper smelting, the calcining of arsenical ores, the making of coke and breeze, lime burning, ballast burning, the firing of pottery, and the making of bricks and of cement. These latter two businesses have been mentioned already elsewhere on page 155; the others, while involving the use of materials largely differing from each other, have this in common, that in the greater number the causes of offence and nuisance are such gases as chlorine, sulphurous acid, sulphuretted hydrogen, nitrous acid, carbon monoxide, carbon dioxide, marsh gas (methyl hydride), and olefiant gas (ethylene).

Among remedial or preventive agents free ventilation takes the first place; supplementary to it may be mentioned the employment of flannel respirators damped with water, or in the case of chlorine fumes with a solution of sulphite of soda. Practically, in the majority of these trades the best mode of preventing danger to health is to pass the deleterious vapours from kilns and other generators by a suitable hood and flue, assisted by a fan if necessary, through a furnace, and thence into a tall chimney. In some cases attempts may be made to deal with the nuisance by condensing and washing the fumes in a cold-water scrubber, or by passing them through absorbent media, such as sawdust, alkalies, milk of lime, and oxides of copper or iron; or through oxidising media, such as lead and manganese dioxide. Even these methods, however, are not always successful.

Trades associated with the use of Poisonous Metals.—There are practically six metals used in the arts and manufactures which more or less affect the health of the workers in them; these metals are arsenic, chromium, lead, mercury, phosphorus, and zinc.

"*Arsenic* is generally recovered from its ores by roasting, or by being exposed to a current of heated air in a reverberatory furnace, arsenious acid being formed. This is carried off as a vapour into long flues where it is precipitated." Metallic arsenic is rarely used except in the making of shot to give hardness. The emptying of the flues or chambers in which arsenious acid has condensed is a dangerous operation for workmen, necessitating the adoption of special leather suitings and head-pieces in which to work.

Arsenic enters largely into the composition of pigments, more particularly Scheele's green, Vienna or Schweinfurth green, and King's yellow; it is also much used in the preparation of artificial flowers. Absorption of the poison may take place through a mucous or raw surface, and even without any solution of continuity of the skin.

Prevention of poisoning depends largely upon the personal hygiene of the workmen, who should maintain great personal cleanliness, avoid taking any food or drink in the workrooms, regularly change their clothing before leaving the workshops, shave the face daily, and keep the hair short. All arsenic works should have suitable condensing chambers and be adequately ventilated. No water containing arsenic should be discharged into either sewers or streams. All persons who show symptoms of being affected by arsenic, no matter how trivially, should be at once removed from the influence of the poison.

Chromium salts are chiefly employed in calico-printing and calico-dyeing; they are also used in mordanting wool and in the dyeing of silk and linen, as well as in glass and porcelain painting. Poisoning follows the swallowing of small quantities of these chrome salts, the symptoms being not unlike those of poisoning with arsenic or mercury. The danger following the industrial use of the chromates depends less upon the risk of swallowing them than upon their action on the skin and mucous membranes, where they cause destructive ulceration. The pulverising of the chrome ironstone, which is the principal ore of chromium, does not appear to produce these specific injuries, but is chiefly objectionable by virtue of its being a dust. On the other hand, grinding of the chromates is particularly offensive. The fine dust falls on the skin and adheres to moist parts, which it quickly irritates, acting with the greatest severity on the nasal mucous membrane.

These latter effects are minimised by the use of respirators soaked in a solution of bismuth, which forms with chrome dust an insoluble compound. At all times the operation of pulverising these dangerous salts should be done in a closed chamber, provided with well-fitting glass windows to allow of observation of the progress of the work. The chimneys of all calcining ovens must be furnished with means to draw off the dust and fumes into suitable chambers, in order to prevent destruction of neighbouring vegetation and injury to men and animals. Care needs also to be taken that pollution of ponds, rivers, and rain-water does not occur.

Lead is used in a great variety of industries, and constitutes a most important article of commerce. Poisoning by this metal is also far from uncommon, it being introduced into the system either by direct absorption through the skin or mucous membranes, or by the inhalation of the vapour or powder produced in certain stages of its manufacture.

Among the more important industrial operations in which danger from lead-poisoning is liable to arise are,—varnishing of leather, and the imparting of a glaze to visiting and playing cards; the making of artificial flowers, leaves, and jewels; the weighting and dyeing of silk and alpaca; the preparation of lace and straw hats; the preparation of paints; calico-printing and dyeing; the glazing of pottery, bricks, &c.; the enamelling of iron plates and hollow ware; file-cutting, glass-cutting, type-founding, and type-setting. Lead-mining operations are not, as a rule, characterised by any special danger of lead-poisoning. During the smelting of the ore, however, the risks are greater, as there is always more or less of vaporised lead given off with the sulphur dioxide. For this reason, smelting always necessitates the use of condensing chambers, and the application of water in the form of either a shower-bath or steam.

In the making of red lead much dust is produced; and the escape of dust or vapour from the furnaces requires constant control. The grinding of the minium is also attended with danger, necessitating the use of closed chambers. As regards white lead or the carbonate, the manufacture is much more dangerous when carried out by some processes than by others. Three processes are in common use: (1) Thénard's method, by which the carbonate is developed directly by the action of carbon dioxide on the lead; (2) the Birmingham method, in which the carbon dioxide given off in the combustion of coke is utilised for the same purpose; (3) the Dutch method, in which acetic acid is slowly volatilised in pots, on the top of which thin sheets of lead are placed. The lead is oxidised so as to form subacetate of lead; this is again decomposed by carbon dioxide evolved from quantities of tan in which the pots are placed, the whole collection of pots piled one on the top of the other being technically known as a "stack."

This Dutch method is still the most extensively used and is distinctly the most dangerous. When the conversion of the lead into a carbonate is complete, girls enter the stack, place the white lead in trays, and carry these first to rolling mills and subsequently to drying stores, kept at a temperature of 200° F. After being dried, the white lead is ground, washed, and then dried to a very fine powder. The women engaged in removing the white lead, and in the various storing, grinding, and packing operations, are the chief sufferers from plumbism in this industry.

Among the important preventive measures to be adopted by workmen are, the wearing of gloves and the inunction of the hands and face with oil or grease. The conveyance of the carbonate from the stacks should be effected with care and, if possible, by covered shoots. The grinding should be performed by rollers in a closed chamber, fitted with an exhauster to draw off the dust into a condenser, water-bath, or other receptacle. Wet grinding would mitigate many of the evils here indicated.

The personal hygiene of the workmen is of the first importance, and above all, personal cleanliness is essential. Clothes should be made close fitting at the neck and wrists, and what is worn in the workshop should be left there and another suit worn at home. The use of warm baths should be encouraged, and on no account should any food, solid or liquid, be taken until the mouth is rinsed out with water, the hands washed, and the teeth brushed. If circumstances prevent workmen leaving the premises at meal times, they should be provided with a room for meals distinct and detached from the workplaces. No workman who has already shown a predisposition to plumbism should be allowed to continue the work; and all persons having open sores should be excluded from the workshops. The drinking of acidulated drinks, or the constant taking of iodide of potassium, should be discouraged. Small doses of sulphur, as favouring the formation of an insoluble sulphide of lead, may be taken advantageously; in a similar way, the freely drinking of milk may be of use. The cleanliness of the workshops is as important as that of the workmen. They should be kept free from dust by constant sweeping and washing, while the floors may be constantly moistened with either chloride of calcium in solution or by water.

Mercury is another important article of commerce, chiefly met with as the sulphide or cinnabar (vermilion) and sometimes as calomel or subchloride. Among the trades in which mercury in some form or another is used, and in which danger arises to the workpeople, may be mentioned the following:—

Bronzing, or that business in which plaster objects are given a metallic appearance by rubbing them with an amalgam consisting of equal parts of mercury, tin, and bismuth, and subsequently varnishing them. In hat-making the skins are often rubbed with a coarse brush, damped with a 10 per cent. solution of acid nitrate of mercury. In the subsequent operations of shaking clouds of mercurial dust are spread about, to the great danger of the workpeople, among whom mercurial poisoning is not uncommon. This sequence of event is also frequent in the operations of preserving and stuffing the skins of animals, from the fact that an arsenical soap and corrosive sublimate are largely used. These materials, on desiccation, generate a dust which permeates all the workrooms and may cause all the symptoms of poisoning by these metals. Gilding, in which a mercurial gold amalgam is employed, is another dangerous occupation, the workpeople being liable to intoxication, both during the preparation of the amalgam and in its application to objects to be gilded. Mercurial vapours are largely volatilised during all these operations. Artificial flower-makers are also exposed to the danger of mercurial poisoning, owing to the employment by them of the dangerous mercurial pigments, such as the chromate, the biniodide, and the sulphide. Photographers, electric battery makers, and also those engaged in making thermometers and barometers, are all exposed to risks of mercurial poisoning, the liability to this being all the greater, as mercury is a metal so volatile that it gives off vapour at all temperatures, and can undoubtedly be absorbed through the unbroken skin.

The sanitary precautions demanded in these mercurial trades necessarily follow closely those already detailed in the case of analogous businesses in which lead is used. All condensing chambers and flues employed in extracting the native cinnabar from the ore must be constructed so as to prevent the escape of fumes or gases. Workmen should be provided with long overalls to protect their clothes from mercurial dust; great cleanliness should be maintained by frequent washing, especially of the hands, face, and mouth. Chambers where mirrors are silvered need to be well ventilated, the outlets being placed below as the hurtful vapours and dust are heavy; similarly, in handling the amalgam, gloves should be worn and all vessels containing mercury should be kept covered, to minimise as much as possible the volatilisation of the objectionable vapours.

The diffusion of ammoniacal vapour in mercurial workshops has been said to be productive of much good in purifying the air of these places, but the *rationale* of the procedure is not very apparent, as metallic mercury does not combine with ammonia. Owing to the constant spilling of mercury on floors during the various operations of these trades, these should be of impermeable material, sloped, and provided with gutters from which the metal can be readily collected. In some places it has been found an advantage to have on the floors of workshops and elsewhere quantities of tin-foil or other metal, which, by readily forming an amalgam, reduces loss by waste and also lessens the danger of volatilisation.

Phosphorus, both as white phosphorus and in its amorphous (red) form, is used on an enormous scale in various manufactures. For industrial purposes phosphorus is prepared from bone-ash, the latter being decomposed by sulphuric acid, sulphate of calcium being formed. Most of the phosphorus is found in the liquid as superphosphate of calcium. The liquid is evaporated to the consistence of a syrup, then mixed with one-fourth its weight of charcoal, and dried by heating in an iron vessel. The resulting dry mass is heated to redness, half the phosphorus distils over and is collected into the water, while the other half remains combined with calcium in the retort as pyrophosphate. At this stage the phosphorus is impure, containing compounds of arsenic, carbon, sulphur, silicon, and red amorphous phosphorus. It is subsequently purified by either pressing, when heated under hot water, or by chemical treatment with bichromate of potassium and sulphuric or nitric acids. It is usually sold in the form of sticks, the melted phosphorus being sucked into glass tubes.

The red or amorphous phosphorus is formed by heating phosphorus in a closed vessel. It consists of red scales, which do not become ignited on coming in contact with the air until it reaches a temperature of 260° C. or 500° F., when it becomes reconverted into the ordinary form. This red phosphorus is largely used in the preparation of "safety" matches.

During the purification of phosphorus arseniuretted and sulphuretted hydrogen, also phosphuretted hydrogen and phosphoric anhydride, are given off in large quantities. Hence great precautions need to be taken by workmen to avoid risks involved in the inhalation of these fumes. The manufacture of red phosphorus may lead to the development of similar gases, owing to the impurities in the phosphorus which is used for conversion into the red form. The most obvious sanitary precaution in all these operations is the careful closing of the digester, the making of it air-tight, and the exercise of care during opening to avoid the escape of the noxious fumes.

The chief business in which phosphorus is employed is that of making matches. After being cut to the required shape and size, the wooden stems of the matches, to the number of from 3000 to 6000 at a time, are fixed in a frame, are warmed on a hearth and then dipped to the required depth into melted sulphur, whose temperature is not much above 235° F. By giving the frame a shake, superfluous sulphur is removed; the sulphur-tipped stems are next dipped into the igniting material; this material is formed of white phosphorus, which should not amount to more than 8 per cent. of the mass, though in England the proportion is usually much larger, melted under hot water and mixed with oxidising materials (such as peroxide of manganese, nitrate of potassium, litharge, or even chlorate of potassium), and some kind of material to fix it on the match (usually glue or gum), and some colouring matter (such as umber, aniline colours, or ultramarine); this mixture is used either hot or cold. Subsequently the matches are left in the frames in warm air (85° F.) until they are quite dried, when they are taken out of the frames, and made up in bundles or put direct into boxes.

In "safety" matches, the red phosphorus which is employed for them is contained in the rough rubbing substance on the box, and not in the igniting material on the match-heads. This igniting material is fixed by glue to the matches, and is composed of chlorate of potash (10 to 40 per cent.), iron pyrites, peroxide of manganese, powdered glass, sulphide of antimony, and some adhesive matter, such as glue.

The dangers attending the purification and distillation of phosphorus have been mentioned. The storage and carriage of phosphorus demands care. It should always be kept in glass or stoneware vessels containing water, and be placed in cool chambers away from all risk of breakage. For transport, all the vessels should be provided with handles, and be invariably labelled to show which is the upper side.

As might be expected, the operations of match-making are by no means free from danger. This arises from the presence of phosphorus in the match-heads, and from the sulphur employed as a medium between it and the wood. Owing to the constant evolution of sulphurous acid, the pans in which the sulphuring is done should be covered with a proper lid, and be provided with a pipe to conduct the fumes into a tall chimney. Owing to the danger of explosion, the preparation of the igniting material must be conducted in proper vessels heated by steam or water, with air-tight covers, means of carrying off offensive vapours, and safety-valves for the ready escape of gases suddenly produced. The removal of the finished matches from the frames, the making of them into packets, and the placing in boxes, all involve risks of ignition. The need of great caution in these operations is manifest, and vessels of water should always be close at hand.

The sanitary precautions required in this business are the provision of large roomy workshops with good ventilation, assisted by fans or flues, and the exercise of extreme personal cleanliness, especially before partaking of food. The same clothing should not be worn at home as in the workshops. The hours of dangerous labour should be reduced to a minimum consistent with industrial economy. The inhalation of turpentine vapour, to favour oxidation of the phosphorus, and the washing out of the mouth with weak alkaline solution of carbonate of sodium or lime-water and charcoal are all to be recommended. As a substitute for turpentine, an aqueous solution of copper sulphate may be employed, as it precipitates the phosphorus as a phosphate, along with metallic copper. Charcoal is of value as a powerful absorbent of phosphorus.

Fortunately, owing to an adequate recognition of the dangers attending the making of matches and other industries in which phosphorus is employed, poisoning by this element is by no means common now in this country. The complete suppression of the use of white phosphorus is the surest preventive.

Zinc is chiefly met with either as a carbonate (calamine), or as a sulphide (blende), or as a red oxide, the colour of which is due to mixture with oxides of iron and manganese. Zinc is not absorbed by the skin, and its effects are limited to absorption of its vapour by inhalation, or inhalation of the dust. Zinc vapours are largely given off during extraction of the metal from its ores, also during the preparation of "galvanised" iron sheets for roofing, of galvanic iron wire, and the preparation of alloys. Iron is "galvanised" either by dipping it into molten zinc, and covering with a layer of sal-ammoniac which dissolves the oxide which forms on the zinc; or by first coating the iron with tin, by galvanic action, and then dipping in molten zinc. Galvanic zincing is performed by placing the metal to be galvanised in a zinc bath filled with a saturated solution of sulphate of zinc. Brass and copper are sometimes zinced.

Zinc is much used as an alloy; thus, brass consists of equal parts of zinc and copper; and German silver is merely brass to which some nickel has been added. Zinc dust is created in large quantities in the grinding of the oxide, and every precaution is needed to carry out this operation in suitable closed chambers, and to protect workmen by respirators. The proper condensation of all zinc vapour is imperative, combined with vigorous ventilation to free the workrooms from it.

The symptoms following exposure to the action of vapour of zinc are,—cough, difficulty of breathing, headache, giddiness, stiffness in the limbs, sickness, and vomiting. Excessive perspiration is not infrequent. The colic and itching of the skin which is frequently observed in persons exposed to zinc dust is often due to the action of impurities, especially of lead or of arsenic. Apart from this, however, zinc powder may mechanically cause irritation.

Manufacture of Horse-hair.—A large industry exists for the preparation of hair for mattresses, chairs, brush-making, &c. The hair so used is not limited to that of the horse, as cow and pig-hair are also employed. The manes and tails of horses and the tails of cows are the parts chiefly used. Except the best quality of horse-hair, all these are more or less filthy and dusty, from the intermixture of dung, pieces of skin, and earth.

The first procedure is to sort the hair into the long and short, the coloured and the white; usually this is a very dusty operation. The hair is then washed, and when dry is combed; this latter process removes the short hairs which have been previously overlooked.

The long white hairs are bleached by exposure to burning sulphur in a closed chamber; the long coloured hairs are dyed, usually black, with logwood and protosulphate of iron. The short hairs are sometimes dyed and sometimes not. If very dirty they are teazed and dusted in a "winnowing" machine; the resulting fine dust is commonly discharged into the air instead of into a furnace flue; the heavier dust is utilised for manure.

The short hair when dyed is commonly so treated with the dirt on; sometimes it is winnowed first. The hair is curled by being twisted into a sort of rope by a curling machine, it is then steeped in cold water, and on removal placed in ovens at a high temperature, after which the curl is permanent.

The chief sources of nuisance in connection with hair-works are the stench from the vapours of the dye-vat, and from the hot liquor discharged into drains. The statutory limit of temperature, above which liquids are inadmissible into sewers, is 110° F. The only remedy against the stenches from the dye-vats is the use of a water-sealed lid, with hood and a flue conducting the vapours into a scrubber or cold-water tank. Mere discharge into a chimney is rarely effective against annoyance, unless the chimney is very high, say 150 feet. As regards the nuisance from the discharge of hot liquors into drains, the only remedy is not to so discharge them until cold.

Another evil in connection with this industry is the possibility of infection with anthrax. It is due to infection by means of virus attached to the hair from animals which have suffered from the disease, and is practically identical with the subject of the succeeding section upon wool-sorting.

Wool-sorting.—A wool-sorter is a person who divides the wool of a fleece into "sorts" or classes of various qualities, that is, the coarser and finer portions are placed apart in separate bundles. In connection with the woollen industry this sorting constitutes an important form of labour. When a dry, dusty material is being sorted, such as mohair, alpaca, and camel's hair, there is always much dust in the air of the sorting-room; but when sheep's wool is being sorted, owing to the greasiness of the fleece, this is not the case. The sorting of wool is usually performed over a movable wire grating covering an opening, through and into which dust and the other fine matter falls. Dust is generated not only during the actual sorting of wool, but also during the opening of bales or other large packages of wool.

Owing to the prevalence of anthrax, malignant pustule or charbon among certain animals, a great liability to the infection of this disease exists among herdsmen, skinners, slaughtermen, unloaders of cargoes of hides, and the manipulators of various wools and hairs. In this respect, the most dangerous wools imported into this country are those from the districts around Lake Van and from Persia. There is liability to infection by the spores and bacilli of anthrax in any of three ways—either by inoculation through wounds of the skin, by swallowing, or by inhalation. In serious cases a fatal termination may result in twenty-four hours, and is rarely postponed beyond three to four days. In other cases the attacks are relatively slight.

As illustrating the sanitary precautions necessary in the conduct of this business, the following regulations modified from those originally drafted by Hime, and adopted by the Town Council of Bradford, may be conveniently quoted in this place:—

1. All bales of wool or hair shall be opened by some person skilled in judging the condition of the material. If he find the contents unobjectionable, they shall be sorted in the ordinary way. If, on opening any bale, dead or fallen fleeces or damaged materials are found, such bale shall be at once taken from the room where opened, and dealt with as noxious. All Van, Persian, damaged wool, fallen fleeces, and foreign skin, wool, or hair shall be deemed noxious, and shall not be opened in the sorting-room. All wool or hair shall, before sorting, be thoroughly saturated with water and then washed in hot suds, rolled and sorted while damp, or if steeping would be injurious to the article, then it shall be disinfected.

2. No noxious material (alpaca, pelitan, or East Indian cashmere) shall be opened in the sorting-room, but in a place specially set apart for the purpose, separate and distinct from the sorting-room, and all such material shall be opened over a fan by some person capable of judging the condition of the material.

3. The sorting-rooms for all dry and dusty materials shall be provided with extracting fans so arranged that each sorting board shall be independently connected with the extracting shaft, in order that the dust arising from the material being sorted may be drawn horizontally or downwards, and thus prevented from injuring the sorter.

4. The dust collected by the fan must not be discharged into the open air, but be received into properly constructed catch-boxes. It must be afterwards burnt. The

catch-boxes should be emptied at least twice a week. The sweepings from floors, walls, and from under the wire gratings or "hurdles" shall be similarly treated. All pieces of dead skin, scab, and clippings must be removed weekly from the sorting-room, and must not be dealt with or sold until they have been disinfected.

5. All bags or coverings in which wool or hair has been imported shall be picked clean and not brushed, and such bags shall not be sold or used for any other purpose until they have been disinfected.

6. No sorter having any exposed open cut or sore upon his person shall be allowed to sort.

7. A suitable room, outside the sorting-room, shall be provided in which the sorters can leave their coats during working hours.

8. Proper provision shall be made for the keeping of the sorters' food out of the sorting-room. No meals shall be taken in the sorting-room.

9. The sorting-rooms shall be well ventilated, by fans or otherwise; but as this cannot be effectually accomplished by open windows only, power shall be employed to secure downward or horizontal ventilation, so arranged as to protect the workmen from draught. The sorting-rooms shall be warmed during cold weather. Windows shall be kept open during meal hours.

10. No wool or hair shall be stored in the sorting-rooms.

11. The floor of the sorting-room shall be thoroughly sprinkled with a disinfectant, so as to allay dust, and swept daily after work is over. The sorting-room shall be thoroughly disinfected and the walls thereof limewashed at least once a year.

12. Requisites for disinfecting and treating scratches and slight wounds should be at hand in the sorting-room.

13. Proper provision shall be made for the sorters to wash in or near the sorting-room.

14. A copy of these precautionary regulations shall be hung up in a conspicuous place in every sorting-room.

CHAPTER XVIII.

SANITARY LAW

In this chapter it is proposed to summarise and review the most important features of the law in respect of the chief matters which concern the public health. While the main basis of so-called sanitary law as now in force in the different parts of the United Kingdom are the various Public Health Acts of 1867 (Scotland), 1875 (England and Wales), 1878 (Ireland), and 1891 (London), there are in addition a large number of other Acts of Parliament which, in various ways, strengthen or otherwise modify the foregoing. This condition of affairs naturally renders the whole subject of sanitary law a matter of some complexity. In the following pages we have deemed it more convenient rather to consider the general effect of these various legislative enactments, as a whole, upon each sanitary matter of importance, than to analyse each Act separately. At the same time, under each section of the subject, references will be made to the peculiarities of the legislation in force in the different parts of the kingdom; that is to say, how far the law, as affects England and Wales, differs from that in London, and how far that of Scotland and Ireland differs from either, both, or each other. By this arrangement, it is hoped that a comprehensive view may be obtained, consistent with the space at our command, of the general bearing of the law in respect of sanitary matters in all parts of the United Kingdom.

The essential and primary element in the administration of the sanitary law is the division of the country into sanitary areas, each of which is controlled by a "Sanitary Authority." Before considering the powers and duties of these authorities in connection with the public health, it will be more convenient, in the first instance, to explain their nature and areas of authority, and, secondly, to consider what are the statutory provisions with reference to the appointment by them of Medical Officers of Health, Surveyors, and Inspectors of Nuisances, and the general scope of the duties of these sanitary officials.

LOCAL SANITARY AREAS AND AUTHORITIES.

In England and Wales.—The whole of England and Wales outside the city of London is divided into (*a*) administrative counties, and (*b*) county boroughs. By the Local Government Act, 1894, the administrative counties are divided into county districts, some of which are urban, and others rural districts. For sanitary administration the county boroughs are deemed to be urban districts, and, with the other urban districts, constitute urban sanitary districts; while the rural districts, each consisting of one or more parishes, are rural sanitary districts.

In every administrative county there is a County Council, who may appoint one or more Medical Officers of Health for the county, and who have various other powers and duties in connection with the sanitary supervision and administration of the county, more particularly of complaining under section 299, Public Health Act, 1875, in cases where a Sanitary Authority is not doing its duty, and of enforcing the provisions of the Rivers Pollution Prevention Act. They have also considerable powers under the Isolation Hospitals Act, 1893, and as appeal authorities under the Local Government Act, 1894.

In county boroughs the mayor, aldermen, and burgesses, acting by the council, constitute the urban Sanitary Authority. In all other boroughs, the same, acting as the Municipal Council, become, for sanitary purposes, an urban District Council, and as such are an urban Sanitary Authority. In urban districts, other than county and municipal boroughs, the District Council constitutes the Sanitary Authority; but they may appoint committees, consisting either wholly or partly of their members, for the exercise of sanitary powers; but no such committee will hold office beyond the next annual meeting of the District Council, and the acts of every such committee must be submitted to the council for their approval (Local Government Act, 1894, section 56).

Similarly, in rural districts the District Council is the rural Sanitary Authority. Where the number of councillors of any such district shall be less than five, the Local Government Board may, by order, nominate such number of persons as are necessary to make up that number from owners or occupiers of property situated in the rural sanitary district. The persons so nominated are entitled to act and vote as members of the rural Sanitary Authority, but not further or otherwise. An alternative procedure is for the Local Government Board to order the affairs of the district to be administered by the District Council of an adjoining district in another county with which it may or may not have been united before the passing of the Local Government Act, 1894 (see section 24). Each rural District Council has all the powers, duties, and liabilities as a rural Sanitary Authority as were exercised by the old Boards of Guardians. They have also the same powers for appointing committees as have the District Councils of urban districts other than boroughs (Local Government Act, 1894, section 56).

The Local Government Act, 1894, creates new authorities in the shape of Parish Councils in every rural parish which has a population of 300 or more. Also, by order of the County Council, providing the "Parish Meeting" so resolve, a Parish Council may be established in any rural parish having a population of 100 and upwards, and, with the consent of the Parish Meeting in any rural parish having a population of less than 100. Also, with the consent of the respective Parish Meetings, neighbouring parishes may be grouped under a common Parish Council, but with a separate Parish Meeting for every parish so grouped. Although, by the Local Government Act, 1894, section 8, some few sanitary powers are possessed by Parish Councils, such as the utilisation of wells, springs, streams within its parish, and power to drain, clean, cover, or remedy the condition of ponds and stagnant pools, also to acquire or hire land for allotments, make official representation to the District Council under the Allotments Act, or to the Medical Officer of Health under the Housing of the Working Classes Act, or to the Local Government Board for granting of urban provisions to their parish or any part of it, these powers in no way derogate from the sanitary obligations of a District Council, which is the true rural Sanitary Authority.

The Parish Council may complain (section 16) to the County Council if the rural District Council have failed to provide or to maintain sufficient drainage or water-supply for the parish, or to enforce any provision of the Public Health Act, and in that event the County Council may take over to themselves the powers of the District Council for the purpose, or may make an Order for the necessary works to be carried out by the District Council, or by some person appointed by the County Council. Apart from expenditure under adoptive Acts, a Parish Council must not incur expenses involving more than a 6d. rate in any year, nor more than a 3d. rate without the consent of the Parish Meeting. They may raise money on loan, but only with the approval of the Parish Meeting, the County Council, and the Local Government Board.

The Parish Meeting has the exclusive power of adopting certain optional Acts, including the Burial Acts, 1852 to 1885, the Baths and Wash-houses Acts, 1846 to 1882, the Lighting and Watching Act, 1833, and the Public Improvements Act, 1860.

In large rural districts the District Council may appoint parochial committees for outlying parishes to act as a resident subordinate authority, and as its agents in the exercise of the powers delegated to them. If such exist, the members of these committees must be selected from the members of the Parish Council. These parochial committees are completely under the control of the rural Sanitary Authority which made them, and have no jurisdiction beyond the places for which they were respectively formed.

By section 15 of the Local Government Act, 1894, a rural District Council may delegate to a Parish Council any power which it may delegate to a parochial committee under the Public Health Acts, and thereupon those Acts will apply as if the Parish Council were a parochial committee.

The duties which, in the opinion of the Local Government Board, may properly be assigned to a parochial committee are:—(1) Inspection of their district periodically as to need of works of construction, and the presence or abatement of nuisances; (2) Superintendence of works of repair or construction; (3) To inquire into and report upon nuisances; (4) To examine and certify all accounts relating to expenditure within their district; (5) To report to the rural Sanitary Authority on all matters requiring attention, and upon the manner in which their officers and servants have discharged their duties.

Although the powers conferred on urban and rural Sanitary Authorities are in many respects identical, they are not invariably so. By section 276 of the Public Health Act, 1875, the Local Government Board may, on application of a rural Sanitary Authority, or of persons rated to the relief of the poor, whose assessments amount to one-tenth of the nett rateable value of the district, declare, by order, any provision of that Act in force in an urban sanitary district to be in force in such rural sanitary district, or part thereof. In like manner, the Private Street Works Act, 1892, and the Public Health Acts Amendment Act, 1890, may be put in force in the whole or part of any rural sanitary district. In amplification of the foregoing, by section 25 (7) of the Local Government Act, 1894, similar powers may be exercised by the Local Government Board, on application of a County Council, or with respect to any parish or part thereof on application of the Parish Council. Experience has shown that the provisions of the Public Health Act hitherto most frequently put in force are, sections 42, 44, 157, and 158, relating to cleansing and watering of streets, and making of bye-laws as to nuisances and new buildings. Other sections which are occasionally put in force are 112 and 114, relating to offensive trades, and 169, 170, which regulate the sanitation of slaughter-houses.

In order to simplify sanitary administration, the Local Government Act, 1894, section 36, requires every County Council to make such orders as will cause—

(1) The whole of each parish, and, unless the County Council for special reasons otherwise direct, the whole of each rural district, to be within the same administrative county.

(2) The whole of each parish, unless the County Council for special reasons otherwise direct, to be within the same county district.

(3) Every rural district which has less than five elected councillors, unless the County Council for special reasons otherwise direct, to be united to some neighbouring district or districts.

After March 5, 1896, these powers of the County Council pass to the Local Government Board.

The constitution of new boroughs can only be made by the grant of a charter by the Crown, on the advice of the Privy Council: notice of application, however, must be sent to the County Council and the Local Government Board (Local Government Act, 1888, section 56).

In London.—While the Public Health Act, 1875, and the Acts passed from time to time amending it, form the basis of the greater part of the sanitary law in the provinces, comparatively few sections of these Acts apply to the metropolis. Among the sections which do apply are sections 108 and 115, relating to the abatement of nuisances; sections 130, 134, 135, and 140 (as amended by section 2 of Public Health Act, 1889), relating to powers of the Local Government Board with respect to cholera and other infectious diseases; also sections 182 to 186, relating to bye-laws; and section 336, defining the relations of new Sanitary Authorities to completed sewage works of the old Metropolitan Board of Works.

In the rest of England and Wales it has been shown that there is practically one Sanitary Authority acting for each district. In London, with the exception of the Port of London which is under the City Corporation, there is no part where there is not more than one public body exercising the functions of a Sanitary Authority. It is impossible in this work to give a full account of the powers and duties exercised by such diverse bodies as the County Council, the Metropolitan Asylums' Board, the Corporation of the City, the Commissioners of Sewers of the City, the Vestries, the District Boards, the Woolwich Local Board of Health, the Police Commissioners, and the Commissioners of Baths and Workhouses.

By the Public Health (London) Act, 1891, section 99, the authority, hereafter called the Sanitary Authority, is (*a*) in the city, the Commissioners of Sewers; (*b*) in the parishes of Schedule A. of the Metropolis Management Acts, 1855 and 1885, the Vestry, except in Woolwich, where it is the Local Board of Health; (*c*) in the districts in Schedule B. the District Boards; and (*d*) in places in Schedule C. the Guardians, or, if there be none, the overseers for such place, defraying their expenses as if they were poor-rates.

In Scotland.—Every burgh is a separate area for public health purposes. Of the rural or "landward" parts of Scotland, the primary division is the county, which again is divided into parishes, which, as a rule, are much larger than in England. These parishes are in most counties divided into groups, known as County Districts, and each district is a unit for highway and rural public health administration. There are, on the average, about four districts in each divided county, and about eight parishes in each county district. The boundaries of a district may be altered from time to time, but a parish may not be partly in one county district and partly in another. In counties not divided into districts, the public health area of administration is the county, which of course in this connection does not include the burghs comprised within its geographical limits. Eight Scottish counties are undivided.

By the Local Government (Scotland) Act, 1894, the central public health authority in Scotland is the Local Government Board (Scotland). In each burgh the provost, magistrates, and town council, acting as "Burgh Commissioners," are the local authority for public health purposes, and as such exercise the powers conferred by the Public Health (Scotland) Acts on a local authority, and by the Burgh Police (Scotland), Act, 1892, on burgh commissioners.

In the landward or rural districts the public health authority, where a county is undivided into districts, is the County Council, acting together with one representative from the Parish Council of each parish in the county. Where a county is divided into districts, the local authority is the District Committee, consisting of the county councillors and of one representative from each Parish Council within the district. In divided counties, certain powers are reserved to the County Council, namely, the appointing of a Medical Officer of Health and Sanitary Inspector, also representing matters to the Local Government Board, and making bye-laws, regulations, and levying rates. The County Council, in addition to the District Committee, has power to enforce the provisions of the Rivers Pollution Prevention Act. County Councils and District Committees may appoint sub-committees to exercise their public health functions. In some counties, a sub-committee is appointed for each parish.

By section 44, Local Government (Scotland) Act, 1894, District Committees can constitute special districts in landward areas for lighting, scavenging, and provision of baths, wash-houses, and drying grounds. The cost of these services fall upon the special district, and is limited to a rate of ninepence in the pound. Though the same Act abolishes the old parochial boards, and constitutes in their place in each parish a Parish Council, this body has no important duties of sanitary administration.

There is nothing in the Scottish Statutes on the lines of section 276 of the English Public Health Act, 1875, or of section 25 (7), Local Government Act, 1894, with the result that there are no means of conferring burghal powers on landward local authorities, except by the constitution of a new police burgh, whereby the authority of the District Committee ceases, and the burgh is for most purposes taken out of the county, to be henceforth governed by elected commissioners. It is anticipated that the application of section 44 of the Scottish Act of 1894, above mentioned, will largely remove the disabilities attaching to the older and somewhat inelastic provision.

By the powers described, part of a landward sanitary area may be converted into a burghal area. By order of a County Council, however, the area of a whole landward district, that is, a county district, may from time to time be altered; and this even without reference to a central authority. The Secretary of State for Scotland is, however, apprised of the formation of any new police burgh.

In Ireland.—The public health administration in Ireland is governed mainly by the provisions of the Public Health Acts of 1878 and 1890, and the special Orders issued by the Local Government Board for Ireland in pursuance of the first of these Statutes. Though many of the urban areas are under the Act of 1878, still a great number are governed by special Acts, particularly the Towns Improvement (Ireland) Act, 1854, and the Towns Improvement Clauses Act, 1847. It would be a great advantage if the various Acts bearing upon public health administration in Ireland were consolidated. In the main, the Irish Act of 1878 is drawn on the lines of the English Act of 1875, but there are some differences in the provisions, as will be seen subsequently.

By the Public Health Act, 1878, the whole of Ireland is divided into (*a*) urban sanitary districts, and (*b*) rural sanitary districts, and each district is subject to the jurisdiction of a Sanitary Authority. Urban sanitary districts consist of:—

1. The city of Dublin.
2. Towns corporate (except Dublin).
3. Town of Carrickfergus, which has Municipal Commissioners under the Municipal Corporations Act (Ireland), 1840.

The foregoing are boroughs within the meaning of the Act of 1878, and the boundary of each urban sanitary district is conterminous with the borough boundary.

4. Eight towns under the Lighting of Towns (Ireland) Act of 1828.
5. Towns under the Towns Improvement (Ireland) Act of 1854.
6. Twelve towns under various local Acts.
7. Towns which have been constituted urban sanitary districts by Provisional Orders of the Local Government (Ireland) Board, and confirmed by Parliament.

The rural sanitary districts are those portions of a poor-law union which are not included in an urban sanitary district. There are 159 of these rural sanitary districts in Ireland.

In the various urban sanitary districts, above detailed, the urban Sanitary Authorities are the Corporations of the city of Dublin and of the corporate towns, and the various town or municipal commissioners of the other townships. These urban Sanitary Authorities have the same power as similar bodies in England to form and appoint committees.

By section 6, Public Health (Ireland) Act, 1878, the guardians of the union as a corporate body are constituted the rural Sanitary Authority. These rural Sanitary Authorities cannot delegate their powers to committees.

By an unfortunate omission in the Irish Act of 1878, no power is given to the Local Government Board to invest a rural Sanitary Authority in Ireland with urban powers. An exception exists in the case of a lapsed urban district, which, on becoming absorbed as part of the rural sanitary district in which it is situated, may, by order of the Local Government Board, be declared subject to any provisions of the Public Health (Ireland) Act, 1878, applicable to an urban district, the rural Sanitary Authority, so far as that particular area, being invested with the powers, duties, and obligations of an urban Sanitary Authority.

The Irish Local Government Board may also, by Provisional Order, separate from a rural district any municipal town or district wholly situated therein, whether the population be more than 6000 or not, and constitute it an urban sanitary district; or include any such town or district in an adjoining urban sanitary district. The Local Government Board may also add any town, constituted an urban sanitary district, to the rural sanitary district in which it lies. No such provisional order may be made except on petition from one or other town or district, nor, in the event of objection, until after due local inquiry. The Provisional Order is of no force unless and until it is confirmed by Parliament.

MEDICAL OFFICERS, SURVEYORS, AND INSPECTORS OF NUISANCES.

In England and Wales.—Section 189 of the Public Health Act, 1875, requires every urban Sanitary Authority to appoint one of each of these officers, and provides that the officers so appointed are to be fit and proper persons. A rural Sanitary Authority is not required to appoint a Surveyor, but by section 190 of the same Act must, from time to time, appoint fit and proper persons to be Medical Officers of Health and Inspector of Nuisances; the latter may also be the Surveyor. No special power has yet been given to County Councils to appoint county Inspectors of Nuisances, although such a course has been adopted in some cases. Two or more Sanitary Authorities may appoint the same Medical Officer of Health or the same Inspector of Nuisances; and, apart from this, the Local Government Board is empowered (section 286) compulsorily to unite districts for the purpose of appointing these sanitary officials to act in such special united districts. County Councils are authorised, by section 17, Local Government Act, 1888, to appoint county Medical Officers of Health, who are forbidden to hold other appointments or engage in private practice without the written consent of the council. Under this same section, Sanitary Authorities have power to avail themselves of the services of these county Medical Officers on such terms as to contribution to his salary as may be agreed with the County Council. So long as such an arrangement is in force, the obligation of the Sanitary Authority under the Act of 1875 to appoint a Medical Officer of Health is to be deemed to be satisfied without the appointment of a separate Medical Officer.

If any part of the salary of the Medical Officer of Health to a local authority is repaid, the Local Government Board has the same powers in regard to qualification, appointment, duties, salary, and tenure of office as it has in the case of a Poor-Law Medical Officer (Public Health Act, 1875, section 191).

Qualifications of Medical Officer.—Section 18 of the Local Government Act, 1888, requires (except when the Local Government Board, for reasons brought to their notice, may see fit in particular cases especially to allow) every Medical Officer of Health appointed after the passing of the Act to be legally qualified in medicine, surgery, and midwifery; and further, if appointed after the 1st of January 1892 to a district having at the last census 50,000 inhabitants or more, to be the registered holder of a diploma in Public Health under section 21 of the Medical Act, 1886; or have been, during some three consecutive years prior to 1892, a Medical Officer of a district with a population, at the last census, of not less than 20,000; or have been for not less than three years a Medical Officer or Inspector of the Local Government Board.

Tenure of Office by Medical Officer.—Unless a portion of the salary is repaid to the Sanitary Authority out of imperial revenue, transferred to the county and borough councils by the Local Government Act, 1888, the Local Government Board have no control over the tenure of office. If appointed under these conditions, the Medical Officer of Health may continue to hold office for such period as the Sanitary Authority may, with the approval of the Local Government Board, determine, or until he die, resign, or be removed by such authority with the consent of the Local Government Board or by that Board. The Sanitary Authority may suspend him, but must forthwith report their action, together with the cause, to the

Local Government Board, the latter Board having power to remove the suspension. In the event of disagreement as to either salary or duties, a Sanitary Authority have power to give six months' notice to determine the appointment, but only with the consent of the Local Government Board. Where no part of a Medical Officer's salary is repayable, none of these approvals is necessary; the authority may fix his salary at as low a sum as they please; and if he is appointed by an urban Sanitary Authority, section 189 of the Public Health Act, 1875, permits of his removal from office at their pleasure.

Duties of the Medical Officer.—The duties of a Medical Officer of Health are the same whether a contribution is made to his salary or not by the Local Government Board, except that in the latter case he must report his appointment to the Board within seven days. "A copy of the annual report and of every special report must be sent to the Local Government Board, whether there is any repayment of salary or not; but there is no compulsion in this respect as regards Medical Officers of Health appointed prior to March 1880, if no repayment of salary is claimed by the authority. County Councils are entitled to receive copies of all annual and other reports which the Medical Officer of any district within the county is required to send to the Local Government Board; and in default may refuse to pay any contribution to his salary which otherwise they would be liable to pay."

The regulations of the Local Government Board, issued March 23, 1891, and still in force, provide that the following shall be the duties of a Medical Officer of Health in respect of the district for which he is appointed, viz.:—

(1) He shall inform himself as far as practicable respecting all influences affecting, or threatening to affect, injuriously, the public health within the district.

(2) He shall inquire into and ascertain by such means as are at his disposal the causes, origin, and distribution of diseases within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation.

(3) He shall, by inspection of the district, both systematically at certain periods, and at intervals as occasion may require, keep himself informed of the conditions injurious to health existing therein.

(4) He shall be prepared to advise the Sanitary Authority on all matters affecting the health of the district, and on all sanitary points involved in the action of the Sanitary Authority; and in cases requiring it he shall certify for the guidance of the Sanitary Authority or of the Justices as to any matter in respect of which the certificate of a Medical Officer of Health or a medical practitioner is required as the basis or in aid of sanitary action.

(5) He shall advise the Sanitary Authority on any question relating to health involved in the framing and subsequent working of such bye-laws and regulations as they may have power to make, and as to the adoption by the Sanitary Authority of the Infectious Disease (Prevention) Act, 1890, or of any section or sections of such Act.

(6) On receiving information of the outbreak of any contagious, infectious, or epidemic disease of a dangerous character within the district, he shall visit without delay the spot where the outbreak has occurred, and inquire into the causes and circumstances of such outbreak, and in case he is not satisfied that all due precautions are being taken, he shall advise the persons competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and take such measures for the prevention of disease as he is legally authorised to take under any Statute in force in the district, or by any resolution of the Sanitary Authority.

(7) Subject to the instructions of the Sanitary Authority, he shall direct or superintend the work of the Inspector of Nuisances in the way and to the extent that the Sanitary Authority shall approve, and on receiving information from the Inspector of Nuisances that his intervention is required in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall, as early as practicable, take such steps as he is legally authorised to take under any Statute in force in the district, or by any resolution of the Sanitary Authority, as the circumstances of the case may justify and require.

(8) In any case in which it may appear to him to be necessary or advisable, or in which he shall be so directed by the Sanitary Authority, he shall himself inspect and

examine any animal, carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk, and any other article to which the provisions of the Public Health Act, 1875, in this behalf shall apply, exposed for sale, or deposited for the purpose of sale or of preparation for sale, and intended for the food of man, which is deemed to be diseased, or unsound, or unwholesome, or unfit for the food of man ; and if he finds that such animal or article is diseased, or unsound, or unwholesome, or unfit for the food of man, he shall give such directions as may be necessary for causing the same to be dealt with by a Justice according to the provisions of the Statutes applicable to the case.

(9) He shall perform all the duties imposed upon him by any bye-laws and regulations of the Sanitary Authority, duly confirmed where confirmation is legally required, in respect of any matter affecting the public health, and touching which they are authorised to frame bye-laws and regulations.

(10) He shall inquire into any offensive process of trade carried on within the district, and report on the appropriate means for the prevention of any nuisance or injury to health therefrom.

(11) He shall attend at the office of the Sanitary Authority or at some other appointed place, at such stated times as they may direct.

(12) He shall from time to time report in writing to the Sanitary Authority his proceedings, and the measures which may require to be adopted for the improvement or protection of the public health in the district. He shall in like manner report with respect to the sickness and mortality within the district, so far as he has been enabled to ascertain the same.

(13) He shall keep a book or books, to be provided by the Sanitary Authority, in which he shall make an entry of his visits, and notes of his observations and instructions thereon, and also the date and nature of applications made to him, the date and result of the action taken thereon and of any action taken on previous reports ; and shall produce such book or books, whenever required, to the Sanitary Authority.

(14) He shall also prepare an annual report, to be made to the end of December in each year, comprising a summary of the action taken during the year for preventing the spread of disease, and an account of the sanitary state of his district generally at the end of the year. The report shall also contain an account of the inquiries which he has made as to conditions injurious to health existing in his district, and of the proceedings in which he has taken part or advised under the Public Health Act, 1875, so far as such proceedings relate to those conditions ; and also an account of the supervision exercised by him, or on his advice, for sanitary purposes, over places and houses that the Sanitary Authority have power to regulate, with the nature and results of any proceedings which may have been so required and taken in respect of the same during the year. It shall also record the action taken by him, or on his advice, during the year, in regard to offensive trades, and to factories and workshops. The report shall also contain tabular statements (on forms to be supplied by the Local Government Board, or to the like effect) of the sickness and mortality within the district, classified according to diseases, ages, and localities. (See Appendix XII.)

(15) He shall give immediate information to the Local Government Board of any outbreak of dangerous epidemic disease within the district, and shall transmit to the Board a copy of each annual and of any special report. He shall make a special report to the Local Government Board as to any advice he may give to his Sanitary Authority as to the closure of any school or schools.

(16) When giving information to the Local Government Board of the outbreak of infectious disease, or transmitting to them a copy of his annual or any special report, he must give the like information, or transmit a copy of such report, to the County Council of the county in which his district is situated.

(17) In matters not specifically provided for in this Order he shall observe and execute the instructions of the Local Government Board on the duties of Medical Officers of Health, and all the lawful orders and directions of the Sanitary Authority applicable to his office.

(18) Whenever the Local Government Board shall make regulations for all or any of the purposes specified in section 134 of the Public Health Act, 1875, relating to the Prevention of Infectious Diseases, and shall declare the regulations so made to be in force within any area comprising the whole or any part of the district, he shall observe such regulations so far as the same relate to or concern his office.

The duties of the Medical Officer of Health to a *Port Sanitary Authority* are defined by the Local Government Board in terms which are very similar to those given above, omitting the references to regulated trades and inspection of food, and substituting "ships" for "houses," and "shipping within the district" for "district."

"He shall inform himself as far as practicable respecting all conditions affecting or threatening to affect injuriously the health of crews and other persons on ship-board within the district. He shall inquire into and ascertain by such means as are at his disposal the causes, origin, and distribution of diseases in the ships and other vessels within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation. . . He shall, by inspection of the shipping in the district, keep himself informed of the condition injurious to health existing therein. . . On receiving information of the arrival within the district of any ship having any infectious or epidemic disease of a dangerous character on board, or of the outbreak of any such disease on board any ship within the district, he shall visit the vessel without delay, and inquire into the causes and circumstances of such outbreak, and advise the persons competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and so far as he may be lawfully authorised to assist in the execution of the same. On receiving information from the Inspector of Nuisances that his intervention is required in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a ship, he shall, as early as practicable, take such steps authorised by the Public Health Act, 1875, on that behalf, as the circumstances of the case may justify and require . . also when any vessel within his district has had dangerous infectious disease on board, he shall give notice thereof to the Medical Officer of Health of any port in the United Kingdom whither such vessel is about to sail."

The Duties of a Sanitary Inspector.—In the Public Health Act, 1875, this officer is always spoken of as the Inspector of Nuisances, and he must be formally appointed under that title; the Act does not recognise the title Sanitary Inspector, whereas, as will be seen subsequently, the Public Health (London) Act, 1891, does so. Practically, the two titles are indifferently employed to indicate one and the same official. His duties are closely connected with those of a Medical Officer of Health, but the broad lines separating them will be apparent from the following definition of his duties formulated by the Local Government Board.

(1) He shall perform, either under the special directions of the Sanitary Authority, or (so far as authorised by the Sanitary Authority) under the directions of the Medical Officer of Health, or in cases where no such directions are required, without such directions, all the duties specially imposed upon an Inspector of Nuisances by the Public Health Act, 1875, or by any other Statute or Statutes, or by the Orders of the Local Government Board, so far as the same apply to his office.

(2) He shall attend all meetings of the Sanitary Authority when so required.

(3) He shall by inspection of the district, both systematically at certain periods, and at intervals as occasion may require, keep himself informed in respect of the nuisances existing therein that require abatement.

(4) On receiving notice of the existence of any nuisance within the district or of the breach of any bye-laws or regulations made by the Sanitary Authority for the suppression of nuisances, he shall, as early as practicable, visit the spot, and inquire into such alleged nuisance or breach of bye-laws or regulations.

(5) He shall report to the Sanitary Authority any noxious or offensive businesses, trades, or manufactories established within the district, and the breach or non-observance of any bye-laws or regulations made in respect of the same.

(6) He shall report to the Sanitary Authority any damage done to any works of water-supply, or other works belonging to them, and also any case of wilful or negligent waste of water supplied by them, or any fouling by gas, filth, or otherwise, of water used for domestic purposes.

(7) He shall from time to time, and forthwith upon complaint, visit and inspect the shops and places kept or used for the preparation or sale of butchers' meat, poultry, fish, fruit, vegetables, corn, bread, flour, milk, or any other article to which the provisions of the Public Health Act, 1875, in this behalf shall apply, and examine any animal, carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, milk, or other article as aforesaid which may be therein; and in case any such article appear to him to be intended for the food of man, and to be unfit for such food, he shall cause the same to be seized, and take such other proceedings as may be necessary in order to have the same dealt with by a Justice: Provided, that in any case of doubt arising under this clause, he shall report the matter to the Medical Officer of Health, with the view of obtaining his advice thereon.

(8) He shall, when and as directed by the Sanitary Authority, procure and submit

samples of food, drink, or drugs suspected to be adulterated, to be analysed by the analyst appointed under "The Sale of Food and Drugs Act, 1875," and upon receiving a certificate stating that the articles of food, drink, or drugs are adulterated, cause a complaint to be made, and take the other proceedings prescribed by that Act.

(9) He shall give immediate notice to the Medical Officer of Health of the occurrence within the district of any contagious, infectious, or epidemic disease; and whenever it appears to him that the intervention of such Officer is necessary in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall forthwith inform the Medical Officer of Health thereof.

(10) He shall, subject to the directions of the Sanitary Authority, attend to the instructions of the Medical Officer of Health with respect to any measures which can be lawfully taken by an Inspector of Nuisances under the Public Health Act, 1875, or under any Statute or Statutes, for preventing the spread of contagious, infectious, or epidemic disease of a dangerous character.

(11) He shall enter from day to day, in a book provided by the Sanitary Authority, particulars of his inspections, and of the action taken by him in the execution of his duties. He shall also keep a book or books, to be provided by the Sanitary Authority, so arranged as to form as far as possible a continuous record of the sanitary condition of each of the premises in respect of which any action has been taken under the Public Health Act, 1875, or under any other Statute or Statutes, and shall keep any other systematic records that the Sanitary Authority may require.

(12) He shall, at all reasonable times, when applied to by the Medical Officer of Health, produce to him his books, or any of them, and render to him such information as he may be able to furnish with respect to any matter to which the duties of Inspector of Nuisances relate.

(13) He shall, if directed by the Sanitary Authority to do so, superintend and see to the due execution of all works which may be undertaken under their direction for the suppression or removal of nuisances within the district.

(14) He shall, if directed by the Sanitary Authority to do so, act as officer of the said authority as local authority under the Contagious Diseases (Animals) Act, 1886, and any orders or regulations made thereunder.

(15) In matters not specially provided for in this Order he shall observe and execute all the lawful orders and directions of the Sanitary Authority, and the Orders of the Local Government Board which may be hereafter issued, applicable to his office.

Under section 191 of the Public Health Act, 1875, the Medical Officer of Health may exercise the powers with which an Inspector of Nuisances is invested by that Act. Section 192 of the same provides that the same person may be both Surveyor and Inspector of Nuisances. In common with other sanitary officials, Medical Officers of Health, Surveyors, and Inspectors of Nuisances are prohibited by section 193 from being concerned in contracts with the Sanitary Authority. Section 2 of the Public Health (Members and Officers) Act, 1885, has to some extent qualified these provisions for exceptional cases; but independently of any of the above, very severe pains and penalties are imposed by the Public Bodies Corrupt Practices Act, 1889, on every person who solicits, receives, or agrees to receive corruptly any gift, fee, loan, or reward on account of any member, officer, or servant of any public body doing or forbearing to do anything in respect of any matter or transaction in which such public body is concerned.

The duties of county Medical Officers of Health and of Surveyors have not yet been authoritatively defined; neither have the qualifications of Inspectors of Nuisances in the provinces been prescribed.

In London, under section 106 of the Public Health Act, 1891, every Sanitary Authority is required to appoint one or more Medical Officers of Health for its district. The same person may, with the sanction of the Local Government Board, be appointed Medical Officer of Health for two or more districts; but, except in cases allowed by the Board, every such person must reside in that district, or within one mile of its boundary. A Medical Officer of Health in London may exercise any of the powers with which a Sanitary Inspector is invested; and his annual report to the Sanitary Authority must be affixed to the annual report of that authority.

The qualifications necessary for a Medical Officer of Health in London are similar to those required for similar officers in the provinces; and subject to the provisions of the Public Health (London) Act, 1891, as to existing officers, the Local Government Board have the same powers as they have in the case of those in the rest of England and Wales, with regard to appointment, salary, duties, and tenure of office. This enactment (section 108) is, however, subject to the following provisions: (*a*) a Medical Officer will be removable by the Sanitary Authority with the consent of the Local Government Board, or by that Board, and not otherwise: (*b*) any such officer must not be appointed for a limited period only.

Every Sanitary Authority must appoint an adequate number of fit and proper persons as Sanitary Inspectors, and every one of them appointed after January 1, 1895, must be a holder of a certificate of such body as the Local Government Board may approve (at present the examining and certifying body is the Sanitary Institute), or must have been, during three consecutive years preceding 1895, a Sanitary Inspector or Inspector of Nuisances of a district in London, or of an urban sanitary district out of London containing, according to the last census, a population of not less than 20,000 inhabitants (Public Health (London) Act, 1891, section 108).

The regulations prescribed by the Local Government Board as to the duties of Medical Officers of Health and Sanitary Inspectors in London are very similar in terms to those which apply to Medical Officers and Inspectors of Nuisances in the provinces. It is noticeable that, under the Acts in force outside the metropolis, no qualification is demanded for this latter office; whereas, in London, such qualification is definitely explained. It is probable that a similar provision will be inserted in any future consolidation of the Public Health Acts for the country generally.

In Scotland, every County Council must appoint and pay one or more Medical Officers and Sanitary Inspectors, who shall not hold any other appointment, or engage in private practice without the express written consent of the council. "These officers may be re-appointed by the District Committees as district officers, every District Committee being empowered to appoint one or more Medical Officers and Sanitary Inspectors for their districts, or for any part of it." If they think necessary, the Local Government Board for Scotland may compel a District Committee as local authority to appoint a Medical Officer or Sanitary Inspector; and under their regulations, Sanitary Inspectors must be appointed wherever there is a town or village population exceeding 2000.

A Medical Officer must be a registered practitioner, and may not now be appointed for a county, district, or parish with a population of 30,000 or upwards unless he holds a diploma in Public Health under the Medical Act, 1886; and no person may, except with the special consent of the Local Government Board, be appointed Sanitary Inspector of a county unless he has been, during the three consecutive years preceding his appointment, the Sanitary Inspector of a local authority under the Public Health (Scotland) Acts.

Burgh Commissioners must appoint a Sanitary Inspector and a Medical Officer of Health. The latter officer must be registered, and if appointed after May 15, 1894, must also have the special qualification required in counties since the beginning of 1893.

"No Medical Officer or Sanitary Inspector, whether for a county, landward district, or burgh, can be removed from office without the sanction of the Scottish Local Government Board."

The model bye-laws recommended by the Local Government Board for Scotland to the various Sanitary Authorities for regulating the duties of Medical Officers and Sanitary Inspectors do not materially differ from those of the English Board.

In Ireland.—By section 11 of the Public Health (Ireland) Act, 1878, the dispensary medical officers are *ex officio* Medical Officers of Health for their respective districts. In addition to the Medical Officers of Health, the Local Government Board for Ireland requires each rural Sanitary Authority, when directed by them, to appoint a consulting sanitary officer or a medical superintendent officer of health, and for either of these posts the medical officer of the union workhouse, or any other duly qualified medical practitioner, is eligible. The officials in England called Inspectors of Nuisances or Sanitary Inspectors are in Ireland known as sanitary sub-officers, and for these posts the relieving officers, or the rate collectors of the several unions or other persons are eligible. Urban Sanitary Authorities are to appoint so many sanitary sub-officers as they, with the consent of the Local Government Board, may determine; also, when directed by the Board, they are to appoint one consulting sanitary officer or one medical superintendent of health, who must be a qualified medical practitioner; and an executive sanitary officer, with such qualification as the Sanitary Authority shall, with the consent of the Local Government Board, determine.

The appointments held by sanitary officers of both urban and rural authorities shall continue for such period as the Sanitary Authority may, with the approval of the Local Government Board, decide, or until the holder thereof die or resign. The regulations as to the duties of the several sanitary officers are similar to those of the English Local Government Board. There is no provision in the Irish Public Health Act for the appointment of a "Surveyor," but there is nothing to prevent a Sanitary Authority employing a Surveyor temporarily in order to execute any special work. There is, further, no power given to Sanitary Authorities to combine for the appointment of sanitary officers. Parliamentary grants are made annually in recoupment of portions of the salaries of sanitary officers; the amounts recouped to local funds is one-half of the salaries.

There is no provision in the Irish Act prohibiting sanitary officials being concerned in contracts made with the authority for any of the purposes of the Public Health Act, nor does the Public Health (Members and Officers) Act, 1885, extend to Ireland. The Public Bodies Corrupt Practices Act, 1889, however, does apply to Ireland as well as to England.

DEFINITIONS.

There are certain definitions of terms in the various Sanitary Acts which give to those terms meanings which are not the same as the common meaning. The more important of these definitions are the following:—

Building.—This word has a very wide significance. It includes wooden structures on wheels, also those without foundations, but resting simply on the ground. Under the Infectious Diseases Notification Act, 1889, the term building applies to boats, vessels, ships, tents, vans, sheds, and other similar structures used for human habitation.

House.—Though not absolutely defined, the term "house" is so extended as to include schools, factories, and other buildings in which persons are employed. For a structure to be a "house" it is not necessary that persons reside in it.

Owner.—Under the Public Health Acts, the term "owner" means the person who, for the time being, receives the rack-rent of the lands or premises in connection with which the word is used, whether on his own account or as agent or trustee for any other person, or who would so receive the same if such premises were let at a rack-rent. By rack-rent is meant the rent that is not less than two-thirds of the full nett annual value of the property.

Under Part II., Housing of the Working Classes Act, the owner of a property is held to be any person or corporation who has at least a twenty-one years' interest in it.

Drain means any drain of, and used for the drainage of *one* building only, or premises within the same curtilage, and made merely for communicating therefrom with a cesspool or like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed.

Sewers include sewers and drains of every description, except drains to which the word "drain," as above defined, applies. In other words, a sewer is a drain receiving the drainage of two or more buildings; and may be an open channel, such as a polluted water-course, as well as an underground culvert. Under the Metropolis Local Management Act, 1862, this distinction between drain and sewer is not accepted, but a combined drain is deemed to remain a drain. So again, in urban districts which have adopted section 19 of the Public Health Acts Amendment Act, 1890, the interpretation of "drain" is different. Whereas under the Public Health Act, 1875, if one or more houses drain into a common pipe, such common pipe or combined drain is a sewer; but under section 19 of the Amended Act this common pipe is deemed to be a sewer only if all the houses *belong to one owner;* if they belong to more than one owner, then the combined drain is a drain repairable at the owners' expense, and not a sewer repairable at the expense of the Sanitary Authority.

Canal.—Under the Canal Boats Acts, 1877 and 1884, the term "canal" includes any river, lake, water, or inland navigation "being within the body of a country, whether it is, or is not, within the ebb or flow of the tide."

Canal Boat.—This includes any and every vessel, however propelled, used for conveyance of goods along a canal, as above defined, but does not include a ship registered under the Merchant Shipping Act, 1894, unless the Local Government Board orders otherwise, which it may do on the representation of a Sanitary Authority or any of its inspectors.

Curtilage is defined as a "court-yard, backside or piece of ground lying near to a dwelling-house."

Slaughter-house includes the buildings and places commonly called slaughter-houses and knackers' yards, and any building or place used for slaughtering cattle, horses, or animals of any description.

Sanitary convenience includes urinals, water-closets, earth-closets, privies, ashpits, and any similar convenience.

Ashpit includes any ashtub or other receptacle for the deposit of ashes, fæcal matter, or refuse.

Lands and **premises** include messuages, buildings, lands, easements, and hereditaments of any tenure.

Dwelling-house means any inhabited building, and includes any yard, garden, outhouses, and appurtenances belonging thereto, or usually enjoyed therewith, and includes the site of the dwelling-house as so defined.

Street includes any highway (not being a turnpike road), and any public bridge (not being a county bridge), and any road, lane, footway, square, court, alley, or passage, whether a thoroughfare or not (Public Health Act, 1875, section 4). The Public Health (London) Act, 1891, section 141, adds to this definition of a street the words "whether or not there are houses in such street." Under the Housing of the Working Classes Act, 1890, section 29, the word "street" is restricted to a road, &c., with houses built in it, and does not include highways or roads without houses.

Earth-closet is defined "as any place for the reception and deodorisation of fæcal matter, constructed to the satisfaction of the local authority."

BYE-LAWS AND REGULATIONS.

In respect of certain matters, and under certain conditions expressly stated in the various Acts dealing with the Public Health, Sanitary Authorities may make bye-laws having the force of law. These bye-laws are intended rather to supplement than to summarise, vary, or supersede the express provisions of the statute law. All bye-laws made by Sanitary Authorities under and for the purposes of the Public Health Acts must be under their common seal; and any such bye-law may be altered or repealed by a subsequent bye-law made pursuant to the provisions of the Acts. But no bye-law is of effect if repugnant to the laws of England or to the provisions of the Acts. A Sanitary Authority may, by any bye-laws made by it, impose such reasonable penalties as it thinks fit, not exceeding £5 for each offence, and, in the case of a continuing offence, a further penalty not exceeding 40s. for each day after written notice of the offence; but all such bye-laws imposing any penalty must be so framed as to allow of the recovery of any sum less than the full amount of the penalty. Bye-laws do not take effect unless and until they have been confirmed by the Local Government Board, who have power to allow or disallow the same as they think proper. The bye-laws, when confirmed, must be printed and hung up in the office of the Sanitary Authority, and a copy of them must be delivered to any ratepayer of the district who applies for them (see Public Health Act, 1875, sections 182 to 185).

Some bye-laws must be made by a local authority; there are others which may be made by both urban and rural authorities, and others also which urban Sanitary Authorities are alone empowered to make. In the greater number, the power to make them is permissive.

Regulations differ somewhat from bye-laws, because, with few exceptions, they do not require the approval of the Local Government Board. They may be simply passed as a resolution at a meeting of the authority, and may be amended or rescinded at a subsequent meeting. In certain cases, as, for instance, under section 125, Public Health Act, 1875, relating to the removal to hospital of infected persons brought by ships, a regulation, just like a bye-law, has to be approved by a superior authority, and its breach involves liability to a money penalty.

Urban Sanitary Authorities are empowered to make bye-laws in respect of the following:—

1. *Common Lodging-houses.*—For fixing and varying the number of lodgers; for the separation of the sexes; for promoting cleanliness and ventilation; for giving of notices and taking precautions in the case of infectious diseases; for the general well-ordering and sanitation of such houses (Public Health Act, 1875, section 80).

2. *Cleansing and Scavenging.*—For the cleansing of footways; for the removal of house refuse; for the prevention of nuisances arising from snow,

dust, ashes, rubbish, and the keeping of animals (Public Health Act, 1875, section 44).

3. *Tenement Houses.*—For regulating the number of persons and separation of the sexes; for promoting cleanliness, ventilation, and prevention of the spread of infectious diseases; besides the general well-ordering of such houses (Public Health Act, 1875, section 90). So far as relates to seamen's lodging-houses, the power to make bye-laws is derived from the Merchant Shipping Act, 1894, section 214.

4. *New Streets and Buildings.*—With respect to the level, width, construction, and sewerage of new streets; and to the structure, stability, ventilation, general sanitary arrangement, alteration, removal, and closure of buildings unfit for habitation (Public Health Act, 1875, section 157, and Part III., Public Health Amendment Act, 1890).

5. *Slaughter-houses.*—For the licensing, registering, and inspection of slaughter-houses and knackers' yards; for ensuring their cleanliness and proper supply of water, as well as to prevent cruelty therein (Public Health Act, 1875, section 169).

6. *Markets and Fairs.*—For the prevention of nuisances, the inspection of slaughter-houses and the daily removal of refuse, the prevention of the exposure or sale of unwholesome food, and various other purposes (Public Health Act, 1875, section 167).

7. *Offensive Trades.*—To control, prevent, or lessen the injurious effects of various or any offensive trade (Public Health Act, 1875, section 113).

8. *Hop and Fruit-pickers.*—For securing these workers decent lodgings and accommodation while so engaged (Public Health Act, 1875, section 314, and Public Health (Fruit-pickers) Act, 1882).

9. *Tents and Vans.*—For the promotion of cleanliness, prevention of nuisances in connection with, and the spread of infectious disease by the occupants of these structures (Housing of the Working Classes Act, 1885, section 9).

10. *Mortuaries and Cemeteries.*—For the regulation of charges, and management (Public Health Act, 1875, section 141, and the Public Health (Interments) Act, 1879).

11. *Open Spaces.*—For the regulation of public grounds and walks, including churchyards or burial-grounds over which the Sanitary Authority may have control (Public Health Act, 1875, section 164, and the Open Spaces Act, 1887).

The Municipal Corporations Act, 1882, section 23, gives power to municipalities or borough councils to make bye-laws for the suppression and prevention of nuisances not already punishable in a summary manner by any other Act in force throughout the borough. County Councils have similar powers under the Local Government Act, 1888, section 16.

Urban authorities can further make bye-laws under the Housing of the Working Classes Act, 1890, for the regulation of all buildings provided under that Act or the Acts which it supersedes.

Rural Sanitary Authorities have similar powers for making bye-laws in respect of the following:—

(1) *Private scavenging*, (2) *Common lodging-houses*, (3) *Tenement houses and Seamen's lodging-houses*, (4) *Hop and fruit pickers*, (5) *Tents and vans*, (6) *Mortuaries, and* (7) *under the Housing of the Working Classes Act*, 1890. Further, by adopting portions of the Public Health Acts Amendment Act, 1890, which are not expressly limited to urban districts, rural Sanitary Authorities can make certain bye-laws as to *new and old buildings.* The Local Government Board may confer on them any other

powers as to bye-laws which the Public Health Acts give to urban authorities (Public Health Act, 1875, section 276).

Every Sanitary Authority *must* make bye-laws as to common lodging-houses; every urban Sanitary Authority *must* do the same as to slaughter-houses: the exercise of power as to other bye-laws is optional.

The London County Council have power to make bye-laws for the regulation of the plans, levels, width, surface, inclination and materials of new streets and roads; for the plan and sites of buildings; as to the dimensions, form, construction, cleansing and repairing of pipes, drains, and traps connected with sewers; and as to the construction, ventilation and cleansing of sewers (London Building Act, 1894, section 164, and certain unrepealed clauses of the Local Management Acts).

Also under the Public Health (London) Act, 1891, for regulating the conduct of offensive trades, and the structure of the premises (section 19). For prescribing the times for removal of any fæcal or offensive matter in or through London, so as to avoid the creation of a nuisance (section 16). As to the closing of cesspools and privies, the removal and disposal of refuse, and as to the duties of the occupier of any premises in connection with house refuse (section 16). As to water-closets, earth-closets, ashpits, cesspools, receptacles for dung, and the proper accessories thereof in connection with buildings (section 39). The power to make bye-laws under section 19 is permissive, but under sections 16 and 39 is compulsory.

The Metropolitan Sanitary Authorities *must* make bye-laws for the control of nuisances arising from snow, ice, salt, dust, rubbish, ashes, carrion, fish, or filth in the streets; or from offensive matters running from any manufactory, brewery, slaughter-house, or dung-hill; for the prevention of keeping animals on any premises in such place or manner as to be a nuisance or dangerous to health; and as to the paving of yards and open spaces in connection with dwelling-houses (section 16). For the keeping of water-closets supplied with sufficient water for their effective action (section 39). For the cleansing and protecting of all cisterns, tanks, &c., used for storing water for domestic purposes, drinking, or the manufacture of beverages (section 50).

The same authorities *may* make bye-laws for the removal to hospital or detention therein of persons suffering from infectious disease (section 66). For preventing the fouling of tents, vans, sheds, and similar structures used for human habitation, and the spread of infectious disease by the inhabitants thereof (section 95). In relation to tenement houses, under section 8 of Housing of the Working Classes Act, 1885. These same authorities must also enforce any bye-laws made by the County Council under sections 16 and 39 of the Public Health (London) Act, 1891.

In the city of London, similar powers are vested in the Commissioners of Sewers, under the City of London Sewers Acts, 1848 and 1851, the Public Health (London) Act, 1891, the Gardens in Towns Protection Act, 1863, the Metropolitan Open Spaces Acts, 1877 and 1881, and the Open Spaces Act of 1887.

Under the Dairies Order, 1885, any Sanitary Authority may make regulations for any of the following purposes:—(*a*) For the inspection of cattle in dairies; (*b*) for prescribing and regulating the lighting, ventilating, draining, cleansing and water-supply of dairies and cow-sheds; (*c*) for prescribing precautions to be taken by purveyors of milk against infection; (*d*) for securing the cleanliness of milk stores, milk shops, and milk vessels used for containing milk for sale.

A Sanitary Authority, subject to approval by the Local Government

Board, may make regulations for the removal to hospital and detention there as long as necessary of all persons who may be brought within their district by either boat or ship, and who may be infected with an infectious disease (Public Health Act, 1875, section 125). They have also power to make regulations for the management of places provided by them for making *post-mortem* examinations ordered by a coroner (section 143).

The Local Government Board has power to make regulations under sections 130 and 134 of the Public Health Act, 1875, in relation to cholera and other dangerous infectious diseases.

The provisions as to making bye-laws in Scotland and Ireland are somewhat similar to those above mentioned. Where offering any marked differences from the English procedures, the fact will be indicated in the following pages.

From time to time the Local Government Board have prepared and issued "Model Bye-laws" to serve as guides to Sanitary Authorities when seeking to frame bye-laws. As these models have been very generally adopted, subject to occasional modifications, by various Sanitary Authorities, a summary of them will be given under each heading where, in respect of certain matters, the Public Health Acts give the Sanitary Authority power to frame them. Supplementary to these model bye-laws, various regulations in regard to the management of mortuaries and cemeteries have been issued by the Home Secretary: these will be detailed in their appropriate places.

SEWERAGE AND DISPOSAL OF SEWAGE.

In England and Wales.—By the Public Health Act, 1875, section 13, it is enacted that all sewers except certain private sewers are vested in the Sanitary Authority of the district. The exceptions mentioned in the section are:—(1) Sewers made by a person or persons for his or their profit. (2) Sewers made and used for draining or improving land under any local or private Act, or for irrigation. (3) Sewers under any Commissioners of Sewers appointed by the Crown. The Sanitary Authority may purchase (section 14) or construct (section 15) sewers. They must provide such sewers as are necessary for effectually draining their district, having, by section 16, powers of taking them through, across, or under lands and streets. Section 308 provides for compensation for damage, to be ascertained by arbitration. The sewers must be so constructed, covered, ventilated, and kept as not to be a nuisance or injurious to health, and must be properly cleansed (section 19). The performance of these duties by a Sanitary Authority can be enforced on complaint by individuals (section 299), while further powers, in this respect, are given by sections 16 and 19 of the Local Government Act, 1894, to County Councils, on complaint by a Parish Council of a defaulting rural Sanitary Authority.

Under section 7, Rivers Pollution Prevention Act, 1876, every Sanitary Authority must give facilities for factories to drain into sewers, but provision is given for the protection of sewers from injurious matters, such as anything which may impede the flow of their contents, any chemical refuse, waste steam, or water or liquid heated above 110° F., by sections 16 and 17, Public Health Acts Amendment Act, 1890. The restrictions imposed by sections 32, 33, and 34 of the Public Health Act, 1875, on the execution of sewerage works by a Sanitary Authority outside its own district, involve the giving of a public notice, and in case of objection, the work not to be commenced without sanction of the Local Government Board, who may appoint an inspector to make inquiry and report.

For the protection of the sewers of an urban Sanitary Authority, section 26, Public Health Act, 1875, provides a penalty for unauthorised buildings over them; and sections 150 and 151 give power to the Sanitary Authority to compel the sewering of private streets, subject to any bye-laws the authority can get confirmed by the Local Government Board. Powers are given by section 27 of the same Act for the treatment and disposal of sewage, but section 17 expressly insists that such disposal of sewage must not be into streams, unless purified before discharge: this latter section, however, needs to be read in connection with the Rivers Pollution Prevention Acts, 1876 and 1893, which give a certain amount of protection to Sanitary Authorities in respect of the pollution of streams and rivers by sewage channels used, constructed, or in process of construction at date of passing of the Act of 1876. Sections 28, 29, and 30 of the Public Health Act, 1875, further give powers to the Sanitary Authority to deal with land appropriated to sewage purposes, to contribute to works executed by others for the disposal of the sewage, and to agree for communication of sewers with sewers of adjoining districts.

The incidence of the charge of sewerage and other public sanitary works in urban districts is usually made by a general district or borough rate. In rural districts, the incidence of charge of expense of sewerage and other sanitary works are not made on the entire district, but constitute a separate charge on the parishes or parts of parishes for which the works have been carried out, and the areas liable to contribute are termed "contributory places" (section 229). There are four kinds of contributory places:—(1) A rural Sanitary Authority may, subject to approval by the Local Government Board, constitute any portion of its area a "special drainage district" for the purpose of charging thereon exclusively the expenses of sanitary works, the cost of which is not spread over the entire district, and thereupon such area becomes a "contributory place." (2) Where no part of a parish is situate in a special drainage district, or in an urban sanitary district, the entire parish is a contributory place. (3) Where no part of a parish is in an urban sanitary district, but part of it is in a special drainage district, the part not in a special drainage district is a contributory place. (4) Where part of a parish is in an urban sanitary district, and part in a rural sanitary district, so much of it as is not in an urban district or special drainage district is a contributory place (section 229).

In London.—The County Council, as the successors of the Metropolitan Board of Works, are the local authority for the purposes of the main sewerage and disposal of the sewage of London, while the Vestries and District Boards are the local authorities for the purposes of the sewerage and drainage other than the main sewerage. The powers of the late Metropolitan Board of Works, and consequently of their successors, the County Council, as regards main sewerage are derived from the Metropolis Management Act, 1855, taken in conjunction with a similar Act of 1862, and the Metropolitan Main Drainage Act, 1858.

While the main sewers are to be constructed and kept so as not to be a nuisance, the County Council have power to declare sewers to be main sewers, and to take jurisdiction over sewerage and drainage matters belonging to the Vestries, also to control these bodies in the construction of sewers, &c., by means of bye-laws. The general powers of the County Council in respect of sewerage and sewage disposal are very similar to those of the Sanitary Authorities in the provinces under the Public Health Act, 1875.

As relates to procedures for the prevention of floods, the powers of the County Council, by inheritance from the Metropolitan Board of Works, are derived from the Metropolitan Management (Thames River Prevention of Floods) Amendment Act, 1879. All sewers, &c., within the city are vested in the Commissioners, who have full powers over them and all drains communicating with the public sewers, under the City of London Sewers Act, 1848.

By the Metropolis Management Act, 1855, section 68, all sewers, other than those now vested in the County Council and the Commissioners of Sewers, are vested in the Vestries and District Boards, who, from time to time, must repair, maintain, alter, or extend as may be necessary; but no new sewers can be made without the approval of the County Council. The powers given by the above provisions are extended in certain cases to areas outside the metropolis by section 58 of the Metropolis Management Act, 1862. The Act of 1855 (sections 73 to 75) further provides for the ventilation, trapping, cleansing, inspection, and proper connection of drains with sewers on the part of the Sanitary Authorities: while section 202 of the same Act gives the local authorities power to make bye-laws as to drains. For the purposes of their sewers, and for other purposes of the Metropolis Management Acts, every Vestry or District Board has the same power as the County Council to purchase lands. These purchase powers, however, are not compulsory (sections 151, 152).

In Scotland.—While the Scottish Acts do not draw any formal distinction between drains and sewers, the duties of local authorities in regard to their provision and maintenance do not materially differ from those of the English Sanitary Authorities; the powers being derived from the provisions of the Public Health (Scotland) Act, 1867, the Burgh Police (Scotland) Act, 1892, and the Local Government (Scotland) Act, 1889. Though the pollution of a stream by sewage is an offence as a nuisance under the common law of Scotland, it is also so under section 21 of the Rivers Pollution Prevention Act, 1876, which applies to Scotland, with the substitution of the Secretary for Scotland for the Local Government Board as central authority. A County Council may enforce this Act as if it were a Sanitary Authority within its meaning.

In Ireland.—The provisions of the Irish Public Health Act, 1878, in respect of sewerage and sewage disposal are identical with those of the English Act of 1875. The Rivers Pollution Prevention Acts, 1876 and 1893, extend also to Ireland, but in their practical application there is some doubt whether the definition of Sanitary Authority contained in the Act of 1876 can be held to include a Sanitary Authority constituted by the Irish Public Health Act of 1878. In respect of the incidence of taxation to meet loan charges for sanitary works, it is noticeable that the definition of a contributory place in the Irish Act is different from that contained in the English Act. By section 232 of the Public Health Act (Ireland), 1878, a contributory place may be (1) the dispensary district; (2) the electoral division; (3) the town-land; (4) such portion of the town-land or town-lands as may be determined by the Local Government Board of Ireland.

Another distinction between the two Acts is that there are no "special drainage districts" in Ireland, their place being taken by the "area of charge," consisting of a contributory place or a number of contributory places benefiting by proposed sanitary improvements. An area of charge differs from a special drainage district, inasmuch as it may be, and usually is, fixed for one particular work, and the same area need not be adopted for the expenses of another sanitary work for the same place.

HOUSE DRAINAGE AND REMOVAL OF EXCRETA FROM HOUSES.

In England and Wales.—The Public Health Act, 1875, sections 21 to 25, gives every Sanitary Authority power to enforce drainage of undrained houses, and in certain cases to close existing drains on condition of providing others. These drains must lead to the public sewer if there be any within 100 feet of the site of the house; if not, to a covered cesspool in such position (not under a house) as the Sanitary Authority may direct. Failing compliance, the authority may carry out the work and recover in a summary manner the expenses incurred from the owner, or may by order declare the same to be "private improvement expenses." These private improvement expenses may be made payable by instalments with interest. They may, moreover, be levied on the occupier, whereas the expenses, if recovered summarily, will only be recoverable from the owner. It occasionally happens that, owing to delay in construction of sewers, houses have been supplied with cesspools and effectual drains leading thereto. In those cases, the Sanitary Authority are under no obligation to pay the costs of drains necessary for enabling the house to discharge its sewage into the new sewers. Where the sewer is in the same sanitary district as that in which the premises are situate, the owner or occupier, upon giving due notice and complying with the regulations of the authority as to how the communication is to be made, is entitled to carry drains into the public sewer. In places where Part III., Public Health Amendment Act, 1890, has been adopted, by section 18 of that Act, the owner or occupier has a right to require the Sanitary Authority to make the communication at his cost. Where the sewer is in another sanitary district, the communication must be made on such terms and conditions as may be agreed upon between the owner or occupier and the authority to whom the sewer belongs.

Where any drain or cesspool is a nuisance, or injurious to health, the Sanitary Authority may take proceedings to remedy the matter either under section 41, Public Health Act, 1875, or under the provisions of the same Act relating to nuisances. All the foregoing provisions apply to existing houses and drains, without regard to the date of their construction, in both urban and rural districts.

In urban districts, and in rural districts, or contributory places endowed with urban powers by section 276, Public Health Act, 1875, not only may *no* house be built or rebuilt after having been pulled down to or below the ground floor, or be occupied after having been built or so rebuilt until proper covered drains have been constructed and duly connected with either a sewer or cesspool, as above indicated, to the satisfaction of the Sanitary Authority (section 25, Act of 1875), but the authority may make bye-laws as to the mode in which connections between drains and sewers are to be made (*idem*, section 157). This 157th section of the 1875 Act is only of limited extent, as it provides that no bye-law made under it shall affect any building erected in any place which, on August 11, 1875, was included in an urban sanitary district before the Local Government Acts came into force in such place, or any building erected in any place which, on that date, was not included in any urban sanitary district before such place became constituted or included in an urban district, by virtue of any order of the Local Governnent Board, subject to this Act. Nor may any bye-law made under the section apply to buildings belonging to any railway company, and used for the purposes of such railway under any Act of Parliament. In places where Part III., Public Health Amendment Act, 1890, has been adopted, section 23 of this same Act has extended the operation of this 157th section of the 1875 Act to buildings erected before the time mentioned, and to rural sanitary districts. Rural Sanitary Authorities can therefore now, by adopting this part of the 1890 Act, obtain these very important powers throughout their districts without the intervention of any order of the Local Government Board.

The law relating to privies, water-closets, excrement and refuse disposal, resembles that relating to house drainage, inasmuch as it is contained partly in statutory enactments applicable to both urban and rural sanitary districts, and partly in bye-laws applicable only to urban districts and to those rural sanitary districts or contributory places to which it has been specially applied by order of the Local Government Board. The general statutory enactments in regard to these matters of excrement and refuse disposal are contained in the Public Health Act, 1875, sections 35 to 45, and practically amount to the following:—It is unlawful to erect any house without a sufficient water-closet, earth-closet, or privy, and an ashpit with proper doors and coverings; and the same must be provided for any existing house on the order of the Sanitary Authority, who may require a separate closet for each house (sections 35, 36, and 37). The Sanitary Authority may order sanitary conveniences in factories where persons of both sexes are employed (section 38), while the Coal Mines Regulation Act, 1887, section 74, makes the same provision applicable to parts of mines above ground in which women and girls are employed. Every Sanitary Authority must see that all drains, closets, ashpits, and cesspools are properly constructed and kept (section 40); while urban Sanitary Authorities may provide public urinals, closets, or receptacles for refuse (sections 39 to 45). On the written application of any person that any drain, closet, ashpit, or cesspool is a nuisance, the Sanitary Authority may, by writing, empower their surveyor or inspector, after giving twenty-four hours' notice, to enter the premises and open the ground; if any defect is found, the Sanitary Authority must serve notice upon the owner or occupier to do the necessary work, but if there is no defect, the Sanitary Authority must close the ground and make good any damage.

The Local Government Board have issued a series of Model Bye-laws relating to the various matters for which bye-laws may be made by a Sanitary Authority under the foregoing provisions. Their general provisions are sufficiently indicated in the following summary:—

Drainage.—Damp sites must be drained by earthenware field pipes properly laid to a suitable outfall, but not directly communicating with any sewer or cesspool or drain containing sewage. Rain pipes must be provided to carry away all water falling on the roof without causing dampness of the walls or foundations. The level of the lowest storey must be such as to allow of the construction of a drain sufficient for the drainage of the building communicating with a sewer at a point above the centre of the sewer. All drains for sewage must be made of impervious pipes 4 inches or more in internal diameter, laid with a proper fall in a bed of concrete, and with water-tight joints. Every drain inlet not intended for ventilation must be trapped. No drain conveying sewage must pass under a building unless no other mode of construction is practicable; in that case it must be laid in a direct line for the whole distance beneath the house, and must be embedded in and covered with concrete 6 inches thick all round, and must be laid at a depth below the surface at least equal to its diameter, and lastly, must be ventilated at each end of the portion beneath the building. The main drain must be trapped at a point within the curtilage, but as distant as practicable from the building. Branch drains must join other drains obliquely in the direction of the flow.

There must be at least two untrapped ventilating openings into the drains, according to one of the following alternative arrangements:—(1) One opening consists of a shaft or disconnecting chamber opening at or near the ground level, and situated as close as possible to the trap specified above, but on the house side of it; the other opening is a pipe or shaft carried from a point as far distant as possible from the said trap, that is, as near as possible to the head of the drain, vertically upwards in such manner and to such height (in no case less than 10 feet) as to prevent any escape of foul air into any building; but (2) if more convenient, the relative positions of these openings may be reversed, the shaft being placed near the trap, and the opening at the ground level at the head of the drain. The ground-level opening must have a grating, with apertures equal in total area to the sectional area of the drain. The pipe or shaft at the other end of the drain (whether used as a soil pipe or not) is required to have a sectional area equal to that of a drain, and in no case to be less than 4 inches; all bends and angles are to be avoided as far as practicable.

No drain inlet is permitted within a building except the inlet necessary for a water-closet. Every soil pipe must be at least 4 inches in diameter, must be placed outside the building, and must be continued upwards in full diameter, without bends or angles, to such a height and such a point as to afford a safe outlet for sewer air. This height and point will usually be above the highest part of the roof of the building to which the soil pipe is attached, and, where practicable, not less than 3 feet above any window within 20 feet measured in a straight line from the open end of such soil pipe. There must be no trap between the soil pipe and the drain to which it leads, nor in any part of the soil pipe except such as may be necessary in the construction of the water-closet. The waste pipe from a slop sink must conform to the same requirements as a soil pipe. The waste pipes from any other sink, bath, or lavatory, the overflow pipe from any cistern and from any "safe" under a bath or water-closet, and every pipe for conveying waste water, must be taken through an external wall, and must discharge in the open air over a channel leading to a trapped gully grating at least 18 inches distant.

Water-closets must have a window opening directly into the external air, and measuring 2 feet by 1 foot clear of the frame; and, in addition to the window, adequate means of constant ventilation by air-bricks, air-shafts, &c. Such closets, if within the building, must adjoin an external wall. The water must be supplied to a water-closet by means of a special cistern. The apparatus must be suitable for effectual flushing and cleansing of the basin; the basin must be made of non-absorbent material, and of such shape and capacity as to receive and contain a sufficient quantity of water, and to allow all filth to fall free of the sides directly into the water. "Containers" and "D-traps" are forbidden.

Earth-closets are subject to the same conditions as water-closets, so far as regards position, lighting, and ventilation. Proper arrangements must be made for the supply of dry earth, and its effectual and frequent application to the excreta; also for convenience of scavenging, and for exclusion of rainfall and drainage. The receptacle for excreta, whether fixed or movable, must be so constructed as to prevent absorption or escape of the contents, and to exclude rainfall and drainage; if fixed, its capacity must not be greater than may suffice for three months, nor in any case greater than 40 cubic feet, and it must in every part be 3 inches above the ground. In the case of earth-closets placed inside houses, the maximum limit of size may with advantage be reduced to 2 cubic feet.

Privies must not be erected within 6 feet of a dwelling, public building, or place of business, nor within 50 feet of any water likely to be used for drinking or domestic purposes, or for manufacturing drinks, nor otherwise in such a position as to entail danger of the pollution of such water. Privies must be built so as to admit of convenient scavenging without carrying the contents through any dwelling, public building, or place of business. There must be an opening for ventilation at the top; the floor must be paved, and raised 6 inches above ground in all parts, with a fall of half an inch towards the door. The receptacle may be fixed or movable. If movable, as in pail-closets, the floor of the area beneath the seat must be flagged or asphalted, and raised 3 inches above the ground level, and all the sides of the said area must be made of flag, slate, or brick, at least 9 inches thick, and rendered in cement. If the receptacle is fixed, it must be in every part 3 inches above the ground level, and its capacity not exceeding 8 cubic feet, presuming that the scavenging will be done weekly: suitable means or apparatus must be provided in connection with the privy for the application of ashes, dust, or dry refuse to the filth deposited; and the receptacle must be so constructed that the contents may not at any time be exposed to rainfall, or to the drainage of any waste water or liquid refuse from any adjoining premises, while at the same time conveniently accessible for scavenging; the materials and construction must be such as to prevent any absorption by any part of it of any filth deposited therein, or any escape by leakage or otherwise of its contents. It must in no way be connected with a drain.

Cesspools must not be constructed within 50 feet of any dwelling, public building, or place of business, nor within 100 feet of any water likely to be used for drinking or domestic purposes, or for manufacturing drinks, or otherwise in such a position as to entail danger of pollution of such water. Cesspools must be so constructed and placed as to conveniently admit of scavenging and cleansing without carrying the contents through any dwelling, public building, or place of business. They must not be connected with any sewer. They must be covered over by an arch, or otherwise, and adequately ventilated. They must be constructed of brick in cement, rendered inside with cement, and with a backing of at least 9 inches of clay.

Ashpits must not be constructed within 6 feet of any dwelling, public building, or place of business, nor within 50 feet of any water likely to be used for drinking or domestic purposes, nor otherwise in such a position as to entail danger of the pollution of such water. Ashpits must be so placed and constructed as to conveniently allow of scavenging without carrying the contents through any dwelling, public building, or place of business. The capacity must not exceed 6 cubic feet, or such less capacity as may suffice for a period not exceeding one week. The walls must be of flag, slate, or brick, at least 9 inches thick, and rendered inside with cement; the floor must be flagged or asphalted, and raised at least 3 inches above the ground level. The ashpit must be roofed and ventilated, and provided with a door so arranged as to allow of the convenient removal of the contents, and to allow also of being closed and fastened. The ashpit must not be connected with any drain.

In London.—In regard to house drainage, water-closets, privies, cesspools, ashpits, the removal and disposal of refuse, the receptacles for dung, and the proper accessories thereof in connection with new buildings or old, by section 39 (1) of the Public Health (London) Act, 1891, the County Council are empowered to make bye-laws, which it is the duty of every Sanitary Authority in London to enforce and observe. Bye-laws made by the County Council under the Act do not, however, extend to the city. These bye-laws and any others made by the County Council, under this Act, are subject to the provisions of sections 182 to 185 of the Public Health Act, 1875, as already explained in connection with bye-laws made by any Sanitary Authority in England and Wales: in their main provisions the bye-laws made by the County Council accord closely with those given above as models by the Local Government Board. Earth-closets, privies, and receptacles for dung must, by the London County Council bye-laws, be emptied and cleansed weekly; while cesspools must be similarly treated every three months.

The obligations and powers of a Sanitary Authority in London in relation to house drainage and the removal of refuse are very similar to those of a Sanitary Authority in other parts of the country. A new house *must* have "one or more water-closets, as circumstances may require," with proper water-supply, trapped soil-pan, and other accessories. The same applies to all houses, irrespective of date, under notice from the Sanitary Authority (section 37). A privy or earth-closet may only be substituted if the available sewerage and water-supply is insufficient for a water-closet. Any person who may think himself aggrieved by any notice or act of the Sanitary Authority may appeal to the County Council, whose decision is final. These appeals are governed by section 126. Penalties are prescribed for (*a*) constructing or re-constructing water-closets, &c., not in accordance with this Act or any bye-laws, or in defiance of notice or prohibition; (*b*) for discontinuing any such water-supply without lawful authority; (*c*) illegally or wilfully injuring or constructing a drain or water-closet so as to create a nuisance or danger to health (section 41).

In Scotland.—When no house drain exists, an owner may, under the Public Health (Scotland) Act, 1867, section 16, be compelled to make one, or provide a cesspool; but there is no provision for compelling or insuring that new houses are properly drained. This defect in the Act is practically minimised by the elasticity of the term nuisance under the same Act, which includes any insufficiency of drainage and water-closet accommodation. In the towns, the Burgh Police Act, 1892, gives powers to the burghal authorities, which do not materially differ from the English provisions (sections 238 to 245), except that what are contained in detailed regulations in the Scottish Acts are, in England, left to be prescribed in the form of bye-laws.

In Ireland, a Sanitary Authority is empowered to enforce the drainage of undrained houses, but it is not compulsory on them to do so, as in England. The Sanitary Authority may also, by the Irish Public Health Act, 1878, require drains and cesspools to be ventilated as may appear necessary (section 25 *et seq.*). As to drainage in the case of newly built or rebuilt houses, a rural Sanitary Authority cannot enforce it; but it can make bye-laws with respect to the drainage of buildings, a provision which to some extent covers the same ground. This power of making building bye-laws is, in Ireland, given to rural as well as to urban Sanitary Authorities, without requiring, as in England, an order by the Local Government Board (section 41). The Irish Board has not issued any special model bye-laws, as those of the English Local Government Board are fully applicable to Ireland.

The general provisions in the Irish Act (section 44 *et seq.*) relating to sanitary conveniences, &c., are almost the same as those in the English Act of 1875.

CLEANSING AND SCAVENGING.

In England and Wales.—By section 42, Public Health Act, 1875, every Sanitary Authority may, and when required by the Local Government Board shall, undertake or contract for the removal of house refuse and cleaning of privies, ashpits, &c. Moreover, every urban Sanitary Authority and every rural Sanitary Authority invested with requisite powers may, and when required by the Local Government Board shall, themselves undertake the cleaning of streets; they may also undertake the watering of the same. All refuse, so collected, shall be the property of the local authority, to be sold or otherwise disposed of, any profits to be applied to the expenses of the Act in urban and rural districts respectively. Further, if Part III. of the Public Health Acts Amendment Act, 1890, has been adopted in their district, the Sanitary Authority may, under section 26 (2) of that Act, make bye-laws imposing on occupiers duties to facilitate the removal of refuse. Any person obstructing removal to be liable to a penalty not exceeding £5, except as regards refuse, &c., which the occupier intends to employ for his own use, unless he meanwhile suffer it to become a nuisance. If the Sanitary Authority neglect, without reasonable excuse, to remove any refuse within seven days of receiving a remonstrance from the occupier, they shall be liable to pay him 5s. for each further day's neglect (section 43, Act of 1875). An urban Sanitary Authority may, by section 45, provide receptacles and places for the temporary deposit of the matter collected.

By section 44, Public Health Act, 1875, the Sanitary Authority has power to make bye-laws imposing the duty of cleansing footways, pavements, ashpits, privies, cesspools, and removing house refuse when they do not themselves contract or undertake to do the same, and may make bye-laws for the prevention of nuisances from accumulations of snow, filth, ashes, &c., and from the keeping of animals. The following is a summary of the Model Bye-laws suggested by the Local Government Board in connection with the terms of this section.

(*a*) *Private Scavenging.*—The occupier of any premises must cleanse the footways and pavements adjoining his premises *daily* except Sunday. He must remove the house-refuse *once a week*, and excreta at intervals not exceeding the following maximum limits:—

	Must be cleansed at least
Earth-closets, with fixed receptacle,	once in three months.
,, ,, movable ,,	once a week.
Privies, whether the receptacles are fixed or movable,	once a week.
Ashpits, whether receiving excreta or not,	once a week.
Cesspools,	once in three months.

(*b*) *Clearing away Snow.*—The occupier of any premises must clear away snow from the footways and pavements adjoining his premises as soon as possible after it ceases to fall.

(*c*) *Removal of Refuse.*—The refuse from any premises shall only be removed in a suitable covered receptacle or carriage, and if removed from premises within 20 yards of any dwelling, place of business, or public building, only between 7 A.M. and 9 A.M. from November to February, and between 6 A.M. and 8 A.M. from March to October. Refuse must not be deposited upon any road, and any refuse accidentally falling upon a road must be immediately gathered up and the place cleansed.

(*d*) *Deposit of Night-soil and other Refuse.*—No load of filth must be deposited for more than twenty-four hours within 100 yards of any street, dwelling, public building, or place of business. Night-soil deposited for agricultural purposes upon land within 100 yards of a street, dwelling, &c., and not deodorised, must at once be dug or ploughed into the ground.

(*e*) *Keeping of Animals.*—Swine must not be kept within 100 feet of any dwelling, nor cattle where they may pollute water likely to be used for drinking, domestic, or dairy purposes, or for manufacturing drinks. The same prohibitions apply to storage of dung. Premises wherein are kept any swine, cattle, horses, &c., must be provided with proper receptacles for manure, and with efficient drainage ; the receptacle must be water-tight, covered, and entirely above the level of the ground, and it must be cleansed at least once a week ; the drain must be properly constructed and kept in order at all times, so as to convey all liquid filth to a sewer, cesspool, or other suitable receptacle.

If the Medical Officer of Health or two medical practitioners certify that any house or part thereof is so filthy as to endanger health, or that the whitewashing and purifying thereof would tend to prevent infectious disease, the Sanitary Authority may require the owner or occupier to cleanse, &c., and in his default may themselves do what is necessary (section 46, Public Health Act, 1875).

Section 47 of the same Act prohibits not only keeping swine in dwelling-houses so as to be a nuisance within an urban district, but also suffering stagnant water to lie in cellars or dwellings twenty-four hours after written notice from the Sanitary Authority, and allowing contents of privies and cesspools to overflow or soak out, on a penalty not exceeding 40s., and a daily penalty not exceeding 5s., after notice, and authorises the abatement of the nuisance by the Sanitary Authority at the expense of the occupier. Moreover, a Sanitary Inspector in an urban district may give notice to the owner of any offensive accumulation of matter, or to the occupier of the premises whereon it exists, to have it removed within twenty-four hours, failing which the Sanitary Authority may remove the same (section 49). An urban Sanitary Authority may give public notice requiring the periodical removal of manure from mews, and other public premises, and enforce the same under penalty (section 50).

In cases where Part III., Public Health Act Amendment Act, 1890, is in force, by section 27 of the same, the Sanitary Authority have powers for keeping common courts and passages clean, apportioning the expenses incurred to the occupiers of the adjacent buildings. Further, by section 48 of the Public Health Act, 1875, provision is made for obtaining a justice's order for cleansing offensive ditches or water-courses lying near to or forming the boundaries of districts.

In London.—The provisions for cleansing and scavenging under the

Public Health (London) Act, 1891, are somewhat more stringent than those of the Public Health Act, 1875, which controls the main actions of Sanitary Authorities in the provinces. By sections 29 and 30 of the London Act, the local authorities *must* cleanse streets, footpaths, cesspits, earth-closets, and privies. They *must* remove house refuse at proper intervals, and trade refuse also, if required to do so, on payment. As to what is or is not *trade* refuse, shall, on complaint of either party, be determined by a petty sessional court, such decision being final (section 33(2)). The Sanitary Authority, further, may undertake the collection of manure and other refuse, on request; or may by order require periodical removal by owner (section 36).

Section 16 (2) of the same Act empowers the County Council to make bye-laws (*a*) for prescribing the times for removal of fæcal or other offensive matter through London, and for providing that the vessel or carriage therefor is properly constructed so as to prevent any nuisance; and (*b*) as to the closing and filling of privies, removal of refuse generally, and as to the duties of the occupier in relation to facilitating the removal of it by the scavengers of the Sanitary Authority. Further, a constable may arrest without warrant and take before a justice any person found committing an offence against such bye-laws, and who refuses to give his true name and address. Swine must not be kept within 40 yards of a street or public place, nor be allowed to stray in any public place. The Court may prohibit the keeping of any animal in any specified place shown to be unfit for the purpose (section 17).

In Scotland.—By the Public Health (Scotland) Act, 1867, there is no direct provision, either by bye-law or otherwise, for securing the scavenging or cleansing of the whole or part of a landward district. As a rule, this difficulty is overcome by a landward local authority levying a rate on the whole district for the supply of a scavenger for such parts as need one; while to some extent a County Council may deal with the matter by means of bye-laws for the prevention of nuisances.

Burgh scavenging and cleansing is fully regulated by the Burgh Police (Scotland) Act, 1892, sections 107, 127, 316, which vest the Burgh Commissioners with powers similar to those in force in England and Wales. The occupiers are required to sweep and wash common stairs, and the owners to whitewash and paint them once a year if required by the Sanitary Inspector.

In Ireland.—Section 52 of the Irish Public Health Act of 1878 is the same as section 42 of the English Act of 1875, and contains similar provisions. It practically, however, only applies to urban Sanitary Authorities, as there is no section in the Irish Act corresponding to section 276 of the English Act, which empowers the Local Government Board to invest a rural Sanitary Authority with all or any of the powers and duties of an urban authority.

Under section 54 of the Irish Act (corresponding to section 44 of the English Act) power is given to the Local Government Board for Ireland to require urban Sanitary Authorities to make bye-laws for the prevention of nuisances arising from snow, dust, ashes, filth, &c., and by section 55 the power to provide receptacles for the deposit of rubbish, which in England is permissive and confined to urban Sanitary Authorities, is in Ireland compulsory and entrusted also to a rural Sanitary Authority. The same extension of powers to rural authorities is given as to penalties for keeping swine in dwelling-houses, and for allowing soakage or overflow from cesspools (section 57).

Although section 28 of the Towns Police Clauses Act, 1847, imposes a penalty of 40s. for keeping a pig-sty in front of any street, or in or near any street, so as to be a common nuisance, this does not apply generally to urban districts in Ireland, as this enactment is not incorporated in the Public Health Act, 1878, and is incorporated in only a few of the local Acts in force in certain urban districts of Ireland.

In other respects the provisions as to cleansing and scavenging are similar in both the English Act of 1875 and the Irish Act of 1878.

WATER-SUPPLY.

In England and Wales.—Owing to the privileges which, from time to time, have been granted to companies and other corporate bodies, Sanitary Authorities are under certain restrictions as to their supplying water. Where a water company has Parliamentary powers to supply water over any given area, the Sanitary Authority must give notice to the company stating the purposes for which and extent to which it requires water; and if the company are able and willing to supply sufficient and proper water for the purposes of the local authority, this latter body may not construct any water-works within that area (Public Health Act, 1875, section 52). Moreover, section 332 of the Act provides that where the supply of water must be taken from a running stream, the Sanitary Authority, before abstracting water from such stream, river, or source, must obtain the consent in writing of any person or persons who have prior claims upon those streams.

When not hampered by either of the foregoing restrictions, any Sanitary Authority may construct works for supplying any part of their district with water, or may take on lease, or hire, or purchase works (with the sanction of the Local Government Board), or contract for the supply (section 51). When a Sanitary Authority supply water within their district, they have the same powers and are under the same restrictions for carrying their mains within and without their district as they have and are subject to in respect of their sewers (section 54). The water supplied must be pure and wholesome, and under sufficient pressure as will carry the same to the top storey of the highest dwelling-house in the district supplied. There is, however, no obligation to provide a constant supply under pressure (section 55). The Sanitary Authority have power to charge water-rates and rents in respect of premises to which they supply water, while all public cisterns, pumps, wells, &c., used for the gratuitous supply of water to the inhabitants of a district, vest in and are under the control of such authority (sections 56 and 64).

The same Act, section 62, gives any Sanitary Authority power to require houses which are without a proper water-supply to be so supplied, if it can be furnished at a cost not exceeding the water-rate authorised by any local Act, or twopence a week, or such other cost as the Local Government Board may, upon application, determine to be reasonable. In order to guard against the pollution of sources of water-supply, the Sanitary Authority have power to proceed against offenders (sections 68, 69). If the water of any well or cistern is deemed to be injurious to health, a justice's order may be obtained for its being permanently or temporarily closed, or the water to be used for certain purposes only, and for the payment of any necessary analysis of the sample at the cost of the Sanitary Authority (section 70).

The general provisions of the Public Health Act, 1875, in respect of water-supply may be briefly summarised by saying that it is the duty of the Sanitary Authority to provide their district with water, where danger exists to the health of the inhabitants from either the unwholesomeness or the insufficiency of the existing supply, and a proper supply can be got at reasonable cost. If the Sanitary Authority neglect to do this duty, the same proceedings can be taken to make them perform it, under section 299 of the Act of 1875, or, if they are a rural Sanitary Authority, under the Local Government Act, 1894, sections 16 and 19, just as can be taken in the case of their failing to supply the district with sewers. But cases arise where it is impossible for the Sanitary Authority to supply water at a reasonable cost; under these circumstances they may require the owner to do so, if he can at reasonable cost (Public Health (Water) Act, 1878, section 3). If neither the Sanitary Authority nor the owner can provide water at a reasonable cost, then, if the absence of a proper water-supply creates a nuisance that the house is unfit for habitation, steps may be taken to obtain a justice's order prohibiting its being so used for human habitation (section 97, Public Health Act, 1875).

It was largely to meet difficulties of this kind, especially in rural districts, that the Public Health (Water) Act, 1878, was designed. It applies to every rural Sanitary Authority, and also to such urban Sanitary Authorities as the Local Government Board may order (section 11). Under section 3 of this Act, it is the duty of the local authority to provide or require the provision of sufficient water-supply to every occupied dwelling-house within their district. From time to time they may take steps, by means of systematic inspections on the part of their officers, to see that these conditions are fulfilled. The same powers of entry upon premises are given as are conferred by sections 102 and 103 of the Public Health Act, 1875, in respect of nuisances (section 7); and if the Medical Officer of Health reports that an occupied house is without a proper water-supply, and the Sanitary Authority are of opinion that such a supply can be provided at a reasonable cost (the interest on which, at 5 per cent., shall not exceed twopence a week, or as the Local Government Board may, on the application of the Sanitary Authority, decide to be reasonable in the circumstances), the Sanitary Authority may require the owner, subject to appeal to the Local Government Board, to provide such supply within a specified time, and, in case of default, may themselves carry out the necessary works at his expense. The authority may, on cause being shown why the requirements of the notice served by them should not be complied with, withdraw the notice or modify the terms thereof. Nothing, however, in this Act must be deemed to relieve the Sanitary Authority from the duty imposed upon them by the Public Health Act, 1875, of providing their district or any contributory part of it with a supply of water, where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply, and a general scheme of supply is required, and can be got at a reasonable cost (sections 3 and 4).

In order to prevent houses being built in situations where they cannot be provided with water, the Water Act, 1878, has prohibited (section 6) the owner of any dwelling in a rural district that may be erected or rebuilt from the ground floor after July 4, 1878, from permitting such house to be occupied without a certificate from the Sanitary Authority that it is provided with a sufficient and available supply of wholesome water; such certificate to be based upon the report of the Medical Officer of Health or Sanitary Inspector. Section 9 of the same Act provides that, if the Sanitary Authority furnish a stand-pipe for water-supply, they may make water-charges upon every dwelling within 200 feet, just as if the supply were actually given on the premises; but they may not make this levy upon houses which have a good supply within reasonable distance from another source, unless the water from the stand-pipe is used by the inmates.

The Local Government Act, 1894, section 8 (1) (*e*) empowers a Parish Council to utilise any well, spring, or stream within the parish, and to provide facilities for obtaining water therefrom, consistent with the just rights of any person or corporation; but these powers do not in any way derogate from the obligations of a rural Sanitary Authority in respect of supplying water.

Under the Rivers Pollution Prevention Act, 1876, proceedings may be instituted, in respect of pollution of streams by sewage or solid matters, by any private person or aggrieved local authority (section 8); but in respect of manufacturing or mining effluents, Sanitary Authorities only can take action, and subject to the approval of the Local Government Board. The Board, in giving or withholding consent, must have regard to the industrial interests involved, and the circumstances and requirements of the locality. They shall not give their consent to proceedings by a Sanitary Authority of a district which is the seat of any manufacturing industry, unless they are satisfied, after due inquiry, that means for rendering harmless the effluents from such manufacturing processes are reasonably practical and available, and that no material injury to the interests of such industry will be caused by the proceedings (section 6).

It is owing to the extensive safeguards which it contains that this Act is so largely inoperative. But it cannot be too clearly understood that, by its provisions, the discharge of solid or liquid sewage, or of any solid matter, into streams, is illegal. Neither may the water-waste of houses, which have no water-closets, be discharged without treatment into streams. The discharge of sewage-farm effluents into rivers is a special question, and permissible, provided the effluent is of a certain purity, and not likely to either create a nuisance or pollute any stream or water-course.

In London, the water-supply is in the hands of eight companies, whose powers and rights are regulated by their local Acts and by the Metropolis Water Acts of 1852 and 1871. These companies control the water-supply not only in London, but also over a large extra-metropolitan area. Practically, the water companies in the metropolis have the same position as they have in the provinces, and so far as this question is concerned, neither the County Council nor any other local authority in London has any direct power. The controlling authority, as affecting the public health, over the water companies is the Local Government Board, who have the water supplied examined periodically, approve or disapprove of new sources of supply, of various regulations made by the companies for preventing waste, misuse or contamination, and who also inquire into complaints made to them as to the quality or quantity of the water supplied by any company for domestic use.

The Metropolis Water Act, 1871, section 19, gives the County Council power to ask for the repeal or alteration of any of the regulations for the above purposes, and, if the companies refuse to do so, to appeal to the Local Government Board, who, on inquiry and report of some impartial engineer or person of engineering knowledge, may make such repeal or alterations as they think fit. Sections 8 and 9 of the same Act have similar provisions as to the County Council asking for a constant supply in any given district. No company can, however, be compelled to give a constant supply to any premises in any district until its regulations, as approved by the Local Government Board, are in operation in the district, nor if the company can show that, at any time after two months from the date of the service of any requisition for a constant supply, more than one-fifth of the premises in the district are not supplied with the prescribed fittings. The County Council have power to supply the prescribed fittings on default of owner or occupier. The Local Government Board have power to order a constant supply without application from the County Council, where they think that, by reason of the insufficiency of the existing supply in the district, or the unwholesomeness of such water in consequence of its being improperly stored, the health of the inhabitants is, or is likely to be, prejudicially affected (section 11).

The London County Council (General Powers) Act, 1890, section 38, gives the County Council authority to conduct inquiries and negotiations as to water-supply in or near London, and to pay out of the county fund the costs and expenses of such inquiries, not exceeding £5000.

So far as relates to the power of Vestries and District Boards in connection with the water-supply, the Public Health (London) Act, 1891, indicates the absence of a proper water-supply, or of proper fittings in a house, to render such house unfit for habitation. A new house must not be occupied until the Sanitary Authority grant a certificate that it has a proper water-supply (section 48). A water company cutting off the supply of water to any house must give immediate notice to the Sanitary Authority (section 49). For the closure of polluted wells, &c., the Sanitary Authority have only to satisfy the justice that the water is "so polluted, or likely to be so polluted, as to be injurious or dangerous to health" (section 54). It must be noted that this section gives a Sanitary Authority somewhat greater powers than section 70 of the Public Health Act, 1875, inasmuch as it says not only when the water is so polluted as to be injurious to health, but when it is so polluted, *or likely to be so polluted*, as to be injurious *or dangerous* to health. Moreover, it gives the Court no power to allow the water to be used for certain purposes only, and imposes a fine not exceeding £20 for disobedience to any order under the section.

Every Sanitary Authority under the Act must make bye-laws for cleansing and guarding tanks, cisterns, and other receptacles for storing water, likely to be used for drinking or domestic purposes, from pollution (section 50). The Model Bye-laws framed by the Local Government Board in connection with this section demand: (1) the emptying and cleansing of cisterns and tanks once at least in every six months, and at such other times as may be necessary to keep them clean; (2) every such tank, cistern, or receptacle to be provided with a proper cover, and to be kept at all times properly covered. In cases where two or more tenants of a premises are entitled to the common use of any tank, cistern, or receptacle to which this bye-law applies, the foregoing requirements apply to the owner instead of to the occupier of the premises.

In Scotland, the difficulty which exists in England in acquiring a compulsory water-supply by means of a provisional order is not felt, because the Public Health (Scotland) Amendment Acts, 1882 and 1891, apply certain compulsory clauses of the Land Clauses Acts not only to the construction of sewers, but also to the provision of a water-supply in landward or rural districts. So soon as a local authority considers a public supply expedient, on representing the facts to the Secretary for Scotland, he is empowered to issue provisional orders (subject to Parliamentary confirmation) to bring those clauses into action for the purposes mentioned.

The cost of the water-supply either falls, in the form of a water-rate, upon the whole district, or upon any special district according to the circumstances. Special districts may be combined, their area may be altered, and in some cases the special water-rate may be supplemented by a general rate over the whole district.

Burghal water-supplies may be obtained either under the Public Health (Scotland) Act, 1867, or under the Burgh Police (Scotland) Act, 1892. Under the former Act, in towns with a population under 10,000, or in burghs where the local Police Act makes insufficient provision, a water-supply may be obtained as in landward districts, proceeding by provisional order where any compulsory clauses are necessary. If a water company exists, the local authority may contract with it, or purchase it, but may not enter into competition with it. In larger towns with a population over 10,000, or having a local Police Act, the local authority may provide a water-supply either by contract with a water company, or, where there is no company, directly.

Under the Burgh Police Act, 1892, which does not for these purposes apply to burghs supplied with water before 1895 under local Acts, the Burgh Commissioners of towns having a population below 5000 may apply the compulsory clauses of the Land Clauses Acts with the consent of the sheriff only, and without a provisional order.

The Public Health (Water) Act, 1878, does not extend to Scotland, hence there is no power to prevent a new house being built without a proper water-supply; but in respect of houses already built, the Sanitary Authority is required by the Public Health (Scotland) Acts "to compel an owner to obtain a water-supply at or near his house, and, in a burgh, may compel him to take it into his house."

In Ireland.—The Public Health (Ireland) Act, 1878, enables all Sanitary Authorities to require all houses to be supplied with water "at such cost as the Local Government Board may determine under all the circumstances to be reasonable," there being no limit of cost prescribed as in England (section 72). If the owner, when required by the Sanitary Authority, does not execute the necessary works, the Sanitary Authority may do them, and recover the cost summarily, or, if it be an urban Sanitary Authority, the cost may be declared to be private improvement expenses. The Public Health (Water) Act, 1878, not being in force in Ireland, the provisions therein offered cannot be applied.

Another important difference between the Irish and English Acts is that, by section 61 of the Irish Act, a Sanitary Authority can acquire the right to abstract water from a running stream or other source otherwise than by agreement. By section 202 every Sanitary Authority is endowed with compulsory powers to acquire water rights for drinking and domestic purposes: there is a saving clause for the existing water companies (section 62, corresponding to section 52 of the English Act), but it has not stood in the way of amicable arrangements being made between the Sanitary Authorities and the water companies, as to the acquirement by the former of new and additional supplies. The law as to water-rates in Ireland is similar to that in England, except that the levying of such rates is entirely optional with the Sanitary Authority, and who, moreover, cannot levy them in respect of either public stand-pipes or street-fountains (section 66).

NUISANCES.

In a legal sense, nuisances are of two chief kinds, namely (1) nuisances at common law; (2) nuisances under the Public Health Acts, commonly called "statutory nuisances."

At common law a nuisance may be public, private, or both. *A public nuisance* is thus defined by Stephen in his *Digest of Criminal Law* (art. 176):—"An act not warranted by law, or an omission to discharge a legal duty, which act or omission obstructs, or causes inconvenience or damage to the public in the exercise of rights common to all Her Majesty's subjects." As examples of public nuisances may be quoted the pollution of the air by smoke or by noxious fumes from a factory, obstruction of a highway, and exposure of infected persons in the public way. *A private nuisance* is anything done to interfere with the proprietary rights of another in land, not amounting to a trespass (Wynter-Blyth). As examples of private nuisances one may mention special annoyance from steam-hammers or engines making a noise, and the special annoyance from smoke. *A mixed nuisance* is obviously a nuisance which belongs to both of the above-mentioned varieties.

Statutory nuisances under the Public Health and Sanitary Acts alone concern the officers of Sanitary Authorities. As relating to the Public Health, these statutory nuisances have been well defined by Wynter-Blyth as being "something which either actually injures, or is likely to injure, health, and admits of a remedy, either by the individual whose act or omission causes the nuisance, or by the local authority." It is important to bear in mind that in the Public Health Act sense, as now understood and interpreted, the idea of a nuisance embraces future as well as present consequences. The Public Health Law, in respect of nuisances, may be summarised, for the various parts of the United Kingdom, in the following manner.

In England and Wales.—The provisions of the Public Health Act, 1875, sections 91 to 111, apply to every urban and rural sanitary district, and are "deemed to be in addition to, and not to abridge any right, remedy, or proceeding under any other provisions of the Act, or under any other Act, or at law or in equity." But no person may be punished for the same offence both under these provisions and under any other law or enactment. Under this Act of 1875 "nuisance" is regarded as likely to arise in connection with: (*a*) Sewers, sections 18 and 19; (*b*) Sewage, section 27; (*c*) Construction of drains, closets, ashpits, and cesspools, sections 40 and 41; (*d*) In connection with snow, filth, dust, ashes, and rubbish, section 44; (*e*) Swine, pig-styes, and stagnant water in cellars, or the overflowing of privies and cesspools, section 47; (*f*) Offensive trades, sections 112, 113, and 114.

In regard to some of these cases, remedies are given by other provisions of the Act, more particularly by sections 41, 49, and 50. It will rest with the Sanitary Authority to determine under which provisions they will proceed, having regard to the circumstances. The main section dealing with nuisances is, however, section 91, which defines the following to be nuisances to be dealt with summarily under the Act:—

(1) Any premises, including buildings and lands, in such a state as to be a nuisance or injurious to health. (2) Any pool, ditch, gutter, water-course, privy, urinal, cesspool, drain, or ashpit so foul, or in such a state as to be a nuisance or injurious to health. (3) Any animal so kept as to be a nuisance or injurious to health. (4) Any accumulation or

deposit which is a nuisance or injurious to health. (5) Any house, or part of a house, so overcrowded as to be dangerous or injurious to the health of the inmates, whether or not members of the same family. (6) Any factory, workshop, or workplace, not kept in a cleanly state, or not ventilated in such a manner as to render harmless as far as practicable any gases, vapours, dust, or other impurities generated in the course of the work carried on therein, that are a nuisance or injurious to health, or so overcrowded as to be dangerous or injurious to the health of those employed therein. (7) Any fireplace or furnace which does not, as far as practicable, consume the smoke arising from the combustible used therein, and which is used for working engines by steam, or in any manufacturing or trade process whatever ; and any chimney (not being the chimney of a private dwelling-house) sending forth black smoke in such quantity as to be a nuisance.

In defining these nuisances, the same section, however, provides that there is no penalty if the accumulation or deposit mentioned in (4) is necessary for, and has not been kept longer than is necessary for, the carrying on of any business or manufacture, and if the best available means have been taken for preventing injury to the public health. The provisions of subsection (6) apply to all buildings, including schools, factories, and workshops, except such as are subject to the special provisions, relating to cleanliness, ventilation, or overcrowding, of the Factories and Workshop Acts. In respect of (7), there is no penalty if the Court is satisfied that the fireplace or furnace is constructed in such manner as to consume as far as practicable, having regard to the nature of the manufacture or trade, all smoke arising therefrom, and that such fireplace or furnace has been carefully attended to by the person in charge thereof. Under the smoke sections, it is not necessary in taking action to prove anything with regard to health, it being sufficient to prove that on such and such a day and hour the chimney emitted *black* smoke. Urban Sanitary Authorities have some other powers with regard to smoke under section 171 of this Act, and under the Railway Regulation Act, 1868, and the Highways and Locomotives Act of 1878.

For interpreting the term "overcrowded" in subsection 5 of section 91, Public Health Act, 1875, a sanitary officer usually takes as his guide the minimum standards laid down by the Local Government Board in their bye-laws, namely, 400 cubic feet for rooms in which persons both live and sleep, and 300 cubic feet for rooms solely used for the waking life of the tenants. In the event of a second conviction for overcrowding within three months, the Court may order the closing of the premises (section 109). Another point to be noted in connection with this subsection is that the words "tent, van, shed, or similar structure" may be included within it by section 9 of the Housing of the Working Classes Act, 1885.

Unfenced quarries and abandoned coal-mines are deemed to be nuisances under section 91 of the Public Health Act, 1875, by the Quarry Fencing Act of 1887, and the Coal-Mines Regulation Act, 1887.

It is the duty of every Sanitary Authority to cause their district to be inspected for the detection of nuisances and to enforce the provisions of the Public Health Act, 1875, in order to abate the same (section 92), but the authority may be put in motion by any person aggrieved, or by any two inhabitant householders of such district, or by any officer of the Sanitary Authority, or by the relieving officer, or by any police officer (section 93). If satisfied of the existence of a nuisance, the Sanitary Authority is required by the Act to serve a notice on the person responsible, or, if he cannot be found, on the owner or occupier of the premises on which the nuisance arises, requiring him to abate the same within a time to be specified in the notice, and to execute such works as are specified in the notice as being necessary. Where the nuisance arises from the want or defective construction of any structural convenience, or where there is no occupier, the notice must be served on the owner. If the person causing the nuisance cannot be found, and the owner or occupier is not responsible for its occurrence, the Sanitary Authority may themselves abate the same without further order (section 94). On non-compliance with the notice, or if the nuisance, although abated, is likely to recur, the Sanitary Authority may apply to a justice, who must thereupon summons the person responsible to appear before a Court of summary jurisdiction (section 95). If the Court is satisfied that the alleged nuisance exists, or that, although abated, it is likely to recur on the same premises, it must make an order requiring him to comply with the notice, or prohibiting the recurrence of the nuisance, and directing the execution of any necessary works. The Court may further impose a penalty not exceeding £5 (section 96). Where the nuisance is such as to render the house unfit for habitation, the Court may order the house to be closed, and may cancel this by a further order when satisfied that the house has been made fit for habitation (section 97). Any person not obeying the order of the Court, or failing to use diligence, is liable to a penalty not exceeding 10s. per day during his default; and the Sanitary Authority may carry out the order and charge him with the expenses (section 98). Where the person responsible for the nuisance cannot be found, the order of the Court may be carried out by the Sanitary Authority; and any matter or thing removed by the authority in abating any nuisance may be sold (sections 100, 101). Where any nuisance under the Act is caused by the acts or defaults of two or more persons, the Sanitary Authority may institute proceedings against any one or more of such persons (section 255). Where a nuisance within a district is caused by some act or default beyond its limits, the Sanitary Authority may institute proceedings, provided that these be taken before a Court having jurisdiction in the district where the act or default is alleged to be committed or take place (section 108).

For the purpose of the provisions of this Act of 1875 relating not only to nuisances but also for infectious diseases and hospitals, any ship or vessel lying in any water within the district of a Sanitary Authority is subject to their jurisdiction, as if it were a house. If in any other water, it is deemed to be within such district as the Local Government Board may prescribe, and in the absence of any such prescription then within the nearest sanitary district (section 110). The master or other officer in charge of any such ship will be deemed to be the occupier; but these provisions do not apply to any of Her Majesty's ships, or to those of any foreign government.

The Sanitary Authority and their officers have rights of entry between 9 A.M. and 6 P.M. upon private premises, and, in the case of a nuisance arising in respect of any business, at any hour when such business is in progress. If admission is refused, a justice's order may be obtained (sections 102, 103).

Where Sanitary Authorities fail to take proceedings for abatement of nuisances, individuals may obtain a remedy in one of three ways, either (1) by complaining to the Local Government Board, who may issue an order, enforceable by mandamus in a High Court of Justice (section 299); or (2) on it being proved to the satisfaction of the Local Government Board that a Sanitary Authority have made default in relation to nuisances under the Public Health Act, 1875, that Board may authorise any police officer, acting within the district of the defaulting authority, to institute proceedings which the defaulting authority might institute with regard to such nuisance (section 106); or (3) an individual may complain direct to a justice as to the existence of a nuisance, and the Court may make orders, penalties for disobedience of orders, &c., as in the case of a complaint relating to a nuisance made to a justice by a Sanitary Authority (section 105). This latter mode of procedure is obviously the most expeditious for any individual to take where he feels aggrieved by the neglect of a Sanitary Authority to take proceedings, and where the existence of a nuisance within the meaning of the Act is clear.

In London.—The powers and duties of the Vestries and District Boards, in the capacity of Sanitary Authorities in London, with respect to nuisances under the Public Health Act (London), 1891, in the main correspond with those relating to nuisances under the Public Health Act, 1875, as explained under England and Wales. But they embody several amendments and extensions of the law which have materially strengthened the hands of the Sanitary Authorities in London in dealing with nuisances. Section 2 of the London Act extends the definition of "nuisance," making it include not only that which is *injurious* to health, but also that which is *dangerous* to health. It also makes it include any cistern, water-closet, earth-closet, or dung-pit, so foul or in such a state as to be a nuisance or injurious or dangerous to health, and any such absence from premises of water-fittings as is a nuisance by virtue of section 3 of the Metropolis Water Act, 1871. Further, *any person* may give information to the Sanitary Authority of a nuisance, and it is the *duty* of every officer of the authority and of the relieving officer so to do, and to give written notice to the persons who may be required to abate it.

In giving notice requiring abatement of a nuisance, it is *optional* to specify the works to be executed: also, where the persons responsible for causing the nuisance cannot be found, the Sanitary Authority may not only themselves abate the nuisance, but also do what is necessary to prevent its recurrence. In cases of overcrowding, the Sanitary Authority *must* take proceedings to abate the nuisance. The penalty for wilful nuisance or non-abatement is a fine of £10 for each offence, whether an order to abate it or prohibiting its recurrence is made or not (section 4). Similarly, the maximum fines for failing to comply with an order for the abatement of a nuisance or for acting contrary to a prohibition order are increased from the amounts fixed by the Public Health Act, 1875, to 20s. a day and 40s. a day respectively during default or contrary action, as the case may be (section 5 (9)). Wilful damage to drains, water-closets, &c., so as to create nuisances involve a fine not exceeding £5 (section 15). Groundless appeals to Quarter Sessions against nuisance orders are checked by daily fines of 20s. (section 6 (3) (4)).

The Sanitary Authority, moreover, are required by section 16 of the London Act to make bye-laws for the prevention of nuisances arising from (1) any snow, ice, salt, dust, ashes, rubbish, offal, carrion, fish, filth, or other matter in the street; (2) from any offensive matter running out of any manufactory, brewery, slaughter-house, knacker's yard, butcher's or fishmonger's shop, or dung-hill, into any uncovered place, whether or not surrounded by a wall or fence; (3) from keeping of animals; (4) as to the paving of yards and open spaces in connection with dwelling-houses. It is, moreover, the duty of the Sanitary Authority to enforce any bye-laws made, in respect of these matters, by the County Council.

As regards the prevention of smoke, section 24 of the Public Health (London) Act, 1891, corresponds closely with section 91 of the Act of 1875; but the main provisions against nuisances arising from smoke in the metropolis are contained in section 23 of the London Act of 1891, which provides that "every furnace employed in the working of engines by steam, and every furnace employed in any public bath or wash-house, or in any mill, factory, printing-house, dye-house, ironfoundry, glass-house, distillery, brew-house, sugar refinery, bakehouse, gas-works, water-works, or other building used for the purpose of trade or manufacture (although a steam-engine be not used or employed therein) shall be constructed so as to consume and burn the smoke arising from such furnace." Sanitary Authorities *must* carry out these provisions of this section, and, moreover, any information under it is not to be laid except under the direction of a Sanitary Authority. This section extends to the Port of London, where it must be enforced by the port Sanitary Authority, which is the City Corporation.

In Scotland.—The statutory enumeration of nuisances which may be summarily dealt with, as contained in the Public Health (Scotland) Act, 1867, is somewhat more comprehensive than that of the English Act of 1875 or the London Act of 1891. This is somewhat fortunate, especially in landward districts, as, owing to "the absence of specific powers of prevention, a local authority is obliged, as a rule, to rely upon its powers of prosecution with a view to the removal of nuisances" (sections 16, 30, 96, 122).

Except in certain cases as regards fireplaces, furnaces, and chimneys sending forth smoke so as to be injurious to health, and also churchyards or cemeteries so situated, or so crowded with bodies, or so conducted as to be offensive or injurious to health, the summary decision of a sheriff, magistrate, or justice upon the alleged existence of a nuisance is final.

As regards manufactories, trades, and businesses injurious to the health of the neighbourhood, or so conducted as to be offensive or injurious to health, or any collection of bones or rags, as well as factories not under any general Act for the regulation of factories or bakehouses, a medical certificate or requisition by ten inhabitants is required before the justice can give an interdict of the nuisance. The sheriff, magistrate, or justice may order remedial works to be carried out, or ordain the local authority to do so and to recover expenses from the owner of the premises or person responsible for the nuisance. There are no saving clauses at all corresponding to those in the English Act.

A County Council, subject to the approval of the Secretary for Scotland, to make bye-laws "for prevention and suppression of nuisances not already punishable in a summary manner by virtue of any Act in force throughout the country"; and Burgh Commissioners, subject to the approval of the Local Government Board, have similar powers in respect of the burghs (Burgh Police (Scotland) Act, 1892).

If a local authority refuse to enforce the provisions of the Public Health (Scotland) Act as to nuisances or otherwise, any two householders, or the inspector of the poor, or the local procurator fiscal, or the Local Government Board may apply to the sheriff for a summary decision and decree. The subsequent course of action is similar to that under similar circumstances in England.

In Ireland.—The nuisance prevention provisions are almost, if not quite, identical in the Public Health (Ireland) Act, 1878, section 107 *et seq.*, with those of the English Act of 1875; consequently, the explanations already given as to the law of nuisances in England and Wales hold good for that in Ireland. The Coal-Mines Regulation Act, 1887, applies to Ireland, but the Quarry (Fencing) Act of the same year does not apply.

CELLAR DWELLINGS.

In England and Wales.—The Public Health Act, 1875, section 71, prohibits the separate occupation as a dwelling of any cellar (including any vault or underground room) built or rebuilt after the passing of the Act, or which was not lawfully so let or occupied at the time of the passing of the Act. Anyone passing the night in a cellar is deemed to occupy it (section 74). No cellar could be considered to be lawfully let or occupied at the time of passing the 1875 Act which was not so let or occupied previously to August 7, 1866; and in the case of some few urban sanitary districts, where section 67 of the Public Health Act of 1848 was still in force in 1875, no cellar could be lawfully let or occupied as a dwelling which was not so let or occupied prior to August 31, 1848.

Cellar dwellings, the letting or occupation of which are not forbidden under section 71, are prohibited by section 72 from being let or occupied unless they comply with the following requirements :—(*a*) The height must in every part be at least 7 feet, 3 feet of which must be above the level of the adjoining street. (*b*) An open area at least 2½ feet wide in every part, and 6 inches below the level of the floor, must extend along the whole frontage. It may be crossed by steps, but not opposite the window. (*c*) The cellar must be drained by a drain at least 1 foot below the floor. (*d*) There must be proper closet and ashpit accommodation. (*e*) There must be a fireplace and chimney, and (*f*) a window at least 9 square feet in area, made to open. The window of a back cellar let or occupied along with a front cellar need only be 4 square feet in area.

Any person who lets, occupies, or knowingly suffers to be occupied for hire or rent any cellar contrary to the Act is liable for every offence to a penalty not exceeding 20s. for every day of default (section 73). Where two convictions relating to the occupation of a cellar as a separate dwelling have taken place within three months, a Court of summary jurisdiction may close, either temporarily or permanently, the premises, as it deems to be necessary (section 75).

In London.—The provisions as to cellar dwellings by sections 96 to 98 of the Public Health (London) Act, 1891, differ somewhat from those given in the preceding section. A cellar dwelling or underground room must not be occupied in London unless :—(*a*) Every part is 7 feet high, and the ceiling is at least 3 *feet* above the surface of the adjoining street; but, if the area outside is as much as 6 feet in width, or not less wide than the depth of the floor below the ground level, then the height may be 1 foot above the street. (*b*) Every wall has a damp-course, and, if in contact with the soil, is effectually secured from damp from the soil. (*c*) There is an open area outside along the frontage, 4 *feet wide* in every part, and 6 *inches* below the floor level. It may be crossed by steps but not opposite a window. (*d*) The area and the soil immediately below the room are effectually drained. (*e*) The hollow space (if any) below the floor is ventilated to the outer air. (*f*) Any drain passing under the room is properly constructed of gas-tight pipe. (*g*) The room is effectually secured against the rising of any effluvia or exhalation. (*h*) There is a proper water-closet and ashpit in a convenient place. (*i*) There is effectual ventilation. (*j*) There is a fireplace, with chimney. (*k*) There are one or more windows opening directly into the open air; the window-area being at least one-tenth of the floor-area, and so constructed that at least half of each window can be opened, and in each case opening to the top.

The same conditions apply to underground rooms occupied separately as dwellings before January 1, 1892; but the Sanitary Authority, either by general regulations or upon special application by the owner, may modify any conditions newly imposed by this Act which involve structural alteration of the building. The power as to closure of underground rooms after two convictions is the same as under the 1875 Act.

In Scotland.—Under the Public Health (Scotland) Act, 1867, sections 45 to 47, the occupation of cellars or underground rooms is regulated under similar conditions to those in force in England and Wales: "but there is no prohibition of the occupation of such dwellings, provided the conditions be observed, even if built after the passing of the Act."

In Ireland.—Practically there are no differences between the provisions of the Irish and English Public Health Acts under this heading: section 82 of the former corresponding to section 71 of the latter.

COMMON LODGING-HOUSES.

In England and Wales.—While the Public Health Act, 1875, does not give any definition of the expression "common lodging-house," it is commonly taken to mean, for the purposes of the Act, those lodging-houses "in which persons of the poorer class are received for short periods, and, though strangers to each other, are allowed to inhabit one common room." The term does not cover rooms common to the members of one family or household, nor inns, nor lodgings let to the middle or upper classes.

Section 76 of the Act requires every urban and rural Sanitary Authority to keep a register of common lodging-houses in their district, in which shall be entered the names and residences of the keepers thereof, and the situation of every such house, and the number of persons authorised by such authority to be received therein. It is unlawful to keep a common lodging-house unless it is registered (section 77), and this can only be done after it has been inspected and approved for the purpose by some officer of the Sanitary Authority (section 78). If required, the notice of registration must be affixed to the house (section 79).

Before any premises are approved as suitable for a common lodging-house they should—

> "(1) Possess the conditions of wholesomeness needed for dwelling-houses in general; and (2) should have arrangements fitting it for its special purpose of receiving a number of lodgers." Thus, the house should have dry foundations, and have proper drainage, guttering, and spouting, with a well-laid and paved yard abutting on it. The drains must be properly connected, the soil pipe ventilated, the water-closets trapped, and all waste pipes from sinks, basins, &c., discharging over gullies outside the house. The closets, privies, and receptacles should be in convenient situations, of proper construction, and adapted to the scavenging arrangements of the district. The walls, roof, and floors should be in good repair. Inside walls should not be papered. Every registered room should have special means of ventilation, by chimney if possible, and a window opening freely and directly upon the outer air. There should be kitchen and day-room accommodation apart from the bedrooms. Rooms partially underground should not be registered as sleeping rooms. There should be a supply of pure water, allowing at least 10 gallons per head per day for the maximum number of inmates, and one closet for every twenty registered lodgers. The washing accommodation should, wherever practicable, be in a special place, and not in the bedrooms; the basins for personal washing being fixed, trapped, and fitted with disconnected waste pipes.

No premises, failing to fulfil the above indicated requirements, should be approved by the Sanitary Authority for registration as a common lodging-house.

When the lodging-house is without a proper water-supply, and this can be furnished at a reasonable rate, the Sanitary Authority may enforce it (section 81). The keeper is required to limewash the walls and ceilings in the first week of April and October in every year (section 82). The Sanitary Authority have power to require the keeper of a house in which vagrants or beggars are received to make returns of persons who have slept there the night before (section 83), and the keeper must always give notice to the Medical Officer of Health and to the relieving officer of any case of infectious disease (section 84). In any urban or rural sanitary district in which Part III. of the Public Health Acts Amendment Act, 1890, has been adopted, any keeper of a common lodging-house who fails to give the notice required by the last mentioned section is liable to a penalty not exceeding 40s., and to a daily penalty not exceeding 5s.

Free access must be allowed to officers of the Sanitary Authority to a common lodging-house or any part thereof, and any person who refuses such access will be liable to a penalty not exceeding £5 (section 85).

Section 80 of the Public Health Act, 1875, requires all Sanitary Authorities to make bye-laws (1) for fixing and varying the number of lodgers who may be received into a common lodging-house, and for the separation of the sexes therein; and (2) for promoting cleanliness and ventilation; and (3) for the giving of notices and the taking of precautions in a case of any infectious disease; and (4) generally for the well ordering of such house. The Local Government Board have issued a series of Model Bye-laws for the purposes of this section, of which the following is a summary:—

(*a*) A greater number of lodgers than the maximum from time to time fixed by the Sanitary Authority by a notice served on the keeper of the house must not be accommodated in each room; it is usual to require at least 300 cubic feet of air-space per head, but to count two children as one adult. (*b*) In general, no person above ten years of age must occupy the same sleeping room as persons of the opposite sex, but rooms may be set apart for the sole use of married couples, to the exclusion of other persons over ten years of age, on condition that every bed is screened off. No bed must be occupied by more than one male above ten years of age. (*c*) The yards, &c., must be kept clean and in good order; all floors swept daily, and washed once a week; all windows, painted surfaces, and fittings of wood, stone, or metal kept clean. (*d*) Closets must be kept clean and in good and efficient order. (*e*) Ashpits must be kept clean and in good order; no filth or wet refuse being thrown into ashpits designed for dry refuse only. (*f*) The windows must be opened fully for an hour in the morning and an hour in the afternoon, except in case of bad weather or occupation of the room by a sick person, or other sufficient cause. Beds must be stripped of clothes and fully exposed to the air for an hour each day, and must not be re-occupied within eight hours after being vacated. All refuse and slops must be removed every day before 10 A.M., and all utensils cleansed daily. Every sleeping room must be provided with sufficient bedsteads, beds, bed-clothes, and utensils for the use of the maximum number of lodgers to be received therein. (*g*) A sufficient supply of suitable basins, water, and towels must be provided for the use of lodgers, and must be kept clean and renewed as required. (*h*) If the keeper finds that any lodger is suffering from an infectious disease, he must at once take all necessary precautions. No person, except a relative or attendant, must occupy the same room as the sick person. If the patient is removed to hospital by the Sanitary Authority, the keeper must afford all facilities for removal, and must adopt all precautions directed by the Medical Officer of Health. He must, if required to do so, temporarily cease to receive lodgers into any infected room. At the end of the case, by removal, recovery, or death, the keeper must at once give notice to the Medical Officer of Health, and must cleanse and disinfect every part of the infected rooms and their contents, and in doing so must comply with all the instructions of the Health Officer. When the cleansing and disinfection are completed, he must give notice thereof to the Medical Officer of Health, and must not receive any lodger into the rooms in question until two days after such notice has been given. (*i*) A copy of the bye-laws in force with respect to common lodging-houses, supplied by the Sanitary Authority, and a statement of the provisions of sections 75 to 89 of the Public Health Act, 1875, must be placed in some conspicuous place in the house, and must not be concealed, altered, obliterated, or injured.

In London.—Outside the city of London the metropolitan common lodging-houses are regulated by the Common Lodging-houses Acts, 1851 and 1853, which, "except as regards the Metropolitan Police District, were repealed by section 343 of the Public Health Act, 1875." Section 3 of the Act of 1851 provided that the Act should be executed within and for all parts of the Metropolitan Police District by the Commissioners of Police. By a provisional order, however, of the Local Government Board, dated May 7, 1894, since confirmed by Parliament, these powers and duties of the Police Commissioners under those Acts have been transferred to the London County Council, from November 1, 1894. Under the Common Lodging-houses Acts of 1851 and 1853, the powers for the control and management of those places are practically the same as those of Sanitary Authorities in other parts of the country under the Public Health Act, 1875; power being given to make regulations for them, subject to confirmation of the Home Secretary (section 9). In the city of London the provisions of the Public Health Act, 1875, as to common lodging-houses appear to apply, the Commissioners of Sewers being the local Sanitary Authority.

In Scotland.—By the Public Health (Scotland) Act, 1867, sections 59 to 70, the provisions respecting common lodging-houses are similar to those in force in England. The definition, however, of a common lodging-house is peculiar, it being defined "as a house or part thereof where lodgers are housed at an amount not exceeding fourpence per night for each person, whether the same be payable nightly or weekly, or at any period not longer than a fortnight, or where the house is licensed to lodge more than twelve persons." The amount charged may, with the approval of the Sanitary Authority, be diminished or raised, but not to exceed sixpence.

In Ireland.—The Irish Public Health Act of 1878, section 2, defines a common lodging-house to mean "a house in which, or in any part of which, persons are harboured or lodged for hire for a single night, or for less than a week at a time." The provision empowering a Sanitary Authority to remove a lodging-house from the register until a proper water-supply has been provided is compulsory, and not merely permissive as in England (section 92). In the case of failure on the part of the keeper to limewash the walls in the first weeks of April and October in each year, the work can be executed by the Sanitary Authority, and the cost recovered in a summary manner (section 93). Excepting some other minor differences, the provisions of the Irish Act, in respect of common lodging-houses, conform closely with those of the English Act; while the Model Bye-laws, issued by the Local Government Board for use in England, will also apply, with some small modifications, to Ireland.

TENEMENT HOUSES.

The term "tenement houses" is here used to express houses which, while not being common lodging-houses as defined in the last section, are let in lodgings or occupied by members of more than one family. So far as relates to sanitary enactments hereafter to be explained, these tenement houses, as above defined, are assumed to be only those houses occupied by persons belonging to the poorer classes, and do not embrace houses of higher rateable value.

In England and Wales.—Every Sanitary Authority, in respect of so-called "tenement houses," has power to make bye-laws for their control and management by the Public Health Act, 1875, section 90, and the unrepealed 8th section of the Housing of the Working Classes Act of 1885. These bye-laws should be framed for (1) fixing, and from time to time varying, the number of persons who may occupy a house or part of a house, which is let in lodgings or occupied by members of more than one family, and for the separation of the sexes in a house so let or occupied; (2) for the registration of such houses; (3) for their inspection; (4) for enforcing drainage, and the provision of privy accommodation, cleanliness, and ventilation; (5) for cleansing, limewashing at stated intervals, and for the paving of the yards; (6) for the giving of notices, and the taking of precautions in case of infectious disease.

Practically, the general tenor of these bye-laws is the same as those proposed for common lodging-houses; but in the absence of any express limitation, in the sanitary Acts, of their scope, Sanitary Authorities are advised by the Local Government Board to insert a clause in their bye-laws relating to these houses, providing for the exemption of lodging or tenement houses, as to which it may be reasonably inferred that such supervision, as elsewhere a Sanitary Authority alone can sufficiently exercise, will be exercised, in fact, by the lodgers themselves. In other words, it is assumed that bye-laws are unnecessary in the case of tenement houses occupied by well-to-do persons.

The Local Government Board have issued Model Bye-laws, dealing with these houses, which are somewhat lengthy. The nature of some of them may be inferred from the models relating to common lodging-houses; but in respect of one or two points, special notice is necessary. Thus, it is suggested that every room should have a notice or placard indicating how many inmates may be received in each sleeping or other apartment. The minimum free air space allowed, for rooms used exclusively for sleeping, should be 300 cubic feet for every person exceeding ten years of age, and 150 cubic feet for those under ten years. Where a room is not used exclusively for sleeping purposes, these spaces may be increased to 400 and 200 cubic feet respectively.

The Model Bye-laws do not contain provisions for the separation of the sexes. This omission arises from a reasonable doubt whether this is practicable under the ordinary conditions of life in lodgings of the poorer class. Where, however, a Sanitary Authority are satisfied that a rule on this subject can be enforced without hardship, it should be framed and enforced. Another point is that, considering the registration of these houses is not laid down by the law as for common lodging-houses, the landlord should furnish a statement, on requisition by the Sanitary Authority, as to (*a*) the total number of rooms in the house; (*b*) the total number let in lodgings or occupied by members of more than one family; (*c*) the manner of use of each room; (*d*) the number, age, and sex of the occupants of each sleeping room; (*e*) the name of the lessee of each room; and (*f*) the amount of rent or charge payable by each lessee. The other Model Bye-laws relating to inspection, drainage, privy accommodation, &c., do not materially differ from those proposed for common lodging-houses.

In sea-port towns, under section 214 of the Merchant Shipping Act, 1894, the Sanitary Authority may make bye-laws as to *seamen's lodging-houses*, subject to sanction of the President of the Board of Trade. Such bye-laws must, amongst other things, provide for licensing, inspection, general sanitation, publication of the fact of a house being licensed, due execution of bye-laws and regulations, the prevention of persons not duly licensed purporting to keep licensed houses, the exclusion of persons of improper character, and sufficient penalties for breach of such bye-laws, not exceeding £50.

If a Sanitary Authority do not make, revoke, or alter bye-laws in respect of these matters, after notice from the Board of Trade, that body may do so; and an Order in Council may be made requiring all seamen's lodging-houses to be licensed, and none but persons duly licensed shall keep seamen's lodging-houses or let lodgings to seamen in any sea-port town or part thereof.

Section 259 of the same Act enables the corporations of municipal boroughs being ports in the United Kingdom to appropriate, with the consent of the Local Government Board, lands belonging to them as sites for sailor's homes.

In London, the regulation of tenement houses or lodgings other than common lodgings, is within the jurisdiction of the metropolitan Vestries and District Boards in the administrative county of London, and of the Commissioners of Sewers in the city, who respectively, by section 94 of the Public Health (London) Act, 1891, are required to make and enforce bye-laws for the several purposes for which Sanitary Authorities may make bye-laws under section 90 of the Public Health Act, 1875. The County Council are the Local Authority in the administrative county of London for the purposes of the Merchant Shipping Act, 1894, and are under the same obligations to make bye-laws and regulations with reference to seamen's lodgings under that enactment as attaches to Sanitary Authorities in whose districts sea-port towns are situated. In the city of London the same duties devolve on the Commissioners of Sewers.

In Scotland.—As regards lodging-houses other than common lodging-houses, section 44 of the Public Health (Scotland) Act, 1867, says that, with the consent of the Local Government Board, regulations may be made "by the local authorities *of burghs* with not less than 2000 inhabitants, for purposes similar to those which may be regulated in England"—not specifically including drainage, and the notification of, or taking of precautions against infectious disease cases. Although the Housing of the Working Classes Act, 1885, section 8, empowering *every* local authority to regulate lodging-houses by bye-law, appears to be intended to apply to Scotland, it is doubtful whether, owing to imperfect drafting, its provisions could be enforced. The provisions of the Merchant Shipping Act, 1894, sections 214 and 259, respecting seamen's lodging-houses, apply to Scotland.

In Ireland.—Section 100 of the Public Health (Ireland) Act, 1878, corresponds to section 90 of the English Act, and empowers Sanitary Authorities to make bye-laws as to houses let in lodgings. Owing to ambiguity of phraseology, it is doubtful whether that section of the Act is in force in the districts in respect of such houses, without a declaration by the Local Government Board. The Housing of the Working Classes Act, 1885, section 8, enabled the Sanitary Authorities in England to make "these bye-laws without any declaration by the Local Government Board, and section 15 of the same Act applied the provisions of section 8 to Ireland." The Act of 1885, with the exception of a few sections which include section 8 but not section 15, was repealed by the Housing of the Working Classes Act of 1890, so that it is very problematical whether section 8 of the 1885 Act is really now in force in Ireland. The provisions for making bye-laws and granting sites for seamen's lodging-houses are the same in the case of Ireland as for England.

HOUSING OF THE WORKING CLASSES.

The legislative enactment which enables Sanitary Authorities to deal with this important branch of the Public Health is the Housing of the Working Classes Act, 1890. This Act repealed and consolidated fourteen Acts dealing with the important but large subject of dwellings for the labouring classes. The Act is divided into seven parts; of these, the last four are supplemental to the first three, hence the natural division of the Act is into three parts only.

Part I. is headed "unhealthy areas," being an amendment and consolidation of the Artisans' and Labourers' Dwellings Acts, formerly known as Cross's Act. The essential point of this part of the Act is to give powers to a Local Authority to clear some well defined unhealthy area in an urban district, and having removed the offending dwellings, narrow courts, &c., to replace the dwellings so removed by structures in all respects fit for human habitation, and to re-arrange the streets on an improved plan, admitting of plenty of air and light.

Part II. deals with the individual house, or with small groups of houses. The basis of this part is the Act known formerly as Torren's Act, but the leading idea is practically the same as that characteristic of Part I.: the chief distinction between them being, that while Part I. is applicable only to urban districts and deals with large areas including many houses, Part II. applies to both urban and rural districts and deals with the individual house, or small groups of houses.

Part III. is an embodiment of the Shaftesbury Acts, and is adoptive. It gives to Authorities facilities for acquiring or appropriating land for the purposes of erecting thereon buildings suitable for lodging-houses for the working classes. Under this part they can also convert any buildings into lodging-houses for the working classes, and may "alter, repair, enlarge, and improve the same respectively, and fit up and furnish and supply the same with requisite furniture, fittings, and conveniences."

Of the remaining or purely supplemental portions of the Act, Part IV. contains the following important provision. "In any contract made after August 14, 1885, for letting for habitation by persons of the working classes a house or part of a house, there shall be implied a condition that the house is at the commencement of the holding in all respects reasonably fit for human habitation."

The Act thus readily lending itself to division into three main parts, or those dealing with "unhealthy areas," "unhealthy dwellings," and "working-class lodging-houses," it will be more convenient to consider the law relating to the whole question of the housing of the working classes under those three main sections.

UNHEALTHY AREAS.

Part I. of the Housing of the Working Classes Act, 1890, which deals with this subject, is applicable to England and Wales, the metropolis, Scotland, and Ireland; and enables the various urban Sanitary Authorities, the London County Council, and the Commissioners of Sewers of the City of London to carry out by means of provisional orders, confirmed by Parliament, improvement schemes for the reconstruction and re-arrangement of the streets and houses in unhealthy areas.

To put the Act in motion, it is the duty of the Medical Officer of Health to make "an official representation" in writing to the Sanitary Authority, whenever he sees cause to do so, that within a certain area either any houses or courts are unfit for habitation; or the bad arrangement or condition of the streets or houses, or want of light, ventilation, or proper conveniences, or any other sanitary defects, are dangerous to the health of the inhabitants; and that the evils cannot be effectually remedied otherwise than by re-arrangement and reconstruction of some or all of the streets or houses. Similarly, upon complaint by two justices of the peace, or twelve ratepayers, the Medical Officer of Health must make an inspection and report upon any area alleged to be unhealthy and dangerous to health. If he fails to do so, or reports that it is not an unhealthy area, such ratepayers may appeal to the confirming authority (which in the case of all urban districts is the Local Government Board, and as regards the metropolis is the Home Secretary), who, upon receiving satisfaction as for costs, may then appoint a medical practitioner to inspect the area, and to make representation to them, stating the facts of the case, and whether, in his opinion, the area, or any part thereof, is or is not an unhealthy area. The representation so made must be transmitted by the confirming authority to the Local Authority, who must treat it in the same manner as if it were an official representation made direct to them in the other or more ordinary way by their own officer (section 16).

The Sanitary Authority must consider this or any representation, and if satisfied of the truth thereof, and of the sufficiency of their resources, must declare the area to be an unhealthy area, and frame an improvement scheme. In any case, if the Sanitary Authority refuse or fail to prepare a scheme upon receipt of an official representation, they must report the facts to the confirming authority, who may then order a local inquiry to be held. The Act, however, does not authorise any action to be taken on the information thus obtained (section 10).

Having passed a resolution to carry out an improvement scheme, the Sanitary Authority may prepare it, with maps, plans, and elaborate details as to sanitary arrangements, widening the approaches and streets, or otherwise opening out the area. It may exclude any part of the area, or include neighbouring lands; but must provide such dwelling accommodation, if any, for the working classes displaced by the scheme as is required by the Act (section 6). Due publicity must be given to the scheme by publishing advertisements in a local newspaper in either September, October, or November, naming a place within such area or in the vicinity where a copy of the scheme may be seen at all reasonable hours; and during the month next following the month in which advertisements were published, notices must be served on all the persons interested (section 7). This being done, application must be made by the Sanitary Authority to the confirming authority for a provisional Order. If this authority think fit to proceed with the case, it must direct a local inquiry to be held respecting the correctness of the official representation, and the sufficiency of the scheme. On receiving the report made by this inquiry, the confirming authority may grant a provisional Order declaring the limits of the area to which the scheme relates, and authorising the scheme to be carried into execution. The Order has no validity unless and until it has been confirmed by Act of Parliament, and such Act must be a public general Act (section 8).

In London, accommodation must be provided in or near the area for the whole number displaced, unless the Order decrees otherwise; under certain conditions the Order may accept in substitution equally convenient accommodation not in or near the area, and may dispense with the obligation to any extent not exceeding one-half. Outside the metropolis such provision is only compulsory if (and to the extent) prescribed by the Order (section 11). In assessing the value of property, no additional allowance for compulsory purchase is to be made in regard to any unhealthy portion of the area; and evidence may be given showing that any premises are (1) unfit for habitation, and cannot reasonably be made fit; or (2) in bad repair, or in an insanitary condition; or (3) that the rental is enhanced by reason of overcrowding or use for illegal purposes. In the first case the compensation is to be based upon the value of the land and building materials only; in the second, upon the value after allowing for the cost of necessary repairs; in the third, upon the value apart from such illegal use (section 21).

The Sanitary Authority must, not less than thirteen weeks before taking any fifteen houses or more, give notice to the occupiers by placards, handbills or other notices, and must also, before actually clearing, obtain a certificate from a justice that they have made known their intention of taking the houses in the manner specified in the Act (section 14). The time taken by all these steps is often considerable. It rarely happens that an area is cleared and built upon under four years. If within five years after the removal of any buildings on the land set aside by any scheme authorised by a confirming Act as sites for working men's dwellings the Sanitary Authority fail to complete it, the Local Government Board have power to sell the land and complete the scheme (section 13).

Reference may conveniently here be made to a practical difficulty which occasionally arises, in connection with this matter of unhealthy areas, in London. Owing to the County Council being the local authority outside the city for the purposes of Parts I. and III. of the Housing of the Working Classes Act, 1890, and the Vestries and District Boards and the Woolwich Local Board the local authorities for the purposes of Part II. of the Act, in cases where the area to be dealt with is neither very large nor very small, differences of opinion arise whether it should be dealt with under Part I. or II. of the Act. When Part I. is put in force, the expenses are necessarily borne by the whole of London exclusive of the city. When recourse is had to Part II., the cost primarily falls on the parish or district subject to the Sanitary Authority. To avoid this difficulty, section 72 says that when official representation deals with not more than ten houses, the case is to be dealt with under Part II. It is obvious, however, that this enactment only solves the difficulty in a limited number of cases, hence a further attempt has been made to remove doubts and differences on this matter that may arise between the County Council and the Sanitary Authorities, by leaving the question to be settled in each case by the Home Secretary (section 73).

Another point of importance, in London, is that the official representation by means of which the County Council are to be set in motion must be made either by the Medical Officer of Health of the Council, or by any Medical Officer of Health in London (section 5 (1)).

Part I. of the Housing of the Working Classes Act, 1890, applying equally to **Scotland** and **Ireland** as to England and the metropolis, no special remarks as to its working in the two former countries are necessary.

UNHEALTHY DWELLING-HOUSES.

The enactments dealing with this matter are practically the Public Health Act, 1875, sections 91 to 111, and Part II., Housing of the Working Classes Act, 1890. It has already been shown (page 854) that any house or part of a house so overcrowded as to be dangerous or injurious to the health of the inmates, no matter whether members of one family or not, and any premises in such a state as to be a nuisance or injurious to health may be dealt with in any urban or rural sanitary district under the provisions of the Public Health Act, 1875, relating to nuisances, and if so deemed necessary may be closed as unfit for habitation. Where the only object of a Sanitary Authority is to close a house, either for the purpose of checking overcrowding or to induce the owner to make certain necessary improvements in it, it is generally better to proceed under the provisions of the Act of 1875. But where the authorities propose to go further, and to take steps to obtain the demolition of the house, they must proceed under the Housing of the Working Classes Act, 1890.

Part II. of this latter Act, which is applicable to all urban and rural Sanitary Authorities in England and Wales, and also, with some minor modifications, to Scotland and Ireland, lays a definite duty upon the Medical Officer of Health to represent to the local authority of his district any dwelling-house "which appears to him to be in a state so dangerous or injurious to health as to be unfit for human habitation" (section 30). He may also be moved to inspect and make a representation by complaints in writing from any four or more householders (section 31 (1)); and in the case of an urban district, should the Sanitary Authority let three months pass away after receiving such representation without doing anything, the householders may petition the Local Government Board to hold an inquiry, and the Board, after such inquiry, may make a binding order on the authority (section 31 (2)). It is further the duty of the authority to make, from time to time, inspection of their district to ascertain whether any dwelling-house therein is in a state so dangerous or injurious to health as to be unfit for human habitation; and, if so satisfied that such is the case, to either take measures to close the house by a magistrate's order, under section 97, Public Health Act, 1875, or to give notice to the owner to do certain work, so as to put the premises in proper order, and, on his failing to comply, summon, and at the hearing ask, for the premises to be closed (section 32). In connection with the use of the term "owner" in this Act, reference should be made to the definition of that term (page 833), as under this Act the Local Authority has only to deal with freeholders and leaseholders, or other persons who have at least a twenty-one years' interest in the property.

If the closing Order of the Court is not terminated by a further Order declaring the dwelling-house habitable, the Sanitary Authority may proceed to make a resolution for demolition, giving notice to owner of same and opportunity for him to present objections. If upon the consideration of the resolution and objections, the Sanitary Authority decide that it is expedient so to do, then, unless an owner undertakes to execute at once the works necessary to render the premises fit for human habitation, they must order the demolition of the building (section 33). It may be, however, that the owner undertakes to execute the said works. If so, the Authority may order the execution of the works within a specified time, and if the works are not completed within that time, or any extended time allowed by the Authority or a Court of summary jurisdiction, the Authority must order the demolition of the building. When an order for demolition has been made, the owner must comply with it within three months; if he fail to do so, then the local Sanitary Authority may demolish, sell the materials, and, after deducting expenses, pay over the balance to the owner. Moreover, no building likely to be dangerous or injurious to health can be erected on the vacant site or any part of it (section 34). There is power of appeal against any of the Orders under this part of the Act, by any aggrieved person to Quarter Sessions; but notice of appeal must be given within one month after notice of the Order of the Sanitary Authority has been served (section 35).

Section 38 raises the interesting question of what are known as "*obstructive buildings*," or those buildings which, although not in themselves unfit for human habitation, are so situated that by reason of their proximity to or contact with any other buildings they stop ventilation, or make other buildings insanitary, or prevent proper measures from being carried into effect for remedying nuisances. In any of the above cases, it is the duty of the Medical Officer of Health to make "a representation" of the particulars to his Sanitary Authority, stating that in his opinion it is expedient that it should be pulled down. A similar representation may be made by any four or more inhabitant householders. In either case, the Sanitary Authority must make inquiries as to the facts, and as to the cost of acquiring the land and pulling down the building. If they decide to proceed, the Authority can make an order for the demolition of the building, after giving the owner notice and an opportunity of stating his objections, and subject to appeal to Quarter Sessions. When such an Order has been made, and there is no appeal, or the appeal fails or is abandoned, the Sanitary Authority may compulsorily purchase the site within a year from the date of the Order, or if it were appealed against, from the date of its confirmation, unless the owner pulls down the obstructive building; in such case he is compensated for the building only. In case of difference as to price the matter goes to arbitration. The owner cannot subsequently re-erect an obstructive building on the vacant site, nor one that is dangerous or injurious to health. Where the Authority purchase land compulsorily under the above powers, a part only of the building can be taken if, in the opinion of the arbitrator, no material detriment will be suffered; but in assessing compensation, the value of the part and also the severance of the part are both taken into consideration. As probably the value of the buildings, which previously had been injuriously affected by the obstructive buildings, will be increased by the removal of the latter, the principle of "betterment" is adopted, and a Local Authority may apportion the compensation on such buildings, declaring them to be private improvement expenses, and levy improvement rates (section 38 (8)).

Where the lands are purchased by the Sanitary Authority, they may keep the site wholly or partly as an open space, highway, or other public place, or, with the consent of the Local Government Board, sell such portion of the site as is not required.

Section 39 empowers the Sanitary Authority to prepare a scheme for dedicating as a highway or open space, or appropriating or exchanging for the erection of working-class dwellings, the site of any building ordered to be demolished under this part of the Act, if it appear to them that it would benefit the health of the inhabitants of the adjoining houses; they may also prepare an improvement scheme for any unhealthy area too small to be dealt with under Part I. of the Act. Notice of the scheme must be given to the owners just as in Part I.; after this a petition must be presented to the Local Government Board for an Order confirming the scheme. It must be noted that in this case under Part II., the petition *in every case* must be to the Local Government Board, while under Part I., so far as London is concerned, it is to be addressed to the Home Secretary. The Local Government Board may, if they think fit, hold a local inquiry, and, if satisfied, may by Order sanction the scheme with conditions or modifications. In these Orders the Local Government Board must require the insertion of provisions, if any, for the dwelling accommodation of persons of the working classes who may be displaced as seem to them to be necessary under the circumstances. On the Order being made, the Sanitary Authority must endeavour to come to terms with the owners as to price, and, if an agreement is arrived at, the Order takes effect without confirmation. If they do not agree, the Authority must insert a notice of the Order in the *London Gazette*, and also serve notices thereof on the owners of every part of the area; but the notice is not restricted to particular months. If two months pass, and no owner petitions against it, or if he petitions and then withdraws it, the Board confirm the Order; but if opposed, the Order is only provisional, and has to be confirmed by Parliament. This procedure is somewhat less complicated than that under Part I., and in the case of small areas fairly expeditious; but when the Order is opposed, the delay and expenses incidental to carrying the scheme through are often large, and frequently act as a check upon action being taken by Local Authorities in respect of the matters which it is the aim of this part of the Housing of the Working Classes Act, 1890, to remedy.

When an official representation has been made under Part II., or a closing Order obtained, all Rural Authorities, the Metropolitan Vestries and District Boards, and the Woolwich Local Board, but not urban Sanitary Authorities, save those named, must forward to their County Council a copy of such "representation, complaint, information, or closing Order," and also report from time to time all further proceedings. If it appear to the County Council that a closing Order should be applied for, or an Order for demolition made, or steps taken for pulling down an obstructive building, and, if the Local Authority, after due notice from the County Council, fail to adopt such measures, the Council may by resolution take over and exercise the powers of the Local Authority, in respect of such buildings, recovering the expenses from the Local Authority (section 45).

Every Sanitary Authority must annually furnish the Local Government Board with an account of what has been done, and of all moneys received and paid by them during the previous year, in carrying into effect the purposes of this part of the Act (section 44). Except in boroughs, a representation by the county Medical Officer of Health, if forwarded by the County Council to any Sanitary Authority, has, for the purposes of Part II. of Housing of the Working Classes Act, 1890, the same effect as if made by the Medical Officer of Health of the district (section 52).

In the County of London, this part of the Act is primarily entrusted to the Vestries and District Boards and the Woolwich Local Board; but the County Council may prepare schemes under Part II. if they think fit, and may apply to the Home Secretary to order a contribution from the district authority, who, in like manner, if they proceed, may apply for a contribution from the County Council (section 46).

In Scotland, section 45, or that provision by which the powers of a district authority which refuses to proceed can be taken over by a County Council, does not apply; with this exception the enactments under Part II.

of the Housing of the Working Classes Act, 1890, are the same as in England. The provisions of Part II. are likewise the same for **Ireland** as for England, with the exception that sections 45 and 52 do not apply in Ireland. Where notices are published in the *London Gazette* for England, the same in Ireland must appear in the *Dublin Gazette.*

LODGING-HOUSES FOR THE WORKING CLASSES.

The expression "lodging-houses for the working classes" includes separate houses or cottages for the working classes, whether containing one or several tenements. The provision of these houses by a Sanitary Authority depends upon the powers conferred by Part III. of the Housing of the Working Classes Act, 1890. A peculiarity about this part of the Act is that it is "adoptive," and cannot be in force in any district until it has been adopted by the Sanitary Authority. In rural districts it can only be adopted after a local inquiry by the County Council, and a certificate that "accommodation for the housing of the poor is necessary, and that there is no probability that such accommodation will be provided without the execution of this part of the Act, and that, having regard to the liability which would be incurred by the rates, it is, under the circumstances, prudent for the authority to undertake the provision of such accommodation." In urban districts, the adoption of the Act is subject to the sanction of the Local Government Board. In the city of London, the administration of this and other parts of the Housing of the Working Classes Act, 1890, is vested in the Commissioners of Sewers. Outside the city, in the metropolis, the administration of Part III. is vested in the County Council.

Having adopted Part III. of the Act, the Sanitary Authority is empowered to purchase or rent land, or to appropriate any lands for the time being vested in them or at their disposal, and on such land to erect any buildings suitable for lodgings for the working classes, and to convert any buildings into lodging-houses for those classes. They may also contract for the purchase or lease of any lodging-houses for the working classes already or hereafter to be provided, and also sell any land vested in them for these purposes, and to apply the proceeds in or towards the purchase of other more suitable lands (sections 53 to 60).

The management of lodging-houses thus established or acquired is vested in the Local Authority, who may make reasonable charges for the tenancy or occupation (section 61). The Authority may also make bye-laws for their management and use, it being obligatory, except in the case of lodging-houses occupied as separate dwellings, to make provision in the bye-laws for the following purposes:—"(1) For securing that the lodging-houses shall be under the management and control of the officers, servants, or others appointed or employed in that behalf by the Authority. (2) For securing the due separation at night of men and boys above eight years old from women and girls. (3) For preventing damage, disturbance, or interruption, and indecent or offensive language and behaviour and nuisances. (4) For determining the duties of the officers, servants, and others appointed by the Authority" (section 62).

These lodging-houses are distinctly for the working classes, and not to be used by persons in receipt of parochial relief. This relief, save for accident or temporary illness, disqualifies a tenant (section 63). Lodging-houses, thus established, are to be at all times open to inspection by the officers of the Sanitary Authority of the district (section 70).

The expenses of urban Sanitary Authorities in supplying these lodging-houses will be borne out of the rates. Those of rural Sanitary Authorities are to be defrayed as special expenses on the contributory places in respect of which they are incurred; or, in special cases, they may be defrayed as general expenses in the execution of the Public Health Acts, and if they are not to be borne by the whole of the district, they will be paid out of a common fund to be raised in the manner provided by the Public Health Act, 1875, section 229. If after seven years' trial a Sanitary Authority find these lodging-houses too expensive, they may sell them with, in the case of urban authorities, the consent of the Local Government Board; in the case of rural authorities, the consent of the County Council.

The application of this Part III. of the Act to **Scotland**, if adopted, involves one small distinction from its similar application in England. It is that the consent of the Local Government Board is necessary in the case of *both* rural and urban districts before these lodging-houses can be provided.

In Ireland, the application and operation of Part III. of the Housing of the Working Classes Act as regards urban Sanitary Authorities is practically identical with its adoption in England. There is this difference, however, that the consent of the Treasury, instead of the consent of the Local Government Board, is required to the appropriation of any lodging-house purchased or taken on lease, and to the sale and exchange of lands. The Commissioners of Public Works, acting with the consent of the Treasury, may advance money for the purposes of the Act, and favourable terms have been laid down by the Treasury. The operation of Part III. of the Act, in rural districts, is practically limited to municipal towns. Its general adoption by purely rural authorities is rendered unnecessary owing to the special facilities afforded by the various Labourers (Ireland) Acts of 1883, 1885, 1886, 1891, and 1892, for the erection of houses for agricultural labourers by any rural Sanitary Authority.

These Acts define an agricultural labourer to mean "a man or woman who does agricultural work for hire at any season of the year on land of some other person or persons, and includes hand-loom weavers and fishermen doing agricultural work as aforesaid, and also herdsmen." The general scope of these Acts amounts to this; that any twelve persons, whether rated for the relief of the poor or not, provided that if not so rated they are agricultural labourers within the meaning of the Acts, and are employed in the district at the date of the representation, may represent to a rural Sanitary Authority that, in the portion of the district in which they reside, the existing house accommodation for agricultural labourers and their families is either deficient or unfit for human habitation. If the Sanitary Authority are satisfied of the truth of the representation, and of the sufficiency of its resources, they are to make an "improvement scheme" for the erection of dwellings, with garden allotments thereto not exceeding one statute acre. The subsequent procedure for obtaining sanction to the scheme is very similar to that of the English Act of 1890. Parliamentary confirmation of provisional Orders is unnecessary; they become absolute if no petition is lodged against it within one month after the making and publication of the Order by an owner or occupier of land proposed to be taken compulsorily, or by twelve ratepayers in any area of charge declared by the Order to be chargeable with the expenses of the scheme. If a petition be lodged, the objections to the Order are adjudicated upon by the Lord Lieutenant in Council, who has power to confirm, modify, or to disallow any provisional Order.

CANAL BOATS.

The definitions of a canal and canal boat have already been given. The legislation which controls the sanitation of the large floating population on the canals are the Canal Boats Acts of 1877 and 1884. These Acts are only applicable to England and Wales. In the following remarks, when the number of a section is quoted, unless expressly stated to be otherwise, such numbering refers to the Act of 1884.

By these Acts the supervision of the canal boats is placed under every Sanitary Authority through whose district a canal takes its course, or which has a piece of water coming under the definition of the word canal (see page 833). It is further the duty of these Authorities to report, within twenty-one days after December 31st in every year, as to the execution of the Acts, and as to the steps taken by the Authority during the year to give effect to them (sections 3 to 5).

No canal boat must be occupied as a dwelling unless it is registered under these Acts, and then only by the number of persons of the age and sex for which it is registered (section 1). The owner can register the boat with any registration Authority having a district abutting on the canal on which such boat is accustomed or intended to ply; and the boat must be registered as belonging to some place which is within the said district (section 7). When the boat passes from the canal on which the district of the Authority with whom it has been registered abuts, its original registry will be recognised as operative on other canals whereon it may ply. If a canal boat is used in contravention of the Acts, the master of the boat, and also the owner, if he is in fault, will be each liable to a fine not exceeding 20s. for each occasion on which the boat is so used. Directly a canal boat ceases to be inhabited it is no longer subject to the Canal Boats Acts. Upon registration, two certificates must be given to the owner, identifying the owner and the boat, and stating the place to which it belongs, and the number, age, and sex of the persons allowed to dwell in the boat. The master of the boat must carry one of these certificates (section 3). A boat cannot be considered to be registered unless it is marked with (*a*) the name of the place to which the boat belongs; (*b*) the number; (*c*) the word "registered," thus, "No. 129, Hanley, Registered." Further, a boat will not be deemed to be lettered, marked, and numbered in conformity with these requirements unless it is so lettered, marked, and numbered on both sides of it, or in some suitable position plainly visible from both sides of the boat (section 7). A certificate of registration will cease to be in force in the event of any structural alterations having been made in the canal boat affecting the conditions upon which it was originally registered (section 1).

If any person on a canal boat is suffering from an infectious disease, the Sanitary Authority of the place where the boat is shall adopt such precautions as appear necessary, upon the certificate of the Medical Officer of Health, or other legally qualified practitioner; and may remove such sick person, and exercise the other powers conferred by the Public Health Act, 1875, in this respect, and may detain the boat as long as is necessary for cleansing and disinfecting (section 4, Act of 1877). If any person duly authorised by the Sanitary Authority has reason to suspect any contravention of the Act, or that a person on board is suffering from an infectious disease, he may enter the boat for the purpose of inspection between 6 A.M. and 9 P.M., and may require the master or whoever is in charge of the boat to afford him facilities for so doing, and to produce the certificate of registry of the boat (section 5, Act of 1877).

Section 2 of the Act of 1877 directs the Local Government Board to make regulations: (i.) for the registration of canal boats; (ii.) for lettering, marking, and numbering such boats; (iii.) for fixing the number, age, and sex of persons who may be allowed to dwell in a canal boat, having regard to the cubic space, ventilation, separation of the sexes, general healthiness, and convenience of accommodation; (iv.) for promoting cleanliness and habitable condition of such boats; and (v.) for preventing the spread of infectious disease by canal boats.

In pursuance of the above powers, the Board issued an Order in 1878, prescribing a series of regulations which are still in force. The following is a summary of their principal sanitary provisions:—

There must be at least one dry, clean, and weather-proof cabin, in good repair. An after-cabin, intended to be used as a dwelling, must contain not less than 180 cubic feet of free air space, and a fore-cabin 80 cubic feet; every such cabin must have means of ventilation besides the door, and must be so constructed as to provide adequate sleeping accommodation. One cabin must contain a stove and chimney. The boat must be furnished with suitable storage for 3 gallons of water. If intended to be ordinarily used for foul cargoes, the hold must be separated from any inhabited cabin by a double bulkhead with an interspace of 4 inches, and the bulkhead next the cargo must be water-tight. Not less than 60 cubic feet of air space must be allowed for each person over twelve years of age, and not less than 40 cubic feet for each person under that age. In "fly-boats" worked by shifts, a cabin occupied at the same time by two persons must have a capacity of 180 cubic feet. A cabin in which a married couple sleep must not be occupied at the same time by any other male above 14, or female above 12 years of age. Males above 14 and females above 12 years of age must not occupy the same sleeping cabin at the same time, but reservation is made for married couples, and also (under certain conditions) in respect of boats constructed prior to 1878. The interior of the cabin must be repainted every three years, and must be kept clean. Bilge water must be pumped out daily. The master of the boat must at once notify the occurrence of any case of infectious disease on the boat to the Sanitary Authority of the district through which the boat may be passing, and also to the Sanitary Authority of the place of destination; he must also inform the owner, who is required to notify to the Sanitary Authority of the place to which the boat belongs. If the boat is detained by the Authority for purposes of disinfection, the Sanitary Authority must obtain a medical certificate that the boat has been cleansed and disinfected, and shall cause such certificate to be delivered to the master of the boat, who cannot proceed until that certificate has been obtained. The Sanitary Authority may pay a reasonable remuneration for any such certificate.

The Acts contain special provisions with respect to the education of children living in canal boats, and enable the Education Department to make regulations on this subject (sections 6 and 12, Act of 1877). Section 4 of the Act of 1884 requires the Local Government Board to make inquiries, from time to time, by an inspector or inspectors, specially appointed for the purpose, as to the working of these Acts and Regulations, and to report annually thereon to Parliament.

So far as their parishes and districts are not within the jurisdiction of the Port Sanitary Authority for the Port of London, the Vestries and District Boards are the local Authorities for the purposes of the Canal Boats Acts, 1877 and 1884, in the metropolis.

MOVABLE DWELLINGS OTHER THAN CANAL BOATS.

There is a considerable population who occupy "movable dwellings other than canal boats," such as vans, tents, sheds, and other similar structures, and whose conditions of life are often a menace to the Public Health. These individuals are for the most part of the so-called gipsy class, while at certain seasons of the year their numbers are materially increased by others engaged in hop or fruit-picking. In order to control the sanitation of this more or less vagrant population, Sanitary Authorities possess certain powers under the Public Health Act, 1875, under the unrepealed 9th and 10th sections of the Housing of the Working Classes Act, 1885, and under the Public Health (Fruit-Pickers' Lodgings) Act of 1882.

Section 9 of the Housing of the Working Classes Act, 1885, provides that a tent, van, shed, or similar structure, used for human habitation (exclusive of those used by a portion of Her Majesty's military or naval forces), which is in such a state as to be a nuisance or injurious to health, or which is so overcrowded as to be injurious to the health of the inmates, whether or not members of the same family, shall be deemed to be a nuisance within the meaning of section 91 of the Public Health Act, 1875, and the provisions of that Act shall apply accordingly. By section 10, any Sanitary Authority may make bye-laws in regard to such habitations. Power of entry between 6 A.M. and 9 P.M. is given to any person duly authorised by the Sanitary Authority or by a Justice of the Peace, if such person has reasonable cause to suspect any contravention of the Act, or of any bye-laws made under it, or that there is in such habitation any person suffering from any dangerous infectious disease. If any such person is obstructed in the performance of his duty under the above provisions, the person obstructing him will be liable on summary conviction to a fine not exceeding 40s.

As regards the accommodation and lodging of hop and fruit-pickers, every Sanitary Authority has power under section 314 of the Public Health Act, 1875, to make bye-laws for securing the decent lodging and accommodation of persons engaged in hop-picking within the district of such authority. This power has been extended by the Fruit-Pickers Act of 1882, so as to enable the same authorities to make bye-laws for securing decent and proper accommodation and lodging of those engaged in the picking of fruit and vegetables.

For the proper control and regulation of the tents, sheds, barns, or other places occupied as temporary dwellings by hop-pickers and others, but not of places inhabited throughout the year, the Local Government Board have suggested Model Bye-laws. Of these, the following is a brief summary:—

(*a*) The habitations must be clean, dry, weather-proof, ventilated, and lighted. (*b*) At least 16 square feet of floor space must be allowed in them for each adult and for every two children under ten years of age. (*c*) When intended for the reception of adults of different sexes, the habitations must be so furnished or provided that every bed is properly separated from any adjoining bed by a suitable screen or partition to secure adequate privacy to the occupants. (*d*) There must be a separate cooking-place for every fifteen persons authorised to be received. (*e*) There must be a sufficient supply of good water for drinking, cooking, and washing. (*f*) There must be adequate privy accommodation for the separate use of each sex. (*g*) Every lodger or occupant shall be provided with a sufficient supply of clean dry straw, or other clean, dry, and suitable bedding, which must be changed or properly cleansed from time to time, as occasion may require. (*h*) Every part of the interior of the premises, the cook-houses, and privies must be thoroughly cleansed immediately before any person is received to lodge therein, the internal surfaces limewashed, and all offensive accumulations cleared away; this cleansing and limewashing must be done at least annually, and repeated as required from time to time during the period of occupation.

In the Metropolis, the various Sanitary Authorities have similar powers and duties to those of other authorities in England and Wales in relation to tents, vans, sheds, or other similar structures used for human habitations, but their action in this matter will be taken by applying section 95 of the Public Health (London) Act of 1891, read in conjunction with section 9, Housing of the Working Classes Act, 1885.

As regards **Scotland** and **Ireland**, these provisions of the Working Classes Act are of very doubtful application; while those of English Statutes dealing with hop and fruit-pickers' lodgings do not apply.

NEW STREETS AND BUILDINGS.

In England and Wales.—The Public Health Act, 1875, and the Amendment Act, 1890, give Sanitary Authorities, especially urban Authorities and such rural Authorities as have obtained urban powers, considerable control over the arrangements, construction, and planning of streets and buildings within their districts.

By the Act of 1875 all public streets in urban districts are vested in the Sanitary Authority, who must cause them to be levelled, paved, and repaired as occasion may require (section 149). All owners of property abutting on any private street or part of a street may be required by an urban Authority to level, pave, sewer, light, or make good such street or part of a street; and in case of default the Sanitary Authority may carry out the work and recover expenses from the owners according to the frontage of their respective premises (section 150). Section 157 of the same Act enables every urban Authority to make bye-laws with respect to the structure of walls, foundations, roofs, and chimneys of new buildings for securing stability, and the prevention of fires, and for purposes of health, and with respect to the sufficiency of the space about buildings to secure a free circulation of air, and with respect to the ventilation of buildings. For the purposes of the Act, the re-erection of any building pulled down to or below the ground floor, or the conversion into a dwelling-house of any building not originally constructed for human habitation, or the conversion into more than one dwelling-house of a building originally constructed as one dwelling-house only, shall be considered the erection of a new building.

These powers have been extended by section 23 of the Public Health Acts Amendment Act, 1890, so as to enable any urban Sanitary Authority to make further bye-laws concerning new buildings upon the following points:—(*a*) adequate water-supply to closets; (*b*) construction of floors, hearths, and staircases; (*c*) height of rooms intended for habitation; (*d*) paving of yards and open spaces in connection with houses; (*e*) provision of secondary approaches to houses, for the purpose of removing refuse. It is further provided that bye-laws respecting closets and drainage may be made applicable to old as well as new houses. Similar power of framing and enforcing bye-laws for each of the above purposes, with the exception of the prevention of fires, has been given to rural Authorities adopting Part III. of the Act. Apart from this, however, the Local Government Board can, as already stated, grant full urban powers to rural Authorities. This same section 23 enables any Sanitary Authority to make bye-laws to prevent buildings erected in accordance with bye-laws from being altered in such way that if at first so constructed they would have contravened the bye-laws.

Other sections of the same Act of 1890 (sections 25 and 24) prohibit any new building being erected upon ground impregnated with animal or vegetable matter, or upon which such matter has been deposited, unless such matter has been properly removed or has become innocuous. Similarly, if in an urban district, any portion of a room is immediately over any privy (not being a water-closet or earth-closet), cesspool, midden, or ashpit, it is illegal to occupy it, or suffer it to be occupied, as a dwelling place, sleeping place, workroom, or place of business. Another enactment is, that buildings described in deposited plans otherwise than as dwelling-houses must not be used as such, under a penalty not exceeding £5, and a daily penalty not exceeding 40s. (section 33). These provisions are, however, subject to the exception, that if the building has in rear thereof, and adjoining and exclusively belonging thereto, such an open space as is required by Act of Parliament or bye-law for the time being in force with respect to buildings intended to be used as dwelling-houses, and if such part of the building as is intended to be used as a dwelling-house has undergone such structural alterations as, in the opinion of the Sanitary Authority, render it fit for that purpose.

Further, an urban Sanitary Authority, if satisfied that any building or wall is in a ruinous state so as to be dangerous to passengers or to the inmates of neighbouring houses, shall cause a fence to be put up, and shall order the owner forthwith to secure or pull down such building; and in default thereof the surveyor may obtain a justice's order to carry out the necessary works, and may recover the expenses. The Authority may also compel the owner of any building adjoining or near to a street to provide within seven days efficient eaves-gutters and rain-pipes (Towns Improvement Clauses Act, sections 74 to 78; Public Health Act, 1875, section 160).

For the guidance of Sanitary Authorities in framing bye-laws in respect of new streets and buildings, the Local Government Board have issued Model Bye-laws; of these models the following is a summary:—

(*a*) No new street must be less than 36 feet wide, if it exceeds 100 feet in length or is intended to be a carriage road: nor less than 24 feet in any case. One end at least must be quite open. (*b*) No buildings must be erected upon soil polluted with animal or vegetable matter. Sites in low and damp situations, near rivers or in excavations, must be elevated artificially. The site of a new house must be entirely asphalted or covered with 6 inches of concrete. (*c*) Walls of all new buildings must be constructed of good bricks, stone, or other hard and incombustible materials, properly bonded and solidly put together with good mortar compounded of good lime and clean sharp sand or other suitable material, or with good cement, or with good cement mixed with clean sharp sand. Every wall must have a proper damp course of durable and impervious material beneath the level of the lowest timbers, and at least 6 inches above the ground. If the ground is to be in contact with a wall above the level of the floor of the lowest storey, that wall must be made double, with a cavity 2½ inches wide extending from the base of the wall to 6 inches above the surface of the adjoining ground; and damp courses must be inserted both at the base of the wall and at the level of the top of the cavity. The minimum thickness of the wall of a new house should be as follows:—Where a wall is not over 25 feet in height, if it does not exceed 35 feet in length, and does not comprise more than two storeys, it shall be 9 inches for its whole height; but if it do comprise more than two storeys, or exceed 35 feet in length, it shall be 13½ inches below the topmost storey, and 9 inches for the rest. Where walls are over 25 feet high, and not exceeding 35 feet in length, they should be 13½ inches thick below the topmost storey, and 9 inches for the rest; but if they be longer than 35 feet, then they must be 18 inches thick for the height of one storey, then 13½ inches thick for the rest of the height below the topmost storey, and 9 inches thick for the rest of its height. Walls over 35 feet high must be 18 inches thick for the first two storeys, and 13½ inches for the rest. If over 50 feet in height, walls should be 22 inches thick for the height of one storey, then 18 inches for the next two storeys, and finally 13½ for the rest of the height. Party walls must be carried up at least 15 inches above the roof, the distance to be measured at right angles to the slope of the roof. (*d*) Roofs must be made of incombustible materials, and provided with gutters leading to rain-pipes. (*e*) A new house must have along its whole frontage an open space measuring at least 24 feet to the boundary of any land or premises immediately opposite or to the opposite side of the street. In the rear there must be an open space exclusively belonging to the house, at least 150 square feet in area, and free from any erection above the ground level, except a closet and an ashpit; the open space must extend along the entire width of the house, and must measure in no case less than 10 feet from every part of the back wall of the house; if the house is 15 feet high, the distance must be 15 feet; if 25 feet, then 20 feet; and if 35 feet or more, then 25 feet at least. (*f*) If the floor of the lowest storey is boarded, there must be a clear space of at least 3 inches between the boards and the impervious covering of the site, and the space must be ventilated. (*g*) Every habitable room must be provided with windows opening directly into the external air. The window area must be at least one-tenth of the floor area; at least half of each window must be made to open, and it must open at the top. Every habitable room must, further, either have a fireplace and chimney, or a special ventilating aperture or air-shaft with an unobstructed sectional area of at least 100 square inches. Every new building must be provided with adequate means of ventilation, and to secure this, so far as dwelling rooms in general are concerned, the minimum height should be 9 feet in every part, except in attics used as bedrooms, when a minimum height of 5 feet is permitted, if in two-thirds of the area the height is not less than 9 feet.

The provisions as to closets, privies, ashpits, and cesspools given in these Model Bye-laws have already been detailed on page 842. They are intended to specially apply to new buildings. The same models proceed to suggest that (*h*) the Sanitary Authority may, under certificate from the Medical Officer of Health or Surveyor, declare any building or part of a building erected after . unfit for habitation, and order it to be closed until rendered fit for habitation. Opportunity must be given to the owner to show cause why such order should not be made. (*i*) Plans and sections must be submitted, showing in detail the construction of all proposed new streets or buildings. (The Authority must signify their approval or disapproval within a month after receiving them, by section 158, Public Health Act, 1875.) (*j*) Notice must be given to the Surveyor of the dates upon which any sewer, drain, or foundation is to be covered up; notice must also be given of the completion of the work; while free access for inspection must be afforded to him at all times during the progress of the work. (*k*) If any work to which the bye-laws apply is done in contravention of such bye-laws, the Sanitary Authority are empowered to remove, alter, or pull down such work.

In London, the control, regulation, and management of all matters relating to the planning and laying out of new streets and the constructing of new buildings is governed, saving in respect of certain matters in connection with the city of London, by the provisions of The London Building Act, 1894. This Act consolidates and amends the previous Metropolitan Building Acts, and also certain provisions relating to the formation and widening of streets, the lines of building frontage, dwelling-houses on low-lying lands, sky-signs, and the naming and numbering of streets, most of which provisions were formerly included in the various Metropolis Management Acts and General Powers Acts of the London County Council. The Act is not, in itself, an absolutely complete code regulating building operations in London, as it is still necessary to refer to existing enactments of the Management Acts for provisions as to drainage of houses, as to the construction of vaults and cellars under streets, and as to the erection of hoardings during building. The sanitary arrangements in houses, the construction of underground rooms, and the structure of premises on which any offensive business is carried on, are regulated by the Public Health (London) Act, 1891, and the bye-laws in force thereunder; and in the city of London, such jurisdiction as was exerciseable by the Commissioners of Sewers, under the Sewers Acts previous to the passing of this 1894 Act, still remains in force.

The Commissioners of Sewers are the local authority within the city for the purposes of this Act, but the city is expressly exempted from certain provisions of the Act; these are sections 9 (4) and (5), 11 (4) and (5), 22 to 31, 84, 164 in part, 165, and 199, whereby the Commissioners of

Sewers retain jurisdiction, within the city, over the altering and planning of streets, lines of frontage, the erection of hoardings, dangerous structures, and sky-signs, the placing of lamps, signs, or other structures overhanging the public way, the making of bye-laws with respect to sites and foundations, prevention of fires, the materials of walls, and duties of district surveyors in relation to general house construction. In respect of these matters, the Sewers' Commissioners hold special powers under the Metropolitan Building Acts, 1855 to 1882, and the City of London Sewers Acts, 1848 and 1851; but, as already stated, with these exceptions the provisions of the London Building Act, 1894, apply within the city of London as in other parts of the metropolis, the Commissioners of Sewers being the local authority under the Act.

A considerable advance upon the previous legislation affecting London has been made, in the power given to the County Council to increase the width of certain new streets, not within 2 miles of St Paul's Cathedral, from 40 to 60 feet (section 12), and to refuse, if they think fit, to sanction plans for streets formed for carriage traffic of less width than 40 feet clear, and those formed for foot traffic, less than 20 feet clear (section 9). Similarly, no new buildings shall be erected with reference to streets intended for carriage traffic or with reference to footways, unless their external wall, fence, or boundary be at least 20 and 10 feet respectively from the centre of such street or footway (section 13). Sections 22 to 31, which do not apply to the city, empower the County Council under certain conditions to move back buildings which do project, and to prevent any new buildings being erected so as to project beyond the frontage line of the street. Part V of the Act, or sections 39 to 52, contains provisions with reference to open spaces about buildings, which are a great advance upon any previously existing law. The application of the principle of measurement by angles (section 41) for the purpose of determining the height, in relation to the space required at the rear of houses, is novel, so far as regards London, though it has been in operation in Liverpool under bye-laws framed with the sanction of the Local Government Board. Every domestic building (that is, a building which is neither a public building nor of the warehouse class) abutting upon streets formed or laid out after January 1, 1895, must have an open space of an aggregate extent of not less than 150 square feet in its rear, and exclusively belonging thereto; this space must extend throughout the entire width of the building, and be at least 10 feet in depth in every part. This open space must be free from any erection thereon above the level of the adjoining pavement, except a water-closet, earth-closet, or privy, and a receptacle for ashes, and enclosing walls, none of which erections shall exceed 9 feet in height. The building itself may be erected to a height equal to twice the width of the open space provided at the rear of the building, but an increase of height is allowed in cases where there is a street or permanent open space in the rear of the building. This result is obtained by confining, except as in the section provided, the height of a building within an imaginary diagonal line, to be drawn at an angle of 63½° from an imaginary horizontal line drawn at right angles to the roadway, and at the level of the pavement in front of the centre of the building. The point in the horizontal, from which the diagonal springs, will be the intersection of the horizontal line with the rear boundary of the open space, except where the boundary of such space is not parallel with the rear wall of the building.

In the case of certain corner buildings, the space in the rear may be occupied by buildings not exceeding 30 feet in height, and the return front of such buildings may be carried up to the full height of the front elevation.

As regards buildings abutting upon a street formed or laid out before the commencement of the Act, the height of such buildings, in relation to the open space required at the rear, will be determined by the same method of drawing diagonal and horizontal lines as provided above, except that the horizontal line may be drawn at a level of 16 feet above the level of the adjoining pavement; and the required open space, except in the case of working-class dwellings, may be above the level of the ceiling of the ground-floor storey, or above a level of 16 feet above the pavement. Certain savings for domestic buildings on old sites, when evidenced by plans certified by the district surveyor, and a provision for cases when an area is cleared of existing buildings, and new streets laid out thereon, are provided by sections 43 and 44. Special provision is made by section 45 for providing adequate light and ventilation for courts constructed within buildings, and for habitable rooms looking on to such courts. If the depth of such court from the eaves to the ceiling of the ground storey exceeds the length or breadth of the court, adequate provision for ventilation must be made by means of a communication between the lower end of the court and the outer air. No habitable room, without a window directly opening into the outer air, otherwise than into a court enclosed on every side, shall be constructed in any building unless the width of such court, measured from such window to the opposite wall, shall be equal to half the height measured from the sill of such window to the eaves or top of the opposite wall. The general limit of the height of buildings is fixed at 80 feet (sections 47 to 52). All matters, relating to the provision of open spaces about buildings, and the height of buildings, are subject to the supervision of the district surveyor (section 138). Every new building exceeding 60 feet in height must be provided, on the storeys the upper surface of the floor whereof is above 60 feet from the street level, with such means of escape in the case of fire as can be reasonably required under the circumstances of the case; and no storeys of such buildings may be occupied until certified by the Council that these provisions have been complied with (section 63). No building may be built nearer than 50 feet to any other building used for dangerous and noxious businesses, such as match factories, turpentine, varnish, tar, resin, or Brunswick black manufactories, blood and bone-boilers, soap-boilers, tallow-melters, fell-mongers, tripe-boilers, and slaughter-houses for cattle or horses (sections 118 to 121). Similarly, no building may be erected upon land of which the surface is below the level of Trinity high-water mark, and which is so situate as not to admit of being drained by gravitation into an existing sewer, except with the permission of the County Council (sections 122 to 124). The first schedule of the Act gives elaborate tables as to the permissible limits for the thicknesses of walls, proportionate to height; these in the main follow the general rules already given in the Model Bye-laws of the Local Government Board, but are more comprehensive.

Before closing this necessarily brief reference to this important London Building Act, 1894, it may be convenient to specifically state that the Statutes, other than this Act of 1894, which are still in force, and which affect building operations in the metropolis, especially in the city, are:—The Act for Better Paving, Improving, and Regulating the Streets of the Metropolis, &c., commonly known as 57 Geo. III. cap. xxix.; the

Metropolis Management Act, 1855, sections 73 to 123, 202 to 204, 211, 212, 227, 231, 242, 247, and 250; the Metropolis Management Amendment Act, 1862, sections 47, 48, 49, 61, 63 to 65, 68, 69, 88, 96, 97, 102, 104 to 107, and 110 to 112; the Metropolis Management Buildings Acts Amendment Act of 1878, Parts I. and III.; the Metropolis Board of Works Act, 1882, sections 1, 3, 45, and 48; the Metropolis Management Amendment Act, 1890; the London Council (General Powers) Act, 1890, sections 1, 2, 32, 39, 40, and 41; the Factory and Workshop Act, 1891, sections 7 and 41; the Public Health (London) Act, 1891; and the City of London Sewers Acts of 1848 and 1851.

In Scotland.—By the Local Government (Scotland) Act, 1895, section 9, in the rural or landward districts, the County Councils have powers to make bye-laws for regulating the erection and construction of new buildings. The section is based upon sections 157–8–9 of the English Public Health Act, 1875. It contains a drastic and advanced definition clause whereby "any alteration of the structure of any house" brings it within the category of a "new house." The wording of the subsections dealing with the purposes for which bye-laws may be made follows the lead of the English Act in failing to distinguish in these instances between new and existing houses. Apart from powers under the Act of 1895, local authorities can deal with any defects in respect of buildings as nuisances under the Public Health (Scotland) Act, 1867, or under the Housing of the Working Classes Act, 1890.

In the rural or landward districts the local authorities have practically no powers of supervision over the construction and general arrangements of new dwellings; but they can, as already intimated, deal with any defects in these respects as nuisances under the Public Health (Scotland) Act, 1867, or under the Housing of the Working Classes Act, 1890.

In the burghs, the Burghal Commissioners have elaborate powers under the Burgh Police (Scotland) Act, 1892, sections 166–180, 201–209. Some of the provisions are embodied in the Act, while others appear as rules in the schedules. The chief distinctive provisions are that (*a*) all rooms in new or altered dwelling-houses must be sufficiently lighted and ventilated from the street, or from an open space equal to three-fourths of the area in which the house stands. (*b*) Not more than twelve flat tenements may open from an inside stair, nor more than twenty-four from an outside stair. (*c*) In new dwellings, rooms on the ground floor must be 9½ feet in height, and on other floors 9 feet, except attics, which must be 8 feet high over one-third of their area, and nowhere less than 3 feet. (*d*) Every new habitable room of less area than 100 feet, built without a fireplace, must have special means of ventilation. There are further provisions as to ventilation of common stairs, and for the prohibition of the erection of any building upon polluted sites.

In burghs, where there is a Dean of Guild Court, this body is practically a committee of the Burghal Commissioners, and discharges all the functions in respect of buildings.

In Ireland.—Under section 41 of the Irish Public Health Act of 1878, urban and rural Sanitary Authorities have very similar powers for making bye-laws, and in respect of the same matters as have the English urban Authorities under section 157 of the Act of 1875. Any bye-laws made under this section 41 are not applicable to buildings erected before August 8, 1878. Although section 23 of the Public Health Amendment Act of 1890 extends to Ireland, its general application is little called for, as sections 41 and 42 of the Irish Act of 1878 apply to both rural and urban

Authorities, thus differing from sections 157 and 158 of the English Act of 1875, which apply only to urban Authorities. Sections 25 and 33 of the Amendment Act, 1890, may be applied to rural and urban districts, and section 24 to urban districts in Ireland as well as in England. Section 36 provides that all buildings, being places of public resort in urban districts, must have proper means of egress and ingress; while in towns constituted under the Towns Improvement (Ireland) Act, 1854, the Town Commissioners have full control over the erection and planning of all places of public entertainment.

OFFENSIVE TRADES.

In England and Wales.—The "offensive trades" are defined by section 112, Public Health Act, 1875, as those of "blood-boiler, bone-boiler, fellmonger, soap-boiler, tallow-melter, tripe-boiler, and any other noxious or offensive trade, business, or manufacture." By the same section it is illegal to establish any of these offensive trades within an urban sanitary district, without the consent in writing of the Authority.

As regards the prohibition of the establishment of any given trade without their consent, it is incumbent upon the prosecuting Local Authority to show that the trade in question is either one of those specifically mentioned above, or *ejusdem generis* with them; that is, that it is necessarily an offensive trade apart from neglect or mismanagement. It will be necessary, therefore, in determining whether a business comes within the definition of "offensive trade" to consider whether the materials used in its processes are identical with or similar to those dealt with in the six trades specified in the definition, and also whether the trade is, or must be, carried on in such manner as to be noxious or offensive. The higher Courts have held that this is the case with rag and bone stores for example, but not in brick-making, manure works, or fish-frying.

An urban Sanitary Authority may make bye-laws with respect to these trades, when they have been established with their consent, so as to prevent or diminish any nuisance arising therefrom (section 113); but a rural Authority would have to apply to the Local Government Board for power, under section 276, to apply these provisions.

The Local Government Board have issued Model Bye-laws in regard to not only the six trades mentioned in section 112 of the Act of 1875, but also in reference to the trades of a leather-dresser, tanner, fat-melter or fat-extractor, glue-maker, size-maker, blood-drier, and gut-scraper. The same general provisions appear in all, with numerous additions or variations as required by the conditions of the particular trade in question. The following summary will show their general scope and character:—

(*a*) All materials not required for immediate use or treatment shall be so stored as to prevent effluvium. (*b*) The best practicable means must be adopted for rendering any offensive vapours emitted during melting, boiling, &c., innocuous. The vapour must be either discharged into the external air in such a manner and at such a height as to admit of its diffusion without injurious effects; or shall be passed directly from the pan, &c., through a fire; or into a condensing apparatus; or through a condensing apparatus and then through a fire, in such a manner as effectually to consume the vapour or deprive it of all noxious or injurious properties. (*c*) The drainage on the premises must be kept in efficient order. Bone-boilers must cool all hot liquid refuse before passing it into any drain. (*d*) Floors must be kept in good order so as to prevent the absorption of filth. In the majority of these trades it is advisable to require the floors to be either swept, washed, scraped, or otherwise cleansed at the close of every working day. All refuse so collected, by scraping or sweeping, shall be removed forthwith from the premises in covered receptacles, unless intended to be forthwith subjected to further trade processes on the premises. (*e*) Walls must be kept in good order so as to prevent the absorption of filth, and, if necessary, be scraped. Limewashing of walls and ceilings twice a year is necessary in regard to these trades. (*f*) All apparatus, including implements and vessels, must be kept clean; where possible, this should be done daily. (*g*) Waste lime resulting from the businesses of fell-mongers and tanners must be removed at once, and under close cover. (*h*) Tanks used by fell-mongers for washing or soaking skins must be emptied and cleansed as often as may be necessary to prevent effluvia. (*i*) Every facility must be allowed for the access to the premises of the Medical Officer of Health, Inspector of Nuisances, Surveyor, or any Committee appointed by the Authority, for the purpose of inspection at all reasonable times.

Section 114 enacts that, if the Medical Officer of Health, or two legally qualified medical practitioners, or ten inhabitants of a district, certify that any of the following places are a nuisance, or injurious to health, it is the duty of the Sanitary Authority to take proceedings against the offender, who is liable to a penalty not exceeding £5, nor less than 40s., unless he can show that he has used the best practical means for abating such nuisance, or preventing or counteracting such effluvia. The premises mentioned in this section are "any candle-house, melting-house, melting-place, or soap-house, or any slaughter-house, or any building or place for boiling offal or blood, or for boiling, burning, or crushing bones, or any manufactory, building, or place used for any trade, business, process, or manufacture causing effluvia." The same powers are applicable where a nuisance, affecting the inhabitants of a district, arises from offensive trades carried on in premises situated beyond the limits of the district (section 115).

In London.—The provisions as to offensive trades under the Public Health (London) Act, 1891, are more stringent than the corresponding provisions of the Act of 1875 in force outside the metropolis. Section 19 of the London Act prohibits any one, under penalty of £50 per day or less, establishing within the metropolitan area the business of a blood-boiler, a bone-boiler, a manure manufacturer, a soap-boiler (if the soap is made from animal fats), a tallow-melter, or a knacker; but old-established businesses of this kind are permitted to remain, subject to the bye-laws of the County Council. A new soap-boiling business may, however, be established with the sanction of the Council, provided the soap is made from olein, or any vegetable fat or oil (*ibid.* (2)). Certain other businesses may, with the consent of the County Council, be established anew: these are those of a fell-monger, tripe-boiler, slaughterer of cattle or horses, or any other business which the Council may declare by Order, confirmed by the Local Government Board, to be offensive. The expression "establishment anew" means reopening after discontinuance of work for nine months, removal to new premises or extension of existing buildings, but not reconstruction, partial or complete, without extension of area. The granting of sanction to establish any new businesses of these kinds, on the part of the Council, is subject to the proviso that at least fourteen days before making any such Order they notify to the Authority, within whose district the premises on which the business is proposed to be established are situate, that application has been made, so that the inhabitants may have an opportunity of opposing it (section 19 (3)).

Subsection (4) of the above mentioned section enables the County Council to make bye-laws as to the arrangement of premises and conduct of such businesses. Any such bye-laws (5) may empower a Petty Sessional Court to prohibit any person from following the same temporarily or permanently subject to a daily penalty not exceeding £50: but any Sanitary Authority or person aggrieved by the enactment, alteration, or repeal of any such bye-law may give notice to the Local Government Board. The Metropolitan and Deptford cattle-markets are exempted from these bye-laws. Section 20 authorises the licensing of cow-houses and slaughter-houses, such licences being made annually. Section 22 of the Act provides that the removal, storage, and disposal of house and street refuse by a Sanitary Authority is to be deemed to be an offensive trade, and any complaint or proceeding made under section 21 may be made or taken by the County Council in like manner as if the Council were a Sanitary Authority. This provision enables the County Council to deal with a class of nuisance which is not unfrequently alleged to be committed by Sanitary Authorities themselves in the discharge of their duties with respect to the removal and disposal of house and street refuse.

With these exceptions, the provisions of the London Act of 1891 as to offensive trades are practically the same as those of the Public Health Act, 1875, sections 114 and 115. In the city of London the Commissioners of Sewers take the place of the County Council for applying these enactments in connection with offensive trades.

In Scotland.—The Public Health (Scotland) Act, 1867, section 30, classifies as offensive trades "the business of a blood-boiler, bone-boiler, tanner, slaughterer of cattle, horses, or animals of any description, soap-boiler, skinner, tallow-melter, tripe-boiler, or other business, trade, or manufacture injurious to health." The Local Government Board have power to determine whether a business, trade, or manufacture is injurious to health; and no such business may be established or enlarged within 500 yards of any burgh or village without the consent of the Local Authority. Any business so conducted as to be offensive and injurious to health is deemed to be a statutory nuisance.

In the towns the Burghal Commissioners have power to pass bye-laws "for reducing or removing the noxious or injurious effects attending these offensive trades" (Burgh Police (Scotland) Act, 1892, section 316). There are no provisions in the Scottish Public Health Acts corresponding to sections 114 and 115 of the English Act of 1875.

In Ireland.—Section 128 of the Irish Public Health Act of 1878 includes the business of a gut-manufacturer among the offensive trades, in addition to those given in section 112 of the English Act. As a rural Sanitary Authority in Ireland cannot be invested with urban powers, it follows that only urban Authorities can prevent the establishment of an offensive trade within the meaning of the Public Health Act. The powers of these urban Authorities to make bye-laws as to offensive trades is imperative in Ireland, and not permissive as in England, subject, of course, to the sanction of the Local Government Board of Ireland (Public Health (Ireland) Act, 1878, section 129). In other respects the provisions of the Irish and English Acts on this matter are similar.

FACTORIES, WORKSHOPS, AND BAKEHOUSES.

The sanitary legislation in respect of these places is somewhat complicated. A reference to page 853 will show that section 91 of the Public Health Act, 1875, includes as a nuisance any factory, workshop, or work-place not kept in a cleanly state, or not ventilated in such a manner as to render harmless as far as possible any gases, vapours, dust, or other impurities generated in the course of the work carried on therein, or so overcrowded while work is carried on as to be dangerous or injurious to the health of those employed therein. These provisions, however, do not apply to a factory which is subject to the provisions of the Factory and Workshop Acts of 1878, 1883, 1891, and 1895. These Acts are in force in England and Wales, the metropolis, Scotland, and Ireland, consequently references as to their working under the special headings of these geographical areas is not necessary. With a view to clear up any misconception as to what are the factories and workshops to which the provisions of the Public Health Act, 1875, as to nuisances apply, section 61 of the Factory and Workshop Act, 1878, declares that the provisions of this latter Act do not apply where persons are employed at home, that is to say, to a private house, room, or place which, although by reason of the work carried on there is a factory within the meaning of the Act, is used as a dwelling, and in which neither steam, water, or other mechanical power is used, and in which the only persons employed are members of the same family dwelling there. Consequently, it is to these places only that section 91 of the Public Health Act, 1875, applies.

The general effect of the Factory and Workshop Acts is to place all factories and workshops under a dual control, namely, the Home Office and the various Sanitary Authorities. The Home Secretary appoints Factory Inspectors, whose primary duty is to inspect *factories*. On the other hand, the primary duty of inspecting *workshops* and workplaces rests with the Local Authorities; this statement, however, must not be interpreted as meaning that the local Sanitary Authorities have no right to inspect a factory under the operation of these Acts, for there is a general duty cast upon the Sanitary Authorities to inspect all parts of their district (see also page 841).

Under the Act of 1878, factories are divided into textile and non-textile; they comprise, practically, all workplaces where mechanical power is used, and also the following, whether power is used or not:—blast-furnaces, copper-mills, iron-mills, foundries, manufactories of earthenware, lucifer matches, percussion-caps, cartridges, tobacco, paper, glass, print-works, fustian-cutting, printing, bookbinding, and flax scutch mills. Subject to the foregoing special exceptions, workshops are places where any manufactures are carried on, but where no mechanical power is employed.

By the Act of 1895, section 22, steam laundries are treated as factories, and other laundries as workshops. This law only applies to laundries carried on for purposes of trade or gain, and not where the persons carrying on the laundry are members of the same family. In every laundry worked by steam, water, or other mechanical power, (*a*) a fan or other means must be maintained for regulating temperature in ironing rooms, and for carrying away the steam in the wash-houses; (*b*) all stoves for heating irons must be sufficiently separated from the ironing rooms; (*c*) the flooring shall be kept in good condition, and drained in such manner as will allow the water to flow off freely.

All factories and workshops must be kept clean and free from effluvia arising from any drain, closet, urinal, or other nuisance. They must not be so overcrowded as to be dangerous or injurious to the health of the workers, and must be ventilated in such manner as to render harmless as far as practicable all gases, vapours, dust, or other impurity generated in the course of the work that may be injurious to health. For the sanitary supervision of these places, Factory Inspectors have exceptional powers of entry, inspection, and of taking legal proceedings. By the Act of 1895, section 1, overcrowding of a factory or workshop is statutorily defined as a minimum of 250 cubic feet of space for every person, and 400 cubic feet for every person doing overtime; moreover, the Home Secretary has power to add to this minimum during hours in which artificial light is employed. If the Home Secretary is not satisfied that any factory or workshop is sufficiently ventilated, he may, if he think fit, by Order authorise an Inspector of Factories to take, during the period mentioned in the Order, such steps as appear necessary or proper for enforcing them (Act of 1891, section 1). In the case of premises which are in an unfit state for manufacturing purposes, section 2 of the Act of 1895 gives power to a Court of summary jurisdiction, on the complaint of an Inspector, to make an Order prohibiting the premises from being so used until the necessary changes have been made to put them in a proper condition.

When an Inspector deems that there is any act or default in relation to the sanitary arrangements or other matters in a factory or workshop, which is punishable or remediable under the Public Health Act, but not under the Factory and Workshop Acts, he shall give notice of the same to the Sanitary Authority; and it is the duty of the Sanitary Authority to make such inquiry, and take such action, within one month, as may be proper for the enforcement of the law, duly notifying the Inspector of the proceedings taken. In case of default, after notice, of the Authority, the Inspector may himself take proceedings, recovering expenses from the Sanitary Authority (Act of 1878, section 4; Act of 1891, section 2; Act of 1895, section 3).

Upon receipt of a certificate from the Medical Officer of Health or Inspector of Nuisances that cleansing, limewashing, or purifying is necessary for the health of the workers in a workshop, the Sanitary Authority must give notice to the owner or occupier; if he makes default, he incurs a daily penalty of 10s., and the Sanitary Authority may carry out the work and recover expenses (Act of 1891, section 4; also see Public Health (London) Act, 1891, sections 25 and 26).

If it comes to the knowledge of the Factory Inspector that work is being done in an unsanitary place, not necessarily a factory or workshop in the meaning of these Acts, it is his duty to give notice to the employer who gives out the work that such is the case, and if, one month after receiving that notice, the employer continues to give out work to be carried on in the place complained of, and nothing has been done in the meantime to remedy the insanitary conditions to which his attention has been drawn, he becomes liable to a penalty of £20. A similar penalty is incurred if any occupier of a factory or workshop knowingly causes or allows wearing apparel to be made, cleaned, or repaired in any building any inmate of which is suffering from scarlet fever or small-pox (Act of 1895, sections 5 and 6).

A Medical Officer of Health must give written notice to the Factory Inspector if he becomes aware that any "child" under fourteen years of age, "young person" of that age and under eighteen years, or "woman" of eighteen years of age or upwards is employed in any workshop (Act of 1891, section 3; also see Public Health (London) Act, 1891, section 27). The Act of 1895 prohibits the employment in any factory or workshop of children under eleven years of age, and of women within four weeks after confinement. Overtime is prohibited in the case of all persons under eighteen years of age in non-textile factories and workshops. For women working in factories and workshops other than laundries, overtime is limited to three days a week, and thirty days in the year; in the case of trades in which the goods are perishable, overtime is extended to sixty days in the year. After January 1, 1897, overtime at night is limited to male young persons of fourteen years of age or upwards (Act of 1895, section 14). Home work is now prohibited altogether for children who are employed in factories or workshops; and also women or young persons who have been employed for full hours in factories or workshops are prohibited from being afterwards employed in the shop (*idem*, section 16).

"Women employed in laundries may work overtime, subject to the following conditions:—No woman shall work more than fourteen hours in any day; the overtime worked shall not exceed two hours in any day; overtime shall not be worked on more than three days in any week, or than thirty days in any year" (section 22 (4), Act of 1895).

As to dangers from fires, which are more common in workshops than factories, section 7 of the Act of 1891 places the duty of providing adequate means of escape from fire upon the Sanitary Authorities. Owing to the neglect of this duty, section 10 of the Act of 1895 enables an Inspector to require structural alterations where there are defects in relation to this matter, and a Court of summary jurisdiction may, on the application of the Inspector, order the provision of movable fire-escapes and the making of structural alterations wherever the Inspector is able to show that the provisions made are not sufficiently practicable in that respect.

By section 29 of the Act of 1895 every medical practitioner attending on or called in to visit a patient whom he believes to be suffering from lead, phosphorus, or arsenical poisoning, or anthrax, contracted in any factory or workshop, must (unless the notice required by this section has been previously sent) send to the Chief Inspector of Factories at the Home Office, London, a notice stating the name and full postal address of the patient and the disease from which he is suffering. The remuneration for this notification is 2s. 6d., and the penalty incurred in default of furnishing the notice is 40s. In every factory or workshop where lead, arsenic, or any other poisonous substance is used, suitable washing conveniences must be provided for the workers (*idem*, section 30).

If the Home Secretary certifies that any particular process or kind of work is dangerous to the life or health of the workers in any factory, or that the provision of fresh air is insufficient, or that the quantity of dust generated or inhaled in any factory or workshop is dangerous to health, the Chief Inspector may prescribe special rules, or the adoption of special precautionary measures (Act of 1891, section 8). The following industrial processes have been scheduled by the Home Secretary as dangerous under this section:—the manufacture of white lead, paints, and colours; the extraction of arsenic; the enamelling of iron plates; the manufacture of lucifer matches, except such as are made with red or amorphous phosphorus; the manufacture of earthenware, and of explosives in which di-nitro-benzole is used; chemical works; quarries; the making of red, orange, or yellow lead; lead smelting; tinning or enamelling of iron hollow ware; electric accumulator works; flax mills and linen factories.

Factory Inspectors have power to require the provision of fans, or other mechanical appliances, if necessary, for preventing inhalation of dust, gas, vapour, or other injurious impurities by workers; also to require all ceilings, walls, passages, and staircases to be limewashed every fourteen months, but the Home Secretary may grant exemptions. He may also make special regulations as to cleanliness and ventilation which may, from time to time, appear to him to be necessary in the interest of the workers (Act of 1878, sections 33 and 36, as amended by the Factory Acts, 1891 and 1895).

By section 31, Act of 1895, all textile factories, in which the atmospheric humidity is artificially increased for trade purposes, and which are not for the time being subject to special rules under section 8 of the Act of 1891, come under the provisions of the Cotton Cloth Factories Act, 1889. By this Act, special arrangements must be made for admitting at least 600 cubic feet of fresh air per hour per occupant. Two sets of standard wet and dry-bulb thermometers must be provided and maintained in working order, and so placed as to be in full view of the operatives. Readings are to be taken between 10 and 11 A.M., and again between 3 and 4 P.M., daily, and records kept. A schedule of this same Act specifies, among other details, for each dry-bulb temperature a maximum permissible reading of the wet bulb, and a copy of this table has to be placed near to each hygrometer. The temperature must not be artificially raised above 70° F. In workshops and factories where wearing apparel is made, the temperature must be kept at not less than 60° F.

Bakehouses occupy a somewhat unique position among factories and workshops, owing to the fact that they have received a certain amount of special legislation. In the first place, a distinction must be made between "wholesale" and "retail" bakehouses. A wholesale bakehouse is represented by such premises as those of Peak & Frean or of Huntley & Palmer; in the eye of the law these are not bakehouses, but factories (Act of 1891, section 36). A "retail" bakehouse is defined by section 18 of the Factory Act, 1883, as meaning "any bakehouse or place, the bread, biscuits, or confectionery baked in which are not sold wholesale but by retail, in some shop or place occupied together with such bakehouse." The same Act places the sanitary supervision of these "retail" bakehouses in the hands of the Sanitary Authorities; these Authorities, outside the metropolis, are the urban and rural Sanitary Authorities, in London, they are in the city the Commissioners of Sewers, and elsewhere the Vestries and District Boards.

The powers and duties of a Medical Officer of Health in connection with the sanitary regulation of retail bakehouses are somewhat exceptional. By section 18 of the Factory Act, 1883, he has all the powers of entry, inspection, taking legal proceedings and otherwise, of a Factory Inspector. He is also required, if he becomes aware of the employment of any child or young person under eighteen years of age, or woman in any retail bakehouse, to forthwith give written notice thereof to the Factory Inspector of the district. The powers of entry and inspection conferred on the Medical Officer of Health are such that he may enter, inspect, and examine any retail bakehouse at any reasonable time by day or by night, without any special written authority or warrant (Act of 1878, section 68, and Act of 1891, sections 25 and 39). In all summary proceedings for offences and fines, the information must be laid within two months, or, where the offence is punishable by imprisonment, within three months after the commission of the offence. There is power of appeal to Quarter Sessions (Act of 1878, sections 89, 90, 91).

By section 27 of the Act of 1895, which amends sections 34 and 35 of the Act of 1878, the statutory requirements for all bakehouses, whenever or wherever erected, are the same as for other factories or workshops. All the inside walls, ceilings, staircases, and passages must be limewashed once at least every six months, or painted every seven years, and if so painted, washed with soap and hot water every six months. And further, there must be no sleeping-place on the same level in the same building, unless there be complete separation from ceiling to floor, and unless the sleeping-room have an external window nine square feet in area, half of which is made to open (Act of 1878, section 35). The fine for not keeping a bakehouse in conformity with these provisions is a penalty not exceeding £10, recoverable in a Court of summary jurisdiction, and if the order to conform to the requirements of the Act is not obeyed within a specified time, to a daily penalty of £1 (*idem*, section 81).

Sections 15 and 16 of the Factory Act, 1883, as amended by section 27 of the Act of 1895, make it illegal to let or occupy as a bakehouse any place, except under the following conditions:—(*a*) No water-closet, earth-closet, privy, or ashpit to be within the bakehouse, or communicate directly with it. (*b*) Any cistern for supplying water to the bakehouse to be separate from any cistern supplying a water-closet. (*c*) No drain or pipe carrying off sewage to have an opening within the bakehouse. Any person contravening these provisions will be liable on summary conviction to a fine not exceeding 40s., and a further fine not exceeding 5s. for every day during which any room or place is occupied in contravention of the section after a conviction. No place under ground may be used as a bakehouse unless so used before January 1, 1896, and if so used must not be in contravention of the above conditions (Act of 1895, section 27 (3)).

As regards London, apart from special mention in section 25 of the Public Health (London) Act, 1891, of the duty of every Sanitary Authority to enforce the limewashing, cleansing, and general sanitary supervision of workshops, section 26 of the same Act particularly makes it the duty of every Sanitary Authority in London to enforce sections 34, 35, and 81 of the Factory Act, 1878, and sections 15 and 16 of the similar Act of 1883 as respects bakehouses which are workshops within the meaning of those Acts. For the purpose of enforcing these provisions, the London Sanitary Authorities are made the Local Authorities within the meaning of those sections, and their Medical Officers of Health have all the exceptional powers and duties as already explained in the previous pages.

The provisions of the Factory and Workshop Acts apply fully to both Scotland and Ireland; in the former country, the central jurisdiction is vested in the Home Secretary.

ALKALI, CHEMICAL, AND OTHER WORKS.

It has already been shown that the provisions of the Public Health Acts relating to what are called offensive trades apply only to a limited class of trades. Outside that class are a number of other trades, works, and businesses in which various noxious and offensive gases are evolved. These latter are placed under the inspection and regulation of officers of the Local Government Board, subject to the Alkali, &c., Works Regulation Acts, 1881 and 1892. These Acts are to be regarded as cumulative, and nothing contained in either of them is to be construed as legalising any act or default which would otherwise be deemed to be a nuisance, or be contrary to law, had these Acts not passed (Alkali Act, 1881, section 31). Further, where it appears to any Sanitary Authority, on the written representation of their officers, or of any ten inhabitants of their district, that any work (either within or without their district) to which these Acts apply is carried on in contravention to them, or that any alkali waste is deposited (either within or without their district), and that a nuisance is occasioned by any such contravention of the Acts, such Sanitary Authority may complain to the Local Government Board, who, after inquiry, are empowered to direct such proceedings to be taken by an Inspector as they think just (section 27).

The same Act of 1881, section 29, defines an "alkali work" to be "every work for the manufacture of alkali, sulphate of soda, or sulphate of potash, in which muriatic gas is evolved; and for the purpose of this definition the formation of any sulphate in the treatment of copper ores by common salt or other chlorides will be deemed to be a manufacture of sulphate of soda."

These Acts of 1881 and 1892 apply to all alkali works and to the following scheduled works:—sulphuric acid works, chemical manure works, gas-liquor works, nitric acid works, sulphate of ammonia works, muriate of ammonia works, chlorine works, venetian red works, lead deposit works, arsenic works, nitrate and chloride of iron works, muriatic acid works, fibre separation works, tar works, zinc works; also the following, unless the process adopted be such that no sulphuretted hydrogen is evolved, namely, alkali waste works, barium works, strontium works, antimony sulphide works, and bisulphide of carbon works (Act of 1881, section 29, and Act of 1892, section 1).

No alkali work, or scheduled work, or work for the extraction of salt from brine, or cement work, may be carried on unless it has been certified to be registered by the Local Government Board. The certificate of registry is in force for one year from April 1st, following the day of the application for the certificate, such application being required to be made in January or February (Act of 1881, section 11). No new works can be registered unless furnished with satisfactory and proper appliances (section 12).

The following are the requirements of the Act of 1881 with respect to alkali works. By section 3, every such work must be carried on in such a manner that 95 per cent. of the hydrochloric acid gas evolved must be condensed, and not more than one-fifth of a grain of hydrochloric acid gas per cubic foot of air, smoke, or chimney gases must escape from the works into the atmosphere. Nor must there be more of the acid gases of sulphur and nitrogen than the equivalent of four grains of sulphuric anhydride per cubic foot of air. The owner of any alkali work which is carried on in contravention of these provisions is liable to a fine in the case of a first offence not exceeding £50, and in the case of every subsequent offence £100. Acid drainage must not be allowed to mix with alkali waste so as to cause a nuisance: the penalties for the contravention of this provision are similar to the above, with a continuing penalty of £5 a day (section 5). The owner may require the Sanitary Authority to provide and maintain, at his expense, a drain for carrying the acid waste into the sea, or any watercourse into which it can be taken without breach of the Rivers Pollution Prevention Act, 1876. Alkali waste must not be deposited or discharged without the best practicable and available means being used to prevent nuisance (section 6). Similar regulations apply to sulphuric acid works. The gases escaping into the atmosphere must not have an acidity equivalent to more than four grains of sulphuric anhydride per cubic foot (section 8). The other works scheduled in the Acts must employ the best practicable means for preventing the escape of noxious and offensive gases, and for rendering them harmless and inoffensive, subject to the qualification in the case of sulphuric acid works as to the degree of aërial vitiation by the escaping gases (section 9).

In calculating the proportion of acid to a cubic foot of air, smoke, or gases, for the purposes of the Act, such air, smoke, or gases are to be calculated at a temperature of 60° F. with a barometric pressure of 30 inches (section 21).

The Alkali Acts apply to Scotland, being locally administered by the public health authorities. The Secretary for Scotland is the central authority in place of the Local Government Board. The same Acts apply equally to Ireland, but the English Local Government Board has the appointing of the Inspectors; while in all other respects the Irish Board is the central authority.

SLAUGHTER-HOUSES.

In England and Wales.—By section 4 of the Public Health Act, 1875, the expression "slaughter-house" includes the buildings and places commonly called slaughter-houses and knackers' yards, and any place or building used for slaughtering cattle, horses, or animals of any description for sale.

Section 169 of the Public Health Act, 1875, which incorporates certain provisions of the Towns Improvement Clauses Act, 1847, enacts that any urban Sanitary Authority may provide abattoirs or slaughter-houses, and if they do so, *must* make bye-laws with respect to their management and charges. They may also license slaughter-houses and knackers' yards, and without their licence no place shall be used for such purposes which was not so used at the time of the passing of the Act in 1875. Every place used as a slaughter-house or knacker's yard before the passing of the Act, and still continued to be so used, shall be registered by the owner or occupier in a book kept by the Sanitary Authority. The distinction, therefore, between a registered and licensed slaughter-house is dependent upon the fact that in the one case the place was used as such before the passing of the Act in 1875, while in the other case it has been established since that date. A legible notice bearing the words Licensed Slaughter-House or Registered Slaughter-House must be attached and displayed in some conspicuous place on every slaughter-house by the owner or occupier (section 170). Prior to the adoption of Part III. of the Public Health Acts Amendment Act, 1890, in any district, licences granted under the above enactment will not be annual licences, but granted once for all; nor in those cases is a fresh licence necessary when part of the premises is rebuilt, or when any addition is made to them. The *continuance of use* is of great importance, as it is frequently found that slaughter-houses are disused as such, and applied to other purposes. In that case they cannot again be used as slaughter-houses without application for a licence. But in urban districts in which Part III. of the Act of 1890 is in force, licences, granted after the adoption of that Act, will be for not less than twelve months, or such periods as the licensing urban Sanitary Authority may deem fit to specify in it.

As regards slaughter-houses and other similar premises for which a licence is sought, the Local Government Board, in a Memorandum dated July 25, 1877, have suggested that the following rules as to site and structure should influence the decision of a Sanitary Authority before granting a licence:—

"1. The premises should not be within 100 feet of any dwelling-house; and the site should be such as to admit of free ventilation by direct communication with the external air on two sides at least of the slaughter-house.

"2. Lairs for cattle in connection with the slaughter-house should not be within 100 feet of a dwelling-house.

"3. The slaughter-house should not in any part be below the surface of the ground.

"4. The approach to the slaughter-house should not be on an incline of more than one in four, and should not be through any dwelling-house or shop.

"5. No room or loft should be constructed over the slaughter-house.

"6. The slaughter-house should be provided with an adequate tank or other proper receptacle for water, so placed that the bottom shall not be less than 6 feet above the level of the floor of the slaughter-house.

"7. The slaughter-house shall be provided with means of thorough ventilation.

"8. The slaughter-house should be well paved with asphalte or concrete, and laid with proper slope and channel towards a gulley, which should be properly trapped and covered with a grating, the bars of which should not be more than three-eighths of an inch apart. Provision for the effectual drainage of the slaughter-house should also be made.

"9. The surface of the walls in the interior of the slaughter-house should be covered with hard, smooth, impervious material to a sufficient height.

"10. No water-closet, privy, or cesspool should be constructed within the slaughter-house.

"There should be no direct communication between the slaughter-house and any stable, water-closet, privy, or cesspool.

"11. Every lair for cattle in connection with the slaughter-house should be properly paved, drained, and ventilated.

"No habitable room should be constructed over any lair."

It is the duty of the Sanitary Authority to make bye-laws for the licensing, registering, and inspection of slaughter-houses and knackers' yards, and preventing cruelty therein, for keeping the same clean, for the daily removal of filth, and for the proper supply of water. The following Model Bye-laws, issued by the Local Government Board, are applicable to the above requirements.

(*a*) *Licences.*—Applications for licence of existing premises, or erection of new slaughter-houses, must be made upon a specified form, and must include full particulars as to the position, form, area, cubic space, &c., of the buildings and appendages; materials and construction of walls and floors; means of water-supply, drainage, lighting, and ventilation; means of access for cattle; number, position, and size of stalls or lairs, and number of animals to be accommodated therein, distinguishing oxen, calves, sheep, and swine. The boundaries must also be shown, and, in the case of old premises, particulars as to the ownership and the applicant's tenure must be given.

(*b*) *Registration.*—If the Sanitary Authority approve the application, a licence shall be issued to the applicant, and must be registered by him at the office of the Sanitary Authority.

(*c*) *Inspection.*—Free access to every slaughter-house for the purpose of inspection must be afforded at all reasonable times to the Medical Officer of Health, Inspector, Surveyor, and Committees appointed by the Sanitary Authority.

(*d*) *Water* must be supplied to every animal kept in a lair prior to slaughter.

(*e*) *Mode of Slaughter.*—Cattle must be secured by the head so as to be felled with as little pain as practicable.

(*f*) *Drainage, water-supply, and ventilation* must be kept in efficient order.

(*g*) *Cleanliness.*—The walls and floor must be kept in good order and repair, and must be thoroughly cleansed within three hours after any slaughtering; the walls and ceiling must be limewashed four times yearly, that is to say, within the first ten days of March, June, September, and December respectively.

(*h*) *Animals not to be kept.*—No dog may be kept in a slaughter-house: nor other animal, unless intended for slaughter upon the premises, and then only in proper lairs, and not longer than may be necessary for preparing it for slaughter by fasting or otherwise.

(*i*) *Removal of Refuse.*—Suitable vessels made of non-absorbent materials, and provided with close-fitting covers, must be provided for the reception of blood, manure, garbage, and other refuse; all such matters must be placed in these vessels immediately after the slaughtering; the refuse must be removed within twenty-four hours, and the vessels forthwith cleansed. All skins, fat, and offal must be removed within twenty-four hours.

If any person is convicted of killing or dressing any cattle contrary to the provisions of the Public Health Act, or of the non-observance of any of the bye-laws or regulations made under the Act, the justices before whom he is convicted may suspend the licence for two months or less, and in the event of a second offence may revoke the licence (Towns Improvement Clauses Act, 1847, sections 125 to 130, incorporated in section 169 of the Public Health Act, 1875). A similar revocation of licence may follow on conviction for sale of meat unfit for food (Public Health Acts Amendment Act, 1890, section 31).

In London, by section 20 of the Public Health (London) Act, 1891, it is provided that a person carrying on the business of a slaughterer of cattle or of horses, knacker or dairyman, may not use any premises in London (outside the city) as a slaughter-house without a licence from the County Council. In the city, the licensing authority is the Commissioners of Sewers. The section does not extend to slaughter-houses erected before or after the commencement of the Act in the Metropolitan Cattle Market, under the authority of the Metropolitan Market Act, 1851, or the similar Act of 1857. The general provisions as to slaughter-houses are the same as in the provinces, particularly when read in conjunction with section 47 relating to the sale of unsound food. Conviction under this section entails cancellation of licence.

In Scotland.—The Public Health (Scotland) Act, 1867, does not specially deal with slaughter-houses, but the business of a "slaughterer of cattle, horses, or any animals of any description" is included under other offensive trades, and is practically subject to the regulations which govern them both in burghs and landward districts (section 30).

In the burghs, the Commissioners have full control over the slaughter-houses, and none can be used without their licence; moreover, if they provide premises of this kind, no others may be used (Burgh Police (Scotland) Act, 1892, sections 278 to 287).

In Ireland, the provisions of the Public Health Act are practically the same as those in force in England. In towns constituted under the Towns Improvement (Ireland) Act, 1854, if section 47 of that Act has been adopted, the provisions of the Towns Clauses Act, 1847, incorporated into the Public Health (Ireland) Act by virtue of section 105, with regard to slaughter-houses, will be in force although such towns may not be urban sanitary districts: and the Town Commissioners "may by special order purchase, rent, build, or otherwise provide such slaughter-houses and knackers' yards as they think proper for slaughtering cattle within the town."

UNSOUND FOOD.

In England and Wales.—Under the Public Health Act, 1875, the Medical Officer of Health and Inspector of Nuisances have power, at all reasonable times, including Sunday, to examine or inspect any animal, carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk exposed for sale, or deposited for the purposes of sale, or of preparation for sale, and intended for the food of man; and may seize the same if diseased, unsound, or unwholesome, and take it to a magistrate (section 116), who may order it to be destroyed or so disposed of as to prevent it from being exposed for sale or used for the food of man, and inflict a penalty not exceeding £20, or a term of imprisonment of not more than three months (section 117). The proof that it was not intended for the food of man rests with the person charged. Any person hindering these officers from inspecting meat, &c., is subject to a penalty of £5 (section 118). On complaint made by oath by any officer of a Sanitary Authority that there is reason to believe that there is kept or concealed on any premises any articles to which these sections apply, a justice may grant a search warrant, and any person hindering the execution of this warrant is liable to a penalty of £20 (section 119).

In the foregoing provisions there are two great defects, namely, (1) that no proceedings can be taken in regard to articles already sold, and (2) that eggs, butter, cheese, and other important articles of food are not included in the scope of these sections of the Act. In districts where Part III. of the Public Health Acts Amendment Act, 1890, is in force, these defects have been remedied by section 28 of the same, which enacts that sections 116 to 119 of the Act of 1875, above mentioned, shall extend to "any article intended for the food of man, sold or exposed for sale, or preparation for sale," and a justice may order destruction under section 117, although it has not been seized as under section 116.

In markets and fairs under the control of a Sanitary Authority the sale of unwholesome meat or provisions is subject to similar provisions under section 15 of the Markets and Fairs Clauses Act, 1847, which is incorporated with the Public Health Act, 1875. Where the market or fair does not belong to the local authority the above provisions will not apply, unless a local Act is in force, with which the Market and Fairs Clauses Act is incorporated. A Sanitary Authority can make bye-laws for preventing the sale of unwholesome provisions in a market or fair by section 42 of the Act of 1847, also incorporated in the Public Health Act, 1875; but owing to the stringency of sections 116 to 119 of this latter Act, these bye-laws will be rarely necessary.

In London, under section 47 of the Public Health (London) Act, 1891, the provisions as to the sale of unsound food are somewhat more stringent. The London Act not only closely follows the lines of section 28 in Part III. of the Amendment Act, 1890, but renders the offender liable, on conviction, to a fine not exceeding £50, or imprisonment for six months with or without hard labour. The section further enforces the liability of the previous vendor of the food, and also renders anyone obstructing an officer acting under a warrant for entry within twelve months after a previous conviction for obstruction, or evidently with intent to prevent detection, liable to imprisonment for a month in lieu of fine. The Sanitary Authority have further the duty placed upon them of removing unsound food, as if it were trade refuse, on the receipt of written notice from a person having possession of the same.

In Scotland, the list of articles of unsound food liable to seizure does not include corn, bread, flour, or milk (Public Health (Scotland) Act, 1867, section 26). This defect is not remedied, so far as relates to Scotland, by the Amendment Act, 1890. In the burghs, there is power to "seize and destroy diseased cattle, whether offered for sale or not, and to prosecute the original sellers of diseased meat or animals intended for human food, whether within or without the burgh" (Burgh Police (Scotland) Act, 1892, sections 428–9).

In Ireland.—Sections 132 to 135 of the Public Health (Ireland) Act, 1878, contain very similar provisions as to unsound food as are contained in the corresponding English Act, with the addition of butter in the classification of articles. Section 42 of the Markets and Fairs Clauses Act, 1847, is not incorporated in the Irish Act, but section 108 of this latter Act enables an urban Authority to make bye-laws for the prevention of the sale of unwholesome food in all markets and fairs belonging to it. Section 15 of the Markets and Fairs Clauses Act, 1847, "applies only in the case of an urban Authority." With these exceptions, the Irish and English enactments in respect of this matter are similar.

HORSE-FLESH.

The provisions controlling the sale of horse-flesh for human food are the same in all parts of England, Wales, Scotland, Ireland, and the metropolis. They are contained in the Sale of Horse-flesh, &c., Regulation Act, 1889, which defines "horse-flesh" to be such flesh cooked or uncooked, alone or mixed with other substances, and includes the flesh of asses and mules (section 7).

This Act (section 1) provides that the flesh of horses, asses, or mules must not be sold or kept for sale for human food, except in a shop or stall over or upon which is placed conspicuously, in legible characters four inches long, an announcement that horse-flesh is sold there. It also prohibits the sale of horse-flesh for human food to any purchaser asking for other meat, or for a compound article not usually made of horse-flesh (section 2). Any person offending against these provisions is liable to a penalty not exceeding £20, to be recovered summarily (section 6). The machinery and procedure for the inspection, obtaining of a search warrant, seizing and taking of suspected meat before a justice, is similar to that contained in sections 116 to 119 of the Public Health Act, 1875, and already detailed under the heading of unsound meat. The principal point of difference is that the power of inspecting is given not only to the Medical Officer of Health and Sanitary Inspector, but also to any other officer of the Sanitary Authority (sections 3 to 5).

In London, the Vestries and District Boards, and the Commissioners of Sewers in the City, are the local authorities for the administration of this Act. In the rest of England and Wales, and in Ireland, the local authorities are the urban and rural Sanitary Authorities under the respective Public Health Acts. In its application to Scotland, the expression "justice" includes a Sheriff and Sheriff-Substitute, and "local authority" means any local authority authorised to appoint a Public Analyst under the Sale of Food and Drugs Act, 1875.

ADULTERATION OF FOOD.

The legislative enactments relating to this matter, in respect of the whole of Great Britain and Ireland, are contained in the Sale of Food and Drugs Act, 1875, the Sale of Food and Drugs Act Amendment Act, 1879, the Margarine Act, 1887, and, so far as concerns England and Wales, also the Local Government Act, 1888.

Section 2 of the Act of 1875 defines "food" as including every article which is used by man for food or drink, except water and drugs; it defines "drug" as including medicine for external as well as internal use. The Act further provides that "no person shall mix, colour, stain, or powder (or order or permit any other person to mix, colour, stain, or powder) any article of food with any ingredient or material so as to render the article injurious to health, with intent that the same may be sold in that state; and no person shall sell any article so mixed, coloured, stained, or powdered under a penalty not exceeding £50 for a first offence, and on a subsequent conviction of imprisonment with hard labour for a period not exceeding six months" (section 3). The same prohibitions and penalties apply to the like treatment of drugs (section 4), but no liability is incurred if the accused person can show that he was unaware of the admixture, and could not "with reasonable diligence" have known that the food or drug was so adulterated (section 5).

Further, "no person shall sell, to the prejudice of the purchaser, any article of food or any drug which is not of the nature, substance, and quality of the article demanded by such purchaser, under a penalty not exceeding £20; but no offence shall be deemed to be committed under this section in the following cases:—(1) Where any matter or ingredient not injurious to health has been added to the food or drug because the same is required for the production or preparation thereof as an article of commerce in a state fit for carriage or consumption, and not fraudulently to increase the bulk, weight, or measure of the food or drug, or conceal the inferior quality thereof; (2) where the drug or food is a proprietary medicine, or is the subject of a patent in force, and is supplied in the state required by the specification of the patent; (3) where the food or drug is compounded . . [and the provisions of the seventh and eighth sections are observed]; (4) where the food or drug is unavoidably mixed with some extraneous matter in the process of collection or preparation" (section 6).

As regards these exemptions, the *onus probandi* rests with the defendant (section 24). No person shall sell any compound, drug, or article of food which is not composed of ingredients in accordance with the demand of the purchaser, under a penalty not exceeding £20 (section 7); but no offence under this section is committed in respect of the sale of a drug or article of food mixed with an ingredient not injurious to health if it is labelled as "mixed" at the time of the sale (section 8).

Section 9 of the Act provides that "no person shall (with the intent that the same may be sold in its altered state without notice) abstract from an article of food any part of it, so as to affect injuriously its quality, substance, or nature; and no person shall sell any article so altered without making disclosure of the alteration, under a penalty not exceeding £20." In any prosecution under this Act, the defendant is to be discharged if he proves to the satisfaction of the Court (*a*) that he bought the article as being the same in nature, substance, and quality with that demanded by the purchaser, and with a written warranty to that effect; (*b*) that at the time of sale he had no reason to believe it to be otherwise; and (*c*) that he sold it in the same state as when he purchased it (section 25).

In order to carry out the provisions of this Act, in every district a competent person may be, and if required by the Local Government Board must be, appointed as Public Analyst (section 10). In the case of boroughs having a separate Court of Quarter Sessions, or a separate police force, this appointment is made by the Town Council; while for all other parts of the country the appointment is made by the County Council (Local Government Act, 1888, sections 3, 38, and 39). All these appointments and re-appointments are subject to the approval of the Local Government Board. Where a Public Analyst is thus appointed, any purchaser of an article of food or drug within the district shall be entitled to have it analysed for a fee of 10s. 6d., otherwise by another Public Analyst at such fee as he may require, and in either case to have a certificate of the result (section 12). The Medical Officer of Health, Inspector of Nuisances, or any officer charged by the Sanitary Authority with the execution of the Act, may procure samples of food and drugs, and submit them to the Public Analyst (section 13). The quantities of the samples purchased under section 13 should not be less, in the case of milk, than 1 pint; butter, $\frac{3}{4}$ of a ℔; lard, $\frac{3}{4}$ of a ℔; coffee, $\frac{3}{4}$ of a ℔; spirits, $\frac{3}{4}$ of a pint. Any person purchasing an article for analysis shall, upon the completion of the purchase, forthwith notify to the seller his intention to have it analysed by the *Public* Analyst, and shall offer to divide it into three parts, to be then and there separated, and each part to be marked and sealed or fastened up, and shall, if required to do so, proceed accordingly, and shall deliver one of the parts to the seller. One of the three parts must be retained for future comparison, and the third delivered up to the Public Analyst (section 14). If the seller does not accept the offer of division, the Analyst must divide the sample into two parts, sealing and delivering up one of them to the purchaser (section 15). Samples may be sent by registered parcel post to the Public Analyst, if his residence is two miles from that of the purchaser (section 16; see also Post-Office Act, 1891, section 11).

Any person refusing to sell to an officer of the Sanitary Authority any article of food or drug on sale by retail, the price being tendered and the quantity demanded not being greater than is reasonably requisite, is liable to a penalty not exceeding £10 (section 17). The certificate of the Analyst must be in the following prescribed form (section 18):—

"To [*name of person submitting the article*].

"I, the undersigned, Public Analyst for the [*County, Borough, &c., of* . .], do hereby certify that I received on the . . day of . . from [*name of person delivering it, or the postal officer*], a sample of [*description of article*] for analysis (which then weighed), and have analysed the same, and declare the result of my analysis to be as follows—

I am of opinion that the same is a sample of genuine

or

I am of opinion that the said sample contained the parts as under

or

The percentages of foreign ingredients as under—

Observations.

As witness my hand, this . day of
A. B.
At

When the article cannot conveniently be weighed, the passage in the certificate having reference thereto may be erased or the blank left unfilled. The above certificate of the Analyst is sufficient evidence of the facts therein stated, unless the defendant requires the Analyst to be called as a witness (section 21). The justices before whom a case is heard may, at the request of either party, cause any article of food or drug to be sent to the Commissioners of Inland Revenue for analysis by the chemists of their department at Somerset House (section 22).

Owing to certain defects in the Act of 1875, an Amendment Act was passed in 1879. This latter Act qualifies the earlier one by stating that "it shall be no defence to allege that the purchaser is not prejudiced by the sale of adulterated articles, on the ground that he bought it for analysis only; or to allege that the article in question, though defective in nature, *or* substance, *or* quality, was not defective in all three respects" (section 2). The next section enables the Medical Officer of Health, inspector or constable charged with the execution of the Act to procure, *at the place of delivery*, a sample of milk in course of delivery to the purchaser or consignee, in pursuance of any contract; and may submit the sample to the Public Analyst. "The seller, or his representative, if he refuses to allow a sufficient sample to be taken, is liable to a penalty not exceeding £10" (section 4). "As regards spirits not adulterated otherwise than by admixture of water, it is a good defence to prove that the admixture has not reduced the spirit more than 25 degrees under proof for brandy, whisky, or rum; or 35 degrees under proof for gin" (section 6).

In order to prevent the fraudulent sale of margarine for butter, the Margarine Act, 1887, was passed. Section 3 of this Act defines "butter" as made exclusively from milk, or cream, or both, with or without salt or other preservative, and with or without added colouring matter. "Margarine" includes all substances, whether compounds or otherwise, prepared in imitation of butter, and whether mixed with butter or not. No such substance may be lawfully sold, except under the name of margarine and under the following conditions set forth in the Act.

Every package of margarine, whether open or closed, must be so marked as "margarine" in printed capital letters not less than ¾ of an inch square, and if exposed for sale by retail there must be attached to each parcel thereof so exposed a label marked, in printed capital letters not less than 1½ inch square, "margarine"; and every person selling margarine by retail, save in a package duly branded or marked in accordance with the above requirements, must in every case deliver it to the purchaser in or with a paper wrapper on which is printed "margarine" in capital letters not less than ¼ of an inch square (section 6). All margarine factories must be registered with the Sanitary Authority by whom the Public Analyst of the district is appointed (section 9). Officers authorised to take samples under the Sale of Food and Drugs Act may take samples of butter, or substances purporting to be butter, exposed for sale and not marked as margarine, without going through the form of purchase required by that Act, but otherwise complying with its provisions as to dealing with the samples (section 10). Any such substances not being marked as margarine are to be presumed to be exposed for sale as butter, so that there is a possible offence under both Acts. There is a saving clause similar to section 25 of the Sale of Food and Drugs Act, namely, that the vendor is absolved if he proves that he bought the article with a written warranty, and sold it, in the same state as when bought, believing it to be butter (section 7).

Penalties for offences under the Act may not exceed £20 for the first offence, £50 for the second, and £100 for the third or any subsequent offence (section 4). Any part of these penalties may, if the Court so direct, be paid to the person who proceeds for the same, to reimburse him for the legal costs of obtaining the analysis, and any other reasonable expenses to which the Court may consider him to be entitled (section 11).

DAIRIES, COWSHEDS, AND MILKSHOPS.

In England and Wales.—It has already been shown that, under section 117, Public Health Act, 1875, and under the 15th section of the Markets, Fairs, and Fairs Clauses Act, 1847, unwholesome provisions, including milk, may be dealt with by seizure and condemnation. The Acts, however, which are most active in regulating the milk-supply are the Contagious Diseases (Animals) Acts, 1878–1886. Under these Acts (section 34 of 1878, and section 9 of 1886), the Local Government Board have power to make general or special Orders for (1) the registration with the Local Authority of all persons carrying on the trade of cowkeepers, dairymen, or purveyors of milk; (2) for the inspection of cattle in dairies and the general sanitation of dairies and cowsheds; (3) for securing the cleanliness of milk stores, shops, and vessels for containing milk; (4) for guarding milk against infection; (5) and for authorising Local Authorities to make regulations for any or all of the aforesaid purposes.

Under the powers thus conferred, the Local Government Board issued the Dairies, Cowsheds, and Milkshops Orders of 1885 and 1886, the chief effect of which Orders is to throw upon every urban and rural Sanitary Authority the duty of supervising the milk trade in their district, and of carrying out certain general regulations prescribed by the Orders. These duties are common to all districts alike, but any Sanitary Authority may arm itself with further powers by making regulations under section 13 of the Order of 1885, having the force of bye-laws. The chief provisions of the Order of 1885, as amended by that of 1886, are summarised as follows:—

Section 6. (1) It shall not be lawful for any person to carry on in the district of any Local Authority the trade of cowkeeper, dairyman, or purveyor of milk, unless he is registered as such in accordance with this article. (2) Every Sanitary Authority shall keep a register of such persons, and shall from time to time revise and correct the register. (3) The Sanitary Authority shall register every such person, but the fact of such registration shall not be deemed to authorise such person to occupy as a dairy or cowshed any particular building, or in any way preclude any proceedings being taken against him. (4) The Sanitary Authority shall from time to time give public notice of registration being required, and of the mode of registration. (5) A person who carries on the trade of cowkeeper or dairyman for the purpose only of making or selling butter or cheese, or both, and who is not also a purveyor of milk, need not be registered. (6) A person who sells milk of his own cows in small quantities to his workmen or neighbours for their accommodation need not, by reason thereof, be registered.

Section 7. (1) It shall not be lawful to begin to occupy as a dairy or cowshed any building not so occupied at the commencement of this Order, until provision is made, to the reasonable satisfaction of the Sanitary Authority, for the lighting and ventilation, including air-space, and the cleansing, drainage, and water-supply ; (2) or without first giving one month's notice in writing to the Sanitary Authority.

Section 8. It shall not be lawful for any cowkeeper or dairyman to occupy as a dairy or cowshed any building—whether so occupied at the commencement of this Order or not—if . the lighting and ventilation, including air-space, and the cleansing, drainage, and water-supply thereof are not such as are necessary or proper (*a*) for the health and good condition of the cattle therein ; and (*b*) for the cleanliness of milk vessels used therein for containing milk for sale ; and (*c*) for the protection of the milk therein against infection or contamination.

Section 9. It shall not be lawful for any . cowkeeper, or dairyman, or purveyor of milk, or occupier of a milkshop (*a*) to allow any person suffering from a dangerous infectious disorder, or having recently been in contact with a person so suffering, to milk cows or to handle vessels used for containing milk for sale, or in any way to take part or assist in the conduct of the trade . so far as regards the production, distribution, or storage of milk ; or (*b*) if himself so suffering, or having recently been in contact as aforesaid, to milk cows or handle vessels containing milk for sale, or in any way to take part in the conduct of his trade as far as regards the production, distribution, or storage of milk ; until, in each case, all danger therefrom of the communication of infection to the milk or of its contamination has ceased.

Section 10. It shall not be lawful for any . cowkeeper, dairyman, or purveyor of milk, or occupier of a milk store or milkshop after the receipt of notice of not less than one month from the Local Authority calling attention to the provisions of this article, to permit any water-closet, earth-closet, privy, cesspool, or urinal to be within, communicate directly with, or ventilate into, any dairy or any room used as a milk store or milkshop.

Section 11. It shall not be lawful for any . cowkeeper, or dairyman, or purveyor of milk, or occupier of a milk store or milkshop, to use a milk store or milkshop in his occupation, or permit the same to be used, as a sleeping apartment, or for any purpose incompatible with the proper preservation of the cleanliness of the milk store or milkshop, and of the milk vessels and milk therein, or in any manner likely to cause contamination of the milk therein.

Section 12. It shall not be lawful for any . . . cowkeeper, or dairyman, or purveyor of milk to keep any swine in any . . . building used by him for keeping cows, or in any milk store or other place used by him for keeping milk for sale.

Section 13. Any Sanitary Authority may from time to time make regulations for the following purposes, or any of them :—(*a*) For the inspection of cattle in dairies ; (*b*) for prescribing and regulating the lighting, ventilation, cleansing, drainage, and water-supply of dairies and cowsheds ; (*c*) for securing the cleanliness of milk stores, milkshops, and milk vessels used for containing milk for sale ; (*d*) for prescribing precautions to be taken by purveyors of milk, and persons selling milk by retail, against infection or contamination.

Section 14. The following provisions shall apply to regulations made by any Sanitary Authority under this Order :—(1) Every regulation shall be published by advertisement in a newspaper circulating in the district of the Sanitary Authority. (2) The Sanitary Authority shall send to the Local Government Board a copy of every regulation made by them not less than one month before the date named for such regulation to come into force. (3) If at any time the Local Government Board are satisfied on inquiry with respect to any regulation that the same is of too restrictive a character, or otherwise objectionable, and direct the revocation thereof, the same shall not come into operation, or shall thereupon cease to operate, as the case may be.

Section 15. The milk of a cow suffering from cattle plague, pleuro-pneumonia, or foot-and-mouth disease (*a*) shall not be mixed with other milk ; and (*b*) shall not be sold or used for human food ; and (*c*) shall not be sold or used for food of animals, unless it has been boiled.

The Amending Order of November 1886 imposed penalties of £5 for every offence against the Order of 1885, and, in the case of continuing offences, an additional daily penalty of 40s. The Courts have power to reduce the amounts of these penalties if they think fit.

The expenses of Sanitary Authorities under the Contagious Diseases (Animals) Acts, 1878 and 1886, are to be defrayed as if they were incurred in the execution of the Public Health Act, 1875, and in the case of rural Authorities are to be deemed general expenses.

For the purpose of enforcing Orders under section 34 of the Act of 1878, and any regulations made thereunder, Sanitary Authorities and their officers will have the same right of entry as they have under section 102 of the Public Health Act, 1875, in respect of nuisances.

It is to be regretted that the Dairies, Cowsheds, and Milkshops Orders are not more adequately enforced by Sanitary Authorities; the custom of combining the duties of inspection of dairies, &c., with that of inspectors under the Contagious Diseases (Animals) Acts, and employing police officers for these duties, gives very unsatisfactory results. Moreover, the power to make regulations is very inadequate, and Local Authorities have to be careful not to exceed their powers. Another defect is, that there is no authority by which milk sellers can be compelled to put notice boards or information as to their registration over their doors. To these criticisms may be added that the present state of the law is unsatisfactory in regard to disease among cattle. "Disease," as defined by the Contagious Diseases (Animals) Act, 1878, means "cattle plague, contagious pleuro-pneumonia, foot-and-mouth disease, sheep-pox, or sheep-scab." No mention is made of tuberculosis; an extension of the definition is very necessary.

In London, by section 28 of the Public Health Act, 1891, which repeals, so far as they apply to London, section 34 of the Contagious Diseases (Animals) Act, 1878, and section 9 of the same Act, 1886, the same powers as were given by those sections are given to the Local Government Board to make Orders and regulations for dairies, and to the County Council and the Corporation of London to make bye-laws applicable to so much of the administrative county of London as is not included in the city, and in the city respectively.

In Scotland, the Dairies, Cowsheds, and Milkshops Orders of 1885 and 1886 apply as in England, the Local Government Board of Scotland exercising similar functions as the corresponding English Board, but subject to the consent of the Secretary for Scotland as regards general or special Orders. The Local Government (Scotland) Act, 1895, section 11, practically extends to Scotland the powers of section 4 of the Infectious Disease (Prevention) Act, 1890, which provides for the stopping of infected milk-supplies, but in one material point it goes beyond that section. It provides that if the Medical Officer of Health reports to the Local Authority "that infectious disease is caused by, or is likely to arise from, the consumption of the milk," the Local Authority shall have power to stop the supply. (See also pages 908 and 912.)

In Ireland.—Section 34 of the Contagious Diseases (Animals) Act, 1878, applied to Ireland as well as elsewhere, and in pursuance of its provisions an Order in Council was made in August 1879, known as the Dairies, Cowsheds, and Milkshops Order of 1879, which is still in force as modified by the Act of 1886. This Order corresponds to, and is very similar to the

English Order, above detailed, of 1885. Article 6 of the English Order corresponds to article 12 of the Irish Order; article 7 of the English is similar to article 5 of the Irish Order; while the articles 8, 9, 11, 12, and 15 of the English are the same as articles 6, 9, 10, 11, and 18 of the Irish Order. There are no articles in the Irish Order corresponding to 10 and 14 of the English Order, while in place of article 13 of the latter Order, similar provisions to it are placed in article 7 of the Irish Order.

There was no Irish amending Order, imposing penalties, like that of the English one of 1886; but penalties are recoverable for offences against the Order of 1879, under sections 60 and 61 of the Public Health (Ireland) Act, 1878. In applying these enactments to Ireland, the Local Government Board for Ireland stands in precisely the same position as the English Board does to England. The expenses of Sanitary Authorities, under the Dairies Order, are defrayed as explained in the case of England and Wales; the same similarity exists as to powers of entry, section 118 of the Irish Public Health Act, 1878, being substituted for section 102 of the English Act of 1875.

PARKS, OPEN PLACES, AND COMMONS.

In England and Wales.—The Public Health Act, 1875, section 164, empowers urban Sanitary Authorities to provide and regulate, by means of bye-laws, public parks and pleasure grounds. To pleasure grounds, provided under this enactment, the public have a right of admission, free of charge; but in consequence of the advantages which had been found to result from the insertion in local Acts of provisions to close these parks and grounds at certain times, and to make charges of admission thereto, section 44 of the Public Health Acts Amendment Act, 1890, has enabled the urban Sanitary Authorities of districts in which Part III. of that Act had been adopted to close to the public, on certain days, the public parks, and grant their use to any public charity, or institution, or society, or show, gratuitously or on payment. Section 45 of the same Act has extended the powers of urban Authorities under section 164 of the 1875 Act, to enable them to contribute towards the cost of laying out, planting, and improving, or even of purchasing lands for purposes of public parks and pleasure grounds.

By section 8 (1) (*d*) of the Local Government Act, 1894, Parish Councils can exercise with respect to any recreation ground, village green, open space, or public walk for the time being under their control, or to the expense of which they have contributed, such powers as may be exercised by urban Sanitary Authorities under section 164 of the Public Health Act, 1875.

The Open Spaces Act, 1887, by extending certain provisions of the Metropolitan Open Spaces Acts, 1877 and 1881, to all urban Sanitary Authorities, and to every rural Authority invested by order of the Local Government Board with powers of the Act, gave increased facilities to Sanitary Authorities for the acquisition, maintenance, and regulation of open spaces, including disused burial-grounds, for the use of the public.

Urban Sanitary Authorities of districts containing a population of more than 5000 inhabitants, at the last published census, have powers in connection with the preservation of commons either wholly or partly in their district or within six miles thereof, under section 8 of the Commons Act, 1876.

In London.—The Gardens in Towns Protection Act, 1863, enables the

County Council and the Corporation of London, in the respective areas over which they have jurisdiction, to take over, on the request of the persons entitled thereto, the right to require any garden or ornamental ground to be kept and maintained as such, and to protect it from being built upon. Such gardens may be managed by a committee of the rated inhabitants of the houses surrounding the same, at the cost of the Vestry or District Board, or be vested in the Vestry or District Board subject to the approval of the County Council, or be managed by the Corporation, if within the city. Under the Metropolis Open Spaces Acts of 1877, 1881, and 1887 further powers were given to the County Council and Corporation of London to acquire, maintain, and regulate open spaces and disused burial-grounds within their respective spheres of jurisdiction. In respect of these powers and duties they have power to make bye-laws (section 6, Act of 1881). All powers and duties conferred upon the County Council may be exercised and performed by any Vestry or District Board. They have, further, power in certain cases to rate inhabitants of squares, crescents or circuses for maintenance of gardens (Metropolis Management Act, 1855, section 239).

As regards schemes under the Metropolitan Commons Act, 1878, the County Council, in respect of any common situate within the metropolis, have the same power to oppose inclosure, also to purchase and hold, with a view to prevent the extinction of the "common rights," any saleable rights in common, or any tenement of a commoner having annexed thereto rights of common, as is conferred by section 8 of the Commons Act, 1876, upon an urban Sanitary Authority in respect of a suburban common. So, by the Corporation of London (Open Spaces) Act, 1878, the Corporation can acquire by purchase, gift, or otherwise the freehold or interest in common lands not within the Metropolis Management Act, but within 25 miles of the city, and all rights over such lands.

In Scotland the Open Spaces and Commons Acts do not apply, but a burgh rate may be applied in maintaining or defending rights in commons or open spaces, and the Burgh Commissioners may provide and regulate the same by bye-laws (Burgh Police Act, 1892, sections 307, 308, 316). Also, by section 58 of the Public Health (Scotland) Act, 1867, a Local Authority may provide a recreation ground; while by the Public Parks (Scotland) Act, 1878, and the Secretary for Scotland Act, 1885, the Local Authorities may "purchase, or take on lease, lay out, plant, improve, and maintain lands for the purpose of being used as parks, public walks, or pleasure grounds," as well as to borrow and rate, and also regulate their use by bye-laws, to be approved by the Secretary for Scotland. A further power of acquiring land within two miles outside of a burgh "for a pleasure ground or place of public resort or recreation" has been conferred on Burgh Commissioners by the Burgh Police Act, 1892.

In Ireland.—There is no provision in the Irish Public Health Act analogous to section 164 of the corresponding English Act, but similar powers to those contained in the latter are provided in section 12, Open Spaces Act, 1887, and section 6, Metropolitan Open Spaces Act, 1881, which apply to Ireland. Section 44 of the Public Health Amendment Act, 1890, applies also to urban Sanitary Authorities in Ireland who have adopted Part III. of the Act.

Besides the power of establishing and maintaining public parks and grounds given by the above-mentioned Acts, other similar powers are given to Towns Commissioners and Municipal Authorities of towns with a population exceeding 6000 inhabitants by the Towns Improvement (Ireland) Act, 1854, and the Public Parks (Ireland) Act, 1869; the powers therein given include the borrowing of money for the purposes of the Acts, and the appointment of committees to regulate these public recreation grounds by means of bye-laws. The Open Spaces Acts, 1877 to 1887, apply to Ireland as to England, references therein to the Public Health Act, 1875, being construed as references to the corresponding Irish Act, 1878. The Commons Act, 1876, does not extend to Ireland.

MORTUARIES AND CEMETERIES.

In England and Wales.—Under the Public Health Act, 1875, every Sanitary Authority *may*, and if required by the Local Government Board *must*, provide a mortuary, and may make bye-laws for its management and the charges for its use. They may also provide for the decent interment, at charges to be fixed by such bye-laws, of any dead body which may be received into a mortuary (section 141). A justice may, on a certificate signed by a medical practitioner, order to be removed to a mortuary, at the cost of the Sanitary Authority, the body of any one who has died of any infectious disease, and which is retained in a room in which persons live or sleep, or any dead body which is in such a state as to endanger the health of the inmates of the house or room in which it is retained. He may direct the same to be buried within a specified time. If the friends fail to comply, it is the duty of the Relieving Officer to bury, and the expenses may be recovered from the proper person (section 142).

The Local Government Board have issued a series of Model Bye-laws with respect to the management of a mortuary; the only provisions of sanitary importance suggested in them are the following:—

> A body deposited in the mortuary shall be removed therefrom for interment within . . days after death; but if the deceased has died of an infectious disease, the body shall be removed for interment within days after death.

The Board have also made the following suggestions in regard to the construction and management of mortuaries:—

> The buildings should be isolated and unobtrusive, but substantial, structures of brick or stone. Every chamber for the reception of corpses should be on the ground floor. In addition to such chamber there should be a waiting-room, a caretaker's house, and a shed or outhouse. Every mortuary chamber should be lofty, and there should be a ceiling or a double roof, with an intervening space of 8 inches, for the sake of coolness. The area should be sufficient to allow freedom of movement between the slabs. The windows should be on the north side, if practicable; if otherwise, they should have external louvre blinds. Louvres, or air gratings, under the eaves will be the best means of ventilation. The pavement must be even and close, and a cement floor is preferable. The slabs should be of slate, and 2½ feet to 3 feet from the floor. Water should be laid on within the chamber. The walls and ceiling should be whitewashed, and the outside of the roof also whitened. There should be at least two chambers, one of which may be reserved for bodies of persons who have died of infectious disease.
>
> There should be a resident caretaker, and bodies should be received at any hour of the day or night.

In addition to mortuaries, Sanitary Authorities may provide and maintain proper places, otherwise than at a workhouse or at a mortuary, for the carrying out of *post-mortem* examinations (section 143).

The powers and duties of Sanitary Authorities as regards mortuaries are extended to cemeteries by the Public Health (Interments) Act, 1879, section 2, whereby both urban and rural Authorities are enabled to provide cemeteries for their districts, and must do so if required by the Local Government Board. The cemetery need not be within the district of the Local Authority. In a Memorandum issued in August 1879 the Board point out that it is incumbent upon the Sanitary Authority to take action,

1. Where, in any burial-ground which remains in use there is not proper space for burial, and no other suitable burial-ground has been provided.

2. Where the continuance in use of any burial-ground (notwithstanding there may be such space) is by reason of its situation in relation to the water-supply of the locality, or by reason of any circumstances whatsoever, injurious to the public health.

3. Where, for the protection of the public health, it is expedient to discontinue burials in a particular town, village, or place, or within certain limits.

The necessity may also arise from unsuitability of the site or of the subsoil, or from inconvenience of access from populous parts of the district.

If it is desirable, upon the above or other grounds, to close any existing burial-place, a representation must be made to the Home Secretary for the purpose of obtaining an Order in Council to that effect, under the provisions of the Burial Act of 1853.

Assuming that a cemetery is required in any locality it may be provided either by the Sanitary Authority under the Interments Act, 1879, or by the formation of a Burial Board under the Burial Acts. As to which procedure should be adopted will be mainly decided by the circumstances of the district. The chief arguments in favour of the Sanitary Authority are that it has at its disposal an efficient staff of officers and advisers, besides which it can obtain compulsory powers of purchase of land by means of a Provisional Order, which a Burial Board cannot obtain. On the other hand, the area for which the cemetery is required may not be wholly comprised within the sanitary district, nor be conterminous with any contributory place therein.

Section 10 of the Public Health Interments Act, 1879, forbids the construction of a cemetery within 200 yards of any dwelling without the consent of the owner and occupier. There is no restriction if such consent is obtained, nor any prohibition of future building nearer to the cemetery. In the case of cemeteries constructed under the Burial Acts, this distance is reduced to 100 yards.

The following Regulations for Burial-Grounds provided under the Burial Acts were issued by the Home Secretary in 1863, and are now still in force.

(1) The burial-ground shall be effectually fenced, and, if necessary, underdrained to such a depth as will prevent water remaining in any grave or vault.

(2) The area to be used for graves shall be divided into grave spaces, to be designated by convenient marks, so that the position of each may be readily determined, and a corresponding plan kept on which each grave shall be shown.

(3) The grave spaces for the burial of persons above twelve years of age shall be at least 9 feet by 4 feet, and those for the burial of children under twelve years of age 6 feet by 3 feet, or, if preferred, half the measurement of the adult grave space—namely, 4½ feet by 4 feet.

(4) A register of graves shall be kept, in which the name and date of burial in each shall be duly registered.

(5) No body shall be buried in any vault or walled grave unless the coffin be separately entombed in an air-tight manner; that is, by properly cemented stone or brickwork, which shall never be disturbed.

(6) One body only shall be buried in a grave at one time, unless the bodies are those of members of the same family.

(7) No unwalled grave shall be reopened within fourteen years after the burial of a person above twelve years of age, or within eight years after the burial of a child under twelve years of age, unless to bury another member of the same family, in which case a layer of earth not less than a foot thick shall be left undisturbed above the previously

buried coffin; but if on reopening any grave the soil is found to be offensive, such soil shall not be disturbed, and in no case shall human remains be removed from the grave.

(8) No coffin shall be buried in any unwalled grave within 4 feet of the level of the ground, unless it contains the body of a child under twelve years of age, when it shall not be less than 3 feet below that level.

The application to cemeteries of section 141 of the Public Health Act, 1875, enables Sanitary Authorities to make bye-laws for their management and charges for use. The following represents the essential provisions of the Model Bye-laws issued in respect of this matter by the Local Government Board.

(a) *Definitions.*—A "grave" is defined as a burial-place formed in the ground by excavation, and without any internal wall of brickwork or stonework, or any other artificial lining. A "vault" is an underground burial-place of any other construction. (b) *Vaults.*—Every vault shall be enclosed with walls of brick or stone, solidly put together with good mortar or cement. (c) *Common graves.*—Not more than one body shall be buried at any one time in a grave in respect of which no exclusive right of burial has been granted. (Exception is made in the case of two or more members of the same family.) Such a grave shall not be reopened for the purpose of a further burial within eight years after the burial of a person aged less than twelve years, nor within fourteen years after the burial of a person aged more than twelve years. (Exception is made in the case of members of the same family.) (d) *Minimum covering of earth.*—No part of a coffin shall be buried at a less depth than 3 feet below the ground adjoining the grave, if it contains the body of a person aged less than twelve years; nor at a less depth than 4 feet if the age of the deceased was over twelve years. A layer of earth, not less than 1 foot in thickness, shall be interposed between every coffin and the coffin nearest to it. (e) *Closure of vaults.*—A coffin buried in a vault shall, within . hours after burial, be wholly and permanently embedded in and covered with good cement concrete, not less in any part than inches in thickness; or wholly and permanently enclosed in a separate cell, constructed of slate or flag, not less than 2 inches thick, and jointed in cement, or of brick in cement, and in such manner as to prevent as far as practicable the escape of noxious gas.

Interments underneath or within the walls of any church built after 1848 are forbidden by the Public Health Act, 1848, section 33, incorporated in the Act of 1875. No buildings must be erected upon any disused burial-ground, except for the purpose of enlarging a place of worship (Disused Burial-Grounds Act, 1884).

In London, under the Public Health Act, 1891, every Sanitary Authority must provide mortuaries and places for *post-mortem* examinations when so required by the County Council (sections 88 and 90). Subject to the consent of the Local Government Board, the Local Authorities have power to borrow money for these purposes (section 105). The Commissioners of Sewers are the Burial Board for the city of London. The general law as to cemeteries is the same in the metropolis as in the provinces.

In Scotland a Local Authority may provide a mortuary, but the Local Government Board have no power to require them to do so (Public Health Act, 1867, sections 16 and 43). A Parochial Board has a similar power under section 20, Burial-Grounds (Scotland) Act, 1855. Though the Local Authorities cannot provide burial-grounds, they can act in regard to any of them which are so situated or crowded with bodies, or otherwise so conducted, as to be offensive or injurious to health, as a statutory nuisance. So far as relates to disused burial-grounds, there are no Scottish provisions at all corresponding to the English Statutes.

In Ireland.—The provisions of the Irish Public Health Act, 1878, section 157, relating to mortuaries are similar to those in the English Act of 1875. The Public Health (Interments) Act, 1879, does not apply to Ireland, but, on representation being made, the Local Government Board may restrain the opening of new burial-grounds, and order discontinuance of burials in specified places (Public Health Act, 1879, section 162). Under section 160 of this same Act, the Sanitary Authorities, except in towns having Commissioners under local Acts, are the Burial Board of the district. In the towns just excepted, the guardians of the poor are the Burial Board. Whenever any burial-ground has been closed by order, the Burial Board of the district have power to provide a suitable cemetery, with powers to purchase lands compulsorily, appropriate, lay out and otherwise manage as they may deem necessary, subject at all times, however, to any Regulations which the Local Government Board of Ireland may make in respect of them (sections 172 to 234).

BATHS AND WASH-HOUSES.

In England and Wales.—There have been four Baths and Wash-houses Acts, namely, those of 1846, 1847, 1878, and 1882. These are all adoptive Acts, and under section 10, Public Health Act, 1875, urban Sanitary Authorities can adopt them, the authority having all the powers, rights, duties, capacities, liabilities, and obligations as to the formation, maintenance, regulation, and management of baths and wash-houses within their district. In rural parishes these Acts can only be adopted by the Parish Meeting; and the Parish Council, if there is one, is the authority to carry them into effect. Bye-laws may be framed by the controlling authority for the maintenance of order, decency, and cleanliness in all baths and wash-houses, the Local Government Board having issued a series of models for their guidance in this respect.

Where the Acts have been adopted, the expenses of the authority in their execution, so far as the baths and wash-houses are not self-supporting, will be borne in the same manner as their expenses under the Public Health Act, 1875; and the authority will have the same powers of borrowing in respect of these expenses as in the case of expenses under that Act.

In London.—The Baths and Wash-houses Acts may be adopted in any metropolitan parish by the Vestry, with the approval of the Local Government Board, and where this is done Commissioners selected by the Vestry from among the ratepayers must be appointed to put the Acts into execution. The expenses of carrying the Baths and Wash-houses Acts into execution in each parish, to such amount as may from time to time be sanctioned by the Vestry, are chargeable upon the moneys applicable to the relief of the poor in the parish, so far as they are not met by the revenue from the baths, wash-houses, and bathing-places provided by the Commissioners.

By their Baths and Wash-houses Act of 1895, the Commissioners of Sewers have power to act as Commissioners of Baths and Wash-houses under the Acts 1846 to 1882 for the city, and to erect, or acquire, control, regulate, and make bye-laws for any such baths, wash-houses, or bathing-places as they may deem necessary within the city of London.

In Scotland the Baths and Wash-houses Acts do not apply, consequently the landward authorities have no power to provide such accommodation for the public. But in the burghs the Commissioners may provide such bathing-places with full power to regulate them, subject only to the condition that there must be at least twice as many baths for the working classes as there are baths of the better class (Burgh Police Act, 1892, sections 309 to 314).

In Ireland there is only one Baths and Wash-houses Act, namely, that of 1846. This Act is practically the same as that of the English one of the same year. Further, by the Public Health Act, 1878, urban Sanitary Authorities, who have adopted the former Act, are the controlling authorities for such baths and wash-houses within their district, just as is the case with English urban Authorities under the English Public Health Act, 1875. In rural districts, the Baths and Wash-houses Act cannot be put in force except in municipal towns, not being urban sanitary districts, which are situated therein. The general provisions as to expenses, borrowing of money, and making of bye-laws are similar to those in force in England.

Some powers to provide baths, &c., are given to Commissioners of towns constituted under the Towns Improvement (Ireland) Act, 1854, by section 55 of that Act, which incorporates sections 136 to 141 of the Towns Improvement Clauses Act of 1847.

INFECTIOUS DISEASES.

In England and Wales.—The Public Health Act, 1875, enacts that, upon the certificate of a Medical Officer of Health or other medical practitioner that the cleansing and disinfecting of any house or part thereof, and of any articles therein, would tend to prevent infectious disease, it is incumbent on the Sanitary Authority to serve notice upon either the owner or occupier, requiring him to cleanse and disinfect. A daily penalty not exceeding 10s. is incurred by default, and the Authority may do what is necessary and recover the costs, or may undertake the duty in the first instance, with the consent of the occupier, at their own cost (section 120). Where the Infectious Diseases Prevention Act, 1890, is adopted, the above section is repealed, and the provisions so far modified that the Sanitary Authority may, after twenty-four hours' notice to the owner or occupier, proceed to carry out such disinfection or cleansing, unless within that time he informs the Authority that he will, within a period fixed in the notice, himself carry out the work to the satisfaction of the Medical Officer of Health. If he fail to do this within the specified period, it is to be done by the officers of the Sanitary Authority, under the superintendence of the Medical Officer of Health, and the expenses may be recovered. Power of entry between 10 A.M. and 6 P.M. is given for the purposes of this section (sections 5 and 17, Act of 1890).

By section 121 of the Act of 1875, the Sanitary Authority may destroy infected bedding, clothing, or other articles, and give compensation. By section 6 of the adoptive Prevention Act, 1890, the Authority may, by written notice, require, under a penalty of £10, any infected clothing or other articles to be delivered to their officer for disinfection. The Sanitary Authority must take away, disinfect, and return such articles free of charge, and, in the event of any unnecessary damage, must compensate the owner.

The Public Health Act, 1875, further enacts that a Sanitary Authority may provide a disinfecting apparatus, and disinfect free of charge (section 122); also provide an ambulance and pay expenses of conveyance of infectious persons to hospital (section 123). Where a hospital is provided within convenient distance, a justice may, on the certificate of a medical practitioner, order the removal of any person who is suffering from any dangerous infectious disorder, and is without proper lodging or accommodation, or lodged in a room occupied by more than one family, or is on board any ship or vessel (section 124). The Authority may make regulations for removing to any available hospital, and for keeping there as long as necessary, any persons brought within their district by vessel who are infected with a dangerous infectious disorder (section 125). It is unlawful for any person so suffering to expose himself wilfully, without proper precautions against spreading the disorder, in any street, public place, shop, inn, or public conveyance, or to enter any public conveyance without previously notifying to the owner, conductor, or driver thereof that he is so suffering; or, being in charge of any person so suffering, to expose such sufferer, or to give, lend, sell, transmit, or expose without previous disinfection any bedding, clothing, rags, or other things which have been exposed to infection from any such disorder, but this does not apply to the transmission with proper precautions of articles for the purpose of having them disinfected (section 126). The owner or driver of a public conveyance so used is required under penalty to have the same immediately disinfected; but he need not convey any person so suffering until he has been paid a sum sufficient to cover any loss or expense incurred by him (section 127). Any person who knowingly lets for hire any house or room in which any person has suffered from such disorder, without having it and its contents disinfected to the satisfaction of a medical practitioner as testified by a certificate signed by him, is liable to a penalty not exceeding £20 (section 128). Any person letting or offering for hire any house or part of a house, who, on being questioned as to the fact of there being, or within six weeks previously having been therein, any person suffering from any dangerous infectious disorder, knowingly makes a false answer to such question, becomes liable to penalty or imprisonment (section 129).

The above provisions have been supplemented in districts where the Infectious Disease (Prevention) Act, 1890, has been adopted by the following enactment of that Act. Section 7 provides that any person who shall cease to occupy any house or room in which any person has, within six weeks, been suffering from any infectious disease, (1) *must* have such house or room, and all articles therein liable to retain infection, disinfected to the satisfaction of a registered medical practitioner, as testified by a certificate signed by him; and (2) *must* give to the owner notice of the previous existence of such disease; and (3) *must not*, knowingly, make a false answer when questioned by the owner, or by any person negotiating for the hire of the house or room, as to there having within six weeks previously been therein any person suffering from any infectious disease. Penalties of £10 are provided in each case. Infectious rubbish must not be thrown into any receptacle for refuse without previous disinfection; or in default a daily penalty of 40s. (section 13). In any district where these sections are in force the Sanitary Authority must give notice of their provisions to the occupier of any house in which they are aware there is a person suffering from any infectious disease (section 14).

The Public Health Act, 1875, sections 131 to 133, enacts that any Sanitary Authority may build or contract for the use of hospitals for their district, two or more authorities, if necessary, combining for this purpose. The Sanitary Authority may recover from a patient, who is not a pauper, the cost of his maintenance in such hospital; and may, with the sanction of the Local Government Board, themselves provide or contract for a temporary supply of medicine and medical assistance for the poor of their district. And the Infectious Disease (Prevention) Act, 1890, requires the same Authorities, when they have adopted section 15 of that Act, to provide free temporary shelter with any necessary attendance for the members of any family in which infectious disease has appeared, who have to leave their dwellings to allow of disinfection by the Sanitary Authority. Any person suffering from any infectious disease, and being an inmate of a hospital for infectious diseases, and who, upon leaving, would be without accommodation in which due precautions could be taken against the spread of infection, may, by order of a justice, be detained in hospital at the cost of the Sanitary Authority for any specified period, and such period may be extended as often as necessary (section 12, Act of 1890).

With a view to promote the establishment of infectious hospitals, a very important Act was passed in 1893, called the Isolation Hospitals Act, giving to County Councils limited power to secure the provision of isolation hospitals in their county. It applies to England and Wales generally, but not to London or to any county borough; other boroughs are also exempt, except by Order of the Local Government Board, if the population be less than 10,000 at the last census, or by consent of the Corporation if the population be 10,000 or more. A *hospital district* under this Act may consist of one or more local areas; a "local area" being defined as including an urban or rural sanitary district, or any contributory place. This district is constituted by Order of the County Council. To put this Act into force, the County Council may take the initiative by directing their Medical Officer of Health to report as to the hospital requirements of any part of their county, and acting upon his report; but they may also be set in motion by a petition from any Local Authority, or from twenty-five ratepayers in any contributory place. The next step is for the County Council to hold a local inquiry, after which they make an Order constituting the hospital district and defining its extent. No local area can be included in a hospital district without the consent of its Local Authority, if it already has (in the judgment of the County Council) adequate accommodation; nor must a hospital district be formed for one local area only, or for one or more local areas within the same rural sanitary district, without the consent of the Sanitary Authority, unless the County Council are satisfied that the Sanitary Authority are unable or unwilling to make suitable provision for the purpose. The Order constitutes a hospital committee, consisting of local representatives, but if a grant be made out of county funds the committee may consist wholly or in part of County Councillors. The Order further gives the committee power to provide and maintain a hospital; and apart from this they are authorised by the Act to make temporary arrangements for isolation, and to establish district hospitals in cottages or small buildings. They may also (subject to any regulations made by the County Council) undertake the training of nurses, and may charge for their attendance outside the hospital. Every hospital is to be provided with one or more ambulances, and must, if practicable, be "in connection with the system of telegraphs" (section 13).

The County Council have the power of inspecting any such hospital, and of raising money by loan for the purposes of the hospital.

"Structural" and "establishment expenses" are borne by the several local rates of the constituent local areas, in proportions to be fixed by the County Council's Order. The cost of conveying, removing, feeding, medicines, disinfecting, and "all other things required for patients individually, exclusive of structural and establishment expenses," are termed "patients' expenses." For ordinary non-pauper patients they are to be paid by the Local Authority out of the rates of the local area from which the patient came, but the guardians are responsible if poor-law relief had been given at or within fourteen days at the time of admission. Patients desiring exceptional accommodation are themselves responsible for the cost of maintenance, on such terms as the committee may appoint ("special patients' expenses") (sections 17 to 19).

It is, of course, of the greatest importance from a sanitary point of view that the dead bodies of persons who have died of infectious diseases should not remain unburied in such a manner as to endanger the health of the survivors. Section 142 of the Public Health Act, 1875, provides that where the dead body of one who has died of any infectious disease is retained in a room in which persons live and sleep, any justice may, on a certificate signed by a medical practitioner, order the body to be removed by the Sanitary Authority to a mortuary, and direct the same to be buried within a time limited by the order; unless the friends of the deceased undertake to so bury the body within the time specified, it is the duty of the Relieving Officer to bury such body at the expense of the poor-rate; but any expenses so incurred may be recovered in a summary manner from any person legally liable to pay the expenses of the burial. A penalty of £5 attaches to any person obstructing the execution of an order made under this section.

Further provisions in respect of this matter are contained in sections 8 to 11 of the adoptive Infectious Disease Prevention Act, 1890, which enact that the body of a person who has died of any infectious disease must not, without a certificate from the Medical Officer of Health, or a registered medical practitioner, be retained for more than forty-eight hours elsewhere than in a mortuary, or in a room not used at the time as a dwelling place, sleeping place, or workroom. In such cases, and also where any corpse is retained in a building so as to endanger the health of the inmates, a justice may, upon the application of the Medical Officer of Health, order the body to be removed by the Sanitary Authority to a mortuary, and to be buried within a specified time. Unless the friends undertake to bury, and do bury within the specified time, the Relieving Officer must do so. The body of any person who has died from infectious disease in a hospital must not be removed except for immediate interment or to a mortuary, if the Medical Officer of Health or other practitioner certify that such restriction is desirable for preventing infection. The body of any person who has died from an infectious disease must not be conveyed in any public conveyance, other than a hearse, without due warning to the owner or driver, who must forthwith provide for disinfection.

In cases where there is any suspicion that an epidemic of infectious disease has its origin in any milk-supply of the district, the powers of Sanitary Authorities, under the Contagious Diseases (Animals) Acts, 1886, should not be lost sight of (see page 896). In addition to these provisions, Sanitary Authorities of districts in which section 4 of the Infectious Disease (Prevention) Act, 1890, is in force have power to prohibit the supply of milk from suspected dairies. If the Medical Officer of Health has reason to believe that the consumption of milk from any dairy, farm, farmhouse, cowshed, milk store, milkshop, or other place from which milk is supplied within or without his district, has caused or is likely to cause infectious disease to any person residing in the district, he may, if authorised by a justice having jurisdiction in the place where the dairy is situate, inspect the dairy. He may further, if accompanied by a veterinary surgeon, inspect the animals therein. If after inspection he is of opinion that infectious disease is caused by the consumption of the milk, he must report to the Sanitary Authority, forwarding also any report furnished to him by the veterinary surgeon. The Local Authority may then give not less than twenty-four hours' notice to the dairyman to appear before them, and show cause why the supply of the milk in their district should not be prohibited. If, in their opinion, he fails to show such cause, they may order accordingly, and must give notice of the facts to the Sanitary Authority and the County Council of the district in which the dairy is situate, and also to the Local Government Board. The order must be forthwith withdrawn on the Sanitary Authority or the Medical Officer of Health being satisfied that the milk-supply has been changed, or that the cause of infection has been removed. Penalties of £5, and if a continuing offence of 40s. a day are provided for contravention of this section of the Act.

The relation of schools to infectious diseases, and the action of Sanitary Authorities in the matter, often presents considerable difficulty. In a Memorandum, issued by the Medical Officer of the Local Government Board in December 1890, the best means of preventing the spread of disease by school children among their fellows are indicated, while avoiding any unnecessary interruption of the work of education. The Memorandum calls attention to the fact that :—

> "In the Code of Regulations approved by the Lords of the Committee of Council on Education, the following Article (Art. 88) prescribes as one of the general conditions required to be fulfilled by a public elementary school in order to obtain an annual Parliamentary grant, that 'the Managers must at once comply with any notice of the Sanitary Authority of the district in which the school is situated, requiring them for a specified time, with a view to preventing the spread of disease, either to close the school or to exclude any scholars from attendance, but after complying they may appeal to the Department, if they consider the notice to be unreasonable.'
>
> "The diseases for the prevention of which school closure, or the exclusion of particular children, will be required, are principally those which spread by infection directly from person to person, such as scarlet fever, measles, diphtheria, whooping-cough, small-pox, and rötheln, the order in which the several diseases are here given being about that of the relative frequency with which their occurrence gives rise to these questions at schools. More rarely, the same questions arise in connection with enteric fever and diarrhœal diseases, which spread not so much by direct infection from person to person as indirectly through the agency of local conditions, such as infected school privies.
>
> "It will be seen that Article 88, quoted above, confers upon Sanitary Authorities an alternative power with respect to public elementary schools, (*a*) to cause particular scholars to be for a specified time excluded from attendance, or (*b*) to require the school to be closed for a specified time."
>
> First, as to exclusion from school of particular scholars, it may be laid down as a principle "that all children suffering from any dangerous infectious disorder should be excluded from school until there is reason to believe that they have ceased to be in an infectious condition.
>
> "Secondly, as to the closing of schools, this, by more seriously interfering with the educational work of a district, is a much more grave step for a Sanitary Authority to take than to direct the exclusion of particular scholars. It is a measure that seldom ought to be enforced, except in presence of an actual epidemic, nor even then as a matter of routine, nor unless there be a clear prospect of preventing the propagation of disease, such as could not be looked for from less comprehensive action.
>
> "The Medical Officer of Health, on becoming aware of the presence of dangerous infectious disease in his district, should . send immediate notice to the teacher of the school or schools which the children of infected households may be attending, requesting that such children may be excluded from school for such time as he (the M. O. H.) may specify as being necessary. Ready compliance with such request may often render formal action under Article 88 of the Education Code unnecessary.
>
> "The attention of school attendance officers and of schoolmasters should also be drawn to the following considerations. Frequently they themselves will obtain the earliest information of the occurrence of infectious disease among scholars, and it is most desirable that such officer or master should, without delay, communicate the facts to the Medical Officer of Health.
>
> "As regards duration of exclusion from school of particular children, the time to be specified will vary in different diseases and different cases, and in this matter the Sanitary Authority will doubtless be guided by the advice of their Medical Officer, who may properly be entrusted with some general duty of acting for the Authority in this subject matter.

"In deciding whether an outbreak of infectious disease among children of school age may be best combated by closing a school, or whether it will suffice to exclude the children of infected households, the two most important points to be considered are :—

"The completeness and promptness of the information received by the officers of the Sanitary Authority respecting the occurrence of infectious cases.

"The opportunities which exist for intercourse between the children of different households elsewhere than at school.

"In places where there are several public elementary schools, if an outbreak of infectious disease be confined to the scholars of one particular school, it may be sufficient to close that school only. But where different schools have all appeared to aid in the spread of disease (though perhaps to an unequal extent) the Sanitary Authority may consider it advisable that all should be closed lest children in an infectious state who previously attended the schools that are closed should be sent to others that might remain open.

"It must be remembered that Sanitary Authorities have no power in respect of Sunday schools, or other private schools; except in so far as these may contravene section 91 (5), section 126, or other provision of the Public Health Act, 1875; but it will often be expedient to invite the co-operation of managers of such schools in efforts for securing the public health. Experience shows that they are usually ready to defer to the representations of the Authority responsible for the public health of the district.

"Reports to Sanitary Authorities, advising the closure of a school or schools in any district, are to be treated as 'special' reports within the meaning of the General Order of the Local Government Board of March 1880, and copies of them should accordingly be sent to the Board. These reports should state the grounds upon which the Medical Officer of Health advocates the closure of the school or schools in preference to the exclusion of particular scholars.

"All notices of the Sanitary Authority for the closing of public elementary schools should be addressed in writing to the Managers, and should state the grounds on which the closing is deemed necessary.

"All such notices should specify a definite time during which the school is to remain closed; this should be as short a period as can be regarded as sufficing on sanitary grounds; a second notice may be given before the expiration of the first, if it should be found necessary to postpone the re-opening of a school. The Managers of schools, after complying with the requirements of the Sanitary Authority, have the right of appeal to the Education Department, if they consider any notice to be unreasonable."

One of the most important and valuable aids to the foregoing provisions has been the *compulsory notification of infectious diseases* under the Notification Act of 1879. This is an adoptive Act, subject to the approval of the Local Government Board; but its general utility is so marked that up to March 31, 1894, it had been adopted in districts with an aggregate population of 26,401,826 out of a total population in England and Wales (1891) of 29,002,525.

The diseases scheduled in this Act are :—Small-pox, cholera, diphtheria, membranous croup, erysipelas, scarlet fever, typhus, enteric fever, relapsing fever, continued fever, and puerperal fever, but power is given to the Sanitary Authority, with the sanction of the Local Government Board, to include any other infectious disease, such as measles, rötheln, or whooping-cough. The above named and scheduled diseases are those practically to which also the Infectious Disease (Prevention) Act, 1890, applies. The adoption of the Notification Act, 1889, is quite optional. "Every medical practitioner attending on, or called in to visit, the patient shall forthwith, on becoming aware that the patient is suffering from an infectious disease to which this Act applies, send to the Medical Officer of Health for the district a certificate stating the name of the patient, the situation of the building, and the infectious disease from which, in the opinion of such medical practitioner, the patient is suffering." The penalty for default is a fine not exceeding 40s. Under the same penalty, the householder is compelled to notify, but in a less formal manner, and without receiving any fee. Forms of certificate are supplied to every practitioner practising in the district, and a fee of 2s. 6d. is paid to him for each certificate regarding a private patient and 1s.

for each case in public practice. Though the system of notification is "dual" under the Act, it is so only in theory; as practically the householder's share in the notification is allowed to lapse as an unnecessary formality, unless there is no doctor in attendance. The Act does not apply to Government buildings, such as barracks, nor to any "hospital" in which persons suffering from an infectious disease are received; it applies to "every ship, vessel, boat, tent, van, shed, or similar structure used for human habitation." The Act gives no power of compulsory removal of patients to hospital, nor even power of entry upon premises for the purpose of making inquiries.

Section 130 of the Public Health Act, 1875, enables the Local Government Board to make regulations for the treatment of persons affected with cholera or any other infectious disease, and for preventing the spread of such diseases as well on the seas, rivers, and waters of the United Kingdom, and on the high seas within 3 miles of the coast thereof, as on land, and may declare by what Sanitary Authorities such regulations shall be enforced and executed. Cholera regulations have been issued under this section, and are further discussed under the part of this chapter which deals with Port Sanitary Authorities.

In addition to these regulations, the Local Government Board have power, under section 134 of the Act of 1875, whenever any part of England appears to be threatened with, or is affected by, any formidable infectious disease, to make, and from time to time alter or revoke, regulations for any of the following purposes, namely, for the speedy interment of the dead, for house to house visitation, for the provision of medical aid and accommodation, for the promotion of cleansing, ventilation, and disinfection, and for guarding against the spread of disease; and may by Order declare all or any of the regulations so made to be in force within the whole or any part of the district of any Sanitary Authority, and to apply to any vessels whether on inland waters or on parts of the sea within the jurisdiction of the Lord High Admiral of the United Kingdom. The Local Authorities are required to do everything that is necessary to carry out these regulations. The only occasion on which the Board have found it necessary to issue regulations under these sections was in September 1893, to the urban Sanitary Authority of Grimsby and Cleethorpe and the Port Sanitary Authority of Grimsby, when those districts were threatened with a serious invasion of cholera. These orders were revoked on January 8, 1894, on the cessation of the epidemic.

In London the legislative enactments relating to infectious diseases are practically all contained in the Public Health (London) Act, 1891, sections 55 to 87, as both the Infectious Disease Notification and Prevention Acts are embodied in the London Act of 1891. There are, however, a few modifications necessitated by the fact that the whole of the metropolis has been formed into one asylum district, under managers known as the Metropolitan Asylums Board, who, by the Metropolitan Poor Acts of 1867, 1871, and the Diseases Prevention (Metropolis) Act, 1883, provide asylums for the insane and infirm as well as hospitals for infectious diseases. As regards notification, there is an important difference of procedure in London as compared with England and Wales, namely, that a copy of the certificate must be sent by the Medical Officer of Health both to the Asylums Board and to the head teacher of the school attended by the patient (if a child), or by any child who is an inmate of the same house as the patient. Besides this, the different Medical Officers of Health receive weekly a full and complete list from the Asylums Board of all notifications in the respective metropolitan districts.

The County Council have power to extend the provisions of the Act as to the notification of infectious disease to diseases not specifically mentioned. The other general provisions as to disinfection, removal of infected persons or dead bodies, and burial of the infective dead, are similar to those already explained under the heading of England and Wales.

Power is also given to the Local Government Board by section 13 of the London County Council (General Powers) Act, 1893, to assign to the Council any duties and powers under epidemic regulations made by them in pursuance of section 134, Public Health Act, 1875, as they deem desirable. In extension of the same, they may substitute the County Council for any Local Authority, on whose default the Council have power to proceed and act under the London Public Health Act of 1891.

In Scotland the Notification Act of 1889 is in force in respect of more than 93 per cent. of the whole population; but the Infectious Disease (Prevention) Act of 1890 does not apply. The Public Health Act, 1867, contains clauses very similar to sections 120 to 128 of the English Act of 1875, and Part III. of the Scottish Act contains provisions for dealing with extraordinary epidemics, the same coming into operation on the issue of an Order by the Secretary for Scotland, for a period prescribed in the Order not exceeding six months. By section 11, Local Government (Scotland) Act, 1895, the powers of section 4 of the Infectious Disease (Prevention) Act, 1890, which provides for the stopping of infected milk-supplies, are extended to Scotland (see page 898).

The Burgh Police (Scotland) Act, 1892, makes no special provision for the regulation of infectious diseases, but the larger burghs have private Acts which contain clauses dealing effectively with the matter. In respect of the erection and maintenance of hospitals for infective diseases by Local Authorities, ample powers are given, subject to the approval of the Local Government Board, by sections 39, 40, 42 of the Public Health Act, 1867, and by the Amendment Acts of 1871 and 1890. The Isolation Hospital Act, 1893, does not apply to Scotland.

In Ireland.—The Notification Act, 1889, is in force in only nine rural and seven urban sanitary districts; while the Isolation Hospital Act, 1893, does not extend to Ireland at all. The Infectious Disease (Prevention) Act, 1890, extends to Ireland, but at present has been adopted by five urban and four rural Sanitary Authorities only. The general provisions as to the control of infectious diseases, the compulsory removal of patients to hospital, the disinfection of infected clothing, the removal and burial of the infected dead, and the erection and maintenance of infectious hospitals, as contained in the Public Health (Ireland) Act, 1878, are, with the exception of some minor points, similar to those of the English Act of 1875.

PORT SANITARY AUTHORITIES.

In England and Wales.—Under section 287, Public Health Act, 1875, the Local Government Board may, by Order, constitute any Sanitary Authority, whose district abuts upon any port in England or Wales, the Sanitary Authority for the whole or any part of such port. The Board may also combine two or more riparian Authorities for the purpose; or may constitute one Port Sanitary Authority for any two or more ports. The Authority may be constituted permanently or temporarily. Of the sixty Port Sanitary Authorities in existence on December 31, 1893, no less than fifty-three were constituted permanently. An Order constituting a Port Sanitary Authority may assign to it any powers, rights, duties, capacities, liabilities, and obligations of an urban Sanitary Authority, so far as applicable to a Port Sanitary Authority, and to vessels, waters, or persons within its jurisdiction (sections 288 and 289).

The powers and duties of a Port Sanitary Authority consist primarily of those conferred by such of the specified portions of the Public Health Act as the particular Order may decide. The powers usually conferred are those under sections 91 to 111 (nuisances), 120 to 133 (infectious diseases and hospitals), 134 to 138 (prevention of epidemic diseases), 141 and 142 (mortuaries), 182 to 186 and 188 (bye-laws), 189 (appointments of Medical Officer of Health and Inspector of Nuisances), 175 to 177 (relating to purchase of land), and the provisions of the same Act relating to contracts, arbitrations, the conduct of business, audit, and legal proceedings, as well as section 2 of the Public Health (Ships, &c.) Act, 1885, which applies the provisions of the Act of 1875 as to infectious diseases and hospitals to ships, which come for these purposes within the definition of "house." These various powers and duties are further extended by the Cholera Regulations made by the Local Government Board under section 130 of the Public Health Act, 1875, and by the Order prescribing the duties of a Port Medical Officer of Health (see page 829). The regulations now in force under section 130 were made in 1890 and 1892, and have practically the following effect:—

Every Port Sanitary Authority, or other Sanitary Authority within whose district persons are likely to be landed from ships coming from foreign ports, must appoint a place for the mooring of ships infected with cholera, and make provision for the reception of cholera patients, and of persons suffering from illness which is suspected to be cholera. A ship infected with cholera must hoist a yellow flag when within 3 miles of the coast of England or Wales. When a customs officer finds on boarding a vessel that there has been a case of cholera on board, either during the voyage or during a stay in a port in the course of the voyage, he *must* detain the ship, order the master to anchor in a specified place, and then forthwith give notice to the Sanitary Authority (to the Port Sanitary Authority if there be one) of the place at which the ship is about to call. If from such warning from the customs officer, or from other information, the Medical Officer of Health has reason to believe that any ship coming or being within the jurisdiction of his Sanitary Authority is infected with cholera, he *must* forthwith visit and examine the ship; and he *may* do so if the ship comes from a place infected with cholera. If he finds that there has been a case on board, he must certify accordingly to the master, who is thereupon bound to moor in the place appointed (article 10). A copy of the certificate must be transmitted to the local Sanitary Authority, and information of the arrival of an infected ship given at once to the Local Government Board. The Medical Officer of Health *must* then examine every person on board, none being allowed to leave the ship until the examination is made (article 11). All who are found to be suffering from cholera are to be removed to the hospital or place provided by the Sanitary Authority, if their condition admit of it, and must not leave such place until the Medical Officer of Health certifies that they are free from the disease. If they cannot be removed, the ship remains subject to the control of the Medical Officer of Health, without whose written consent the infected persons cannot leave the ship (article 13).

Persons certified, by the Medical Officer of Health, to be suffering from an illness which he suspects may prove to be cholera, may be detained either on the ship or in some place provided by the Local Authority, for not more than two days, in order that it may be ascertained whether their illness is or is not cholera (article 14). No person, not certified as above, is to be permitted to land unless he satisfies the Medical Officer of Health as to his name, place of destination, and address at such place; and the Medical Officer of Health must give such names and addresses to the clerk of the Sanitary Authority, who must transmit them to the Sanitary Authority of the districts in question (article 12). The Medical Officer of Health *must* give directions and take such steps as may appear to him to be necessary for preventing the spread of infection, and the master of the ship must carry out such directions as are given to him (article 15). In the event of a death from cholera on board, the master must, at the direction of the Local Authority, either bury the body at sea, properly weighted, or deliver it to the Sanitary Authority for interment (article 16). He *must* destroy all articles soiled with cholera discharges, and disinfect, and if necessary destroy, the clothing, bedding, and other articles of personal use likely to retain infection, which have been used by persons infected with cholera; and disinfect the ship, and disinfect or destroy all articles therein probably infected with cholera, according to the directions of the Medical Officer of Health (articles 17 and 18).

The following additional regulations were made by the Order of September 6, 1892. Where a vessel is not infected with cholera, but has passengers on board who are in a filthy or otherwise unwholesome condition, the Medical Officer of Health *may* certify to the master that in his opinion it is desirable, with a view to checking the introduction or spread of cholera, that no persons should be allowed to land until they have satisfied him as to their names and places of destination, and addresses at such place. Thereupon the same measures are to be adopted as in the case of persons permitted to leave an infected ship.

It is noteworthy that the powers thus given by regulations made under section 130 of the Act of 1875 were extended by the Public Health Act, 1889, which declared that regulations made under the above section might provide for their being enforced and executed by the officers of the customs as well as by other Authorities and Officers.

In addition to the foregoing regulations, Orders are from time to time issued, and afterwards rescinded, by the Local Government Board, prohibiting the importation of rags, &c., from infected foreign ports, or requiring that they shall be disinfected or destroyed, to the satisfaction of the Medical Officer of Health. The regulations in this connection, now in force, are contained in Orders dated August 5 and September 13, 1893; they provide that "no dirty bedding, or disused, or filthy clothing, whether belonging to emigrants or otherwise, from France or from any foreign port in Europe north of Dunkirk, other than ports of Sweden, Norway, and Denmark, or from any port on the Black Sea or Sea of Azov, whether in Russia, Roumania, Bulgaria, or Turkey, or from any other port of Turkey in Asia should be delivered overside, or landed except for the purpose of disinfection or destruction." Disinfection must be carried out at the cost of the owner, and to the satisfaction of the Medical Officer of Health, by steam under pressure at a temperature not less than 212° F. In default of such disinfection within forty-eight hours, the articles are to be destroyed.

The terms "bedding" and "clothing" include all such articles when torn up, but do not include "rags compressed by hydraulic force transported as wholesale merchandise in bales surrounded by iron bands, and with marks and numbers showing their origin, and accepted as such by the Commissioners of Her Majesty's Customs."

The Corporation of London are the Port Sanitary Authority of the Port of London, by the Public Health Act, 1872, and since confirmed by section 111 of the Public Health Act (London), 1891. The duties, powers, and obligations of the Sanitary Authority of the Port of London are the same as those of all other Port Sanitary Authorities in England and Wales.

In Scotland there are no general provisions for constituting Port Sanitary Authorities. By the Greenock Corporation Act, 1893, section 39, however, that Local Authority exercises the exceptional powers of Sanitary Authority on behalf of Glasgow and other ports higher up the Clyde than Greenock, subject to an equitable allocation of expenses. As regards the possible importation of epidemic diseases, the Public Health Act, 1889, does not extend to Scotland, but by an Order in Council issued, under section 56 of the Public Health (Scotland) Act, 1867, on September 9, 1893, regulations are prescribed corresponding generally with the regulations issued by the English Local Government Board for England and Wales under section 130 of the English Act of 1875, and under the above-named Act of 1889.

In Ireland there are no Port Sanitary Authorities such as exist in England and Wales. The Irish Local Government Board have similar powers to make regulations in respect of sea-borne cholera or other infectious disease, by section 148 of the Public Health (Ireland) Act, 1878, as have the English Board under the English Acts; and the provisions of the Public Health Act, 1889, apply equally to Ireland as to England. The regulations now in force in Ireland under these enactments are contained in the Orders of the Local Government Board for Ireland, dated December 6, 1890 (as amended on July 26, 1892), and September 10, 1892. These regulations are practically the same as those of the English Board. With reference to the importation of rags from places in which cholera has been prevalent, the Irish Local Government Board issued Orders on August 15, 1893, and September 18, 1893, which, in all essential particulars, correspond to the analogous Orders of the English Board.

CHAPTER XIX.

MILITARY HYGIENE.

THE term military hygiene is used to signify the care of troops. The State employs a large number of men, whom it places under its own social and sanitary conditions. It removes from them much of the self-control with regard to hygienic rules which other men possess, and is therefore bound by every principle of honest and fair contract to see that these men are in no way injured by the system. But more than this: it is as much bound by its own self-interest. It has been proved over and over again that nothing is so remunerative as the outlay which augments health and, in doing so, augments the amount and value of the work done. As an army depends entirely on the physical character of the men who compose it, it is necessary briefly to refer to this part of the subject.

Selection of Recruits.—The British Army is enlisted on the voluntary system. The terms of enlistment are for *Long Service*, which consists of twelve years' service with the colours and no reserve service, or *Short Service*, which consists of periods of service with the colours and in the reserve, varying in the different arms of the service. The limits of age at which recruits are taken are from eighteen to twenty-five years, except for the royal engineers and medical staff corps, when the age is extended to thirty and twenty-eight years respectively. Boys, however, may be enlisted as drummers. Recruits must be of a certain height, which varies for the different arms of the service; for the household cavalry, it is from 5 ft. 11 in. to 6 ft. 1 in.; for the cavalry of the line from 5 ft. 6 in. to 5 ft. 11 in.; for drivers in the royal artillery and royal engineers, from 5 ft. 4 in. to 5 ft. 6 in., and for gunners and sappers in the same corps 5 ft. 6 in. and upwards; for the foot guards, 5 ft. 9 in. and upwards; for the infantry of the line, 5 ft. 4 in. and upwards; and for the departmental corps from 5 ft. 3 in. to 5 ft. 5 in. A certain minimum girth of chest is also required, and a certain minimum of weight; the chest measurement must not be less than 33 inches, nor the weight less than 115 ℔. For cavalry and artillery this weight is too small; experience has shown that the minimum weight for these branches of the service should not be less than 125 ℔, as this is the lowest weight that would give a cavalry soldier power at once to control his horse and wield his weapon, or a driver strength to manage a pair of horses.

In time of war the measurements are reduced according to the demand for men; and even in time of peace the same standard is not always maintained.

Before his enlistment is completed, the recruit is carefully examined by a medical officer of the regular or auxiliary forces according to a scheme laid down in the *Regulations for the Medical Services*. The examination is a strict one, and aims at investigating, as far as possible, the mental condition, the senses, the general formation of the body, the absence of any infirmity or injury likely to interfere with his duties as a soldier, the condition of the heart, lungs, and abdominal organs generally, the condition of the joints, the state of his feet, the absence of hernia, varicocele, &c., and his power of vision for long ranges.

The trades of the men furnishing the recruits vary greatly from year to year, labourers, servants, and husbandmen forming the larger proportion generally (in 1893, 67·3 per cent.), and manufacturing artisans contributing the next larger number (14·3 per cent.). Of the recruits examined in the United Kingdom during the year 1893, 405·54 per 1000 were rejected. Among the causes of rejection, the most frequent was defective development, that is, under the standard for height, chest measurement, and weight, the ratio being 181·78 per 1000; defective vision was the next most frequent cause, and accounted for 41·51 rejections; heart affections, diseases of the veins, loss of teeth, and defects of the lower extremities were among the other causes, and in the order given.

After the recruit has been enlisted and approved, he joins his depôt or his regiment; receives his kit, which he subsequently in part keeps up at his own cost; and is put on the soldier's rations. He enters at once on his drill, which occupies from 3½ to 4½ hours daily. Wherever gymnasia are established, he goes through a two months' course of gymnastic training for one hour every day. He then goes to rifle drill, which lasts about six weeks, and then joins the ranks. After the rifle drill, he has another month's gymnastic training, and is then supposed to be a finished soldier.

As regards *age*, many competent officers consider that no recruits should be enlisted under twenty to twenty-one years. This opinion is based on the fact that the most effective armies are those in which the youngest soldiers have been over twenty-two years of age. At eighteen the bones are not fully formed, nor do the muscles reach their mature growth much before twenty-five years; while thus undeveloped and immature, as they must be at eighteen years, it is useless to expect any long-continued exertion or energy from men at that age. If enlisted, the State should recognise this, and suit the work to their strength; at eighteen, recruits have not only to work, but to grow and develop, and they should have precisely the amount of exercise and kind of work best fitted for them.

As regards *vision*, the experience of the London recruiting officers is that imperfect or defective vision increases with ascent in the social scale; it is, on the whole, less perfect among the better than the lower class of recruits, and in town than in country.

Sir W. Aitken pointed out the importance of the correlation of height, weight, and chest measurement in estimating physique as a whole; good weight for height being of the first importance. An easy rule is that up to 5 ft. 7 in. thrice the height in inches ought to be about the weight in pounds; and add 7 ℔ for every inch above 5 ft. 7 in.

It has also been observed that a close correlation exists between the physical and moral development of men; in fact, lowering the physical means lowering the moral standard of recruits: if we dip too low for our recruits, we shall be liable to get men, not only small, but unsteady, wanting in mental ballast as well as in physical strength. The nerves and muscles are built up by the same processes of nutrition, and the weighing machine is the best of all means we have for testing the general fitness of the recruit.

The measurement of the "chest capacity" is of great importance in determining the vigour of the recruit. From a large number of observations made at St George's Barracks it has been found that the maximum expansion of the chest of a man of average size, between eighteen and twenty-five years of age, is about 2 to 2½, rarely 3 inches. The method adopted for ascertaining these measurements is as follows:—On carefully adjusting the linen tape over the point of the shoulder-blades behind and above the nipples in front, the recruit is directed to take a deep breath and expand himself to the utmost; this being done two or three times, the maximum expansion is ascertained; the minimum is found by deducting 2 to 2½ inches according to the height and general physique of the man. The minimum and maximum are then recorded above each other, as $\frac{33}{35}$ or $\frac{34}{36\frac{1}{2}}$ as the case may be.

Seggel gives the measurements he had taken of soldiers enlisted at Munich during a period of five years. His results correspond almost entirely with the measurements given by Frölich and Vogl. They are shown in the following table:—

	Seggel.	Vogl.
Average height,	1·6686 m.	1·67 m.
,, weight,	64·3 kilos. (141·5 ℔)	63·2 kilos. (139·1 ℔)
,, chest measurement,	0·848 m.	0·848 m.
,, chest expansion,	7·3 cm.	7 cm. (Frölich)
,, width of shoulders,	41·1 cm.	...
Antero-posterior lines of chest (sagittal measurements),	*a*. 23·7 cm.	...
	b. 21·4 cm.	...
	c. 18·7 cm.	18·7 cm.

Seggel arrives at the conclusion that the width of the shoulder is an important measurement to make in examining soldiers. He takes the measurements with the arms hanging at the sides or held straight out in front of the body; the width of the shoulder should not be less in a properly built man than two-ninths of the man's height, the best minimum to take being one-quarter of the height. The antero-posterior diameter of the chest is measured at three points—the superior border and middle of sternum and tip of ensiform cartilage. Seggel found that the greater this sagittal measurement, the greater was the chest expansion.

In the French Army the minimum height is now fixed (1896) at 67 inches (1·70 metre) for cuirassiers and 61 inches (1·54 metre) for infantry of the line.

In the United States Army the minimum height is 5 ft. 4 in.; maximum height for cavalry, 5 ft. 10 in., the minimum weight being 128 ℔, the maximum 190 ℔.

The Conditions under which the Soldier is placed.—While the principles of water and air supplies for soldiers do not materially differ from those already explained for communities in general, there are certain features of military life which require special consideration, these are *barracks*, *huts*, *tents*, *encampments*, *food*, *clothing*, and *work*. These conditions are extremely various, as the soldier serves in so many stations, but the chief points common to all can be passed in review.

Barracks have been in our army, and in many armies of Europe still are, a fertile source of illness and loss of service. At all times the greatest care is necessary to counteract the injurious effects of compressing a number of persons into a restricted space. In the case of soldiers the compression has been extreme; but the counteracting care has been wanting. It is not much more than sixty years since, in the West Indies, the men slept in hammocks touching each other, only 23 inches of lateral space being allowed for each man. At the same time, in England, the men slept in beds with two tiers, like the berths in a ship; and not infrequently each bed held four men. When it is added, that neither in the West Indies nor in the home service was such a thing as an opening for ventilation ever thought of, the state of the air can be imagined.

The means of removal of excreta were, even in our own days, of the rudest description, both at home and in many colonies; and from this cause alone there is no doubt that the great military nations have suffered a loss of men which, if expressed in money, would have been sufficient to rebuild and purify every barrack they possess. To these two causes must be attributed the great loss suffered by our troops in former years from phthisis and enteric fever.

The selection of the site is of the first importance. Sites should be so selected as to secure a fall from the building in one direction at least, and if possible in more, for this will facilitate drainage, and natural drainage outlets should always be provided for. A perfectly free circulation of air should prevail around the buildings. Aspect should never be sacrificed to prospect. In England the south-east is the best aspect, for it is least exposed to rain and boisterous winds. The soil should be porous; clay soils and all retentive soils should, if possible, be avoided. The level of the ground water should be noted, and when this is near the surface the site should be drained as far as possible, in order to lower its level and to prevent changes, either in a rise or fall, taking place. Provision must also be made for the rapid and effectual removal of all water from the buildings, so that there may be no dampness. In order to test the healthiness of a site an inquiry into the rate of sickness and mortality in the district will afford valuable information, and the nature of the prevalent diseases should, if possible, be ascertained.

In the tropics and in sub-tropical countries all these conditions are of even greater importance. The following sites, which are proved by experience to be unhealthy, should be avoided:—

1. Clay soils, especially in India.
2. Ground at the foot of hills or in deep valleys or ravines which receive the drainage from higher levels.
3. Ravines are always dangerous, as are also elevated sites near them. Malaria is carried up through them by air currents, and generally they are receptacles for decaying and rank vegetation.
4. Any ground covered with rank vegetation, as where this exists the subsoil water is close to the surface, and there is usually much decaying matter.
5. Low-lying banks of rivers or any grounds subject to periodical floodings, and especially any marsh lands, partly covered with salt and fresh water. Military reasons must determine the position to be occupied by a military force, but whenever barracks can be placed in the open country, such positions should, if possible, be selected in preference to sites in town districts, for although it is not always possible to assign the precise influence which the position of barracks exercises on the health of troops, there is no reason to doubt that barracks located in close unhealthy neighbourhoods are influenced by the same conditions which govern health in such neighbourhoods. More especially is this the case with regard to hospitals, on account of the great susceptibility of sick men to the effects of impure air. If barracks must be erected in towns, the buildings should be distributed over an area sufficiently large to secure free access of air and sunlight.

The plan on which barracks were formerly built in Great Britain, Ireland, and the Colonies exhibits every possible variety both as regards their design and internal arrangement. In many cases, the chief object in view appears to have been to place as many men as possible on the ground at the disposal of the engineer who designed them. Since the Royal Commission on the Sanitary Condition of Barracks and Hospitals issued their report and pointed out the errors made in this respect, a great improvement has taken place, and now barracks are built on a standard plan with such modifications as are necessarily required according to locality and climate.

The Barrack Improvement Commissioners very justly recommended that there should be division of the men among numerous detached buildings; and, instead of the square, that the separate buildings should be arranged in lines, each building being so placed as to impede as little as possible the movement of air on the other buildings and the incidence of the sun's rays.

In arranging the lines, the axis of the buildings should be if possible north and south, so as to allow the sun's rays to fall on both sides. One building should in no case obstruct air and light from another, and each building must be at a sufficient distance from the adjoining one, and this distance should not be less than its own height, and if possible more.

If the arrangement is in the form of a square, the angles of the square should be left open to allow of the circulation of air. Free access of sunlight should be provided for.

Barracks are best constructed of only two storeys. The ground floor may be, with advantage, used for libraries, day rooms, and administrative purposes, but this is not practicable as a rule: basements should never be utilised as barrack rooms: they are always liable to damp, and the air in them is generally stagnant.

Each range of barracks should consist of separate houses completely independent of one another. Where houses abut, the party walls ought to be carried above the roof. Each house should be divided up the middle by a large staircase, extending to the top and ventilated through the roof. This will prevent the air of opposite barrack rooms intermingling.

Barrack rooms are now constructed to accommodate twenty-four men or one section—with a non-commissioned officer's room at one end. The following is a summary of the recommendations made by the Barrack Improvement Commissioners:—

The rooms are directed to be narrow, with only two rows of beds, and with opposite windows—one window to every two beds. As each man is allowed 600 cubic feet of space, and as it is strongly recommended that no room shall be lower than 12 feet, the size of a room for twenty-four men will be—length 60 feet, breadth 20 feet, height 12 feet. This size of room will give 14,400 cubic feet (600 × 24), or enough for twenty-four men; but as the men's bodies and furniture take up space, an additional 2 feet has been allowed to the length in some of the new barracks. Assuming the length to be 62 feet, the superficial area for each man will be nearly 52 feet, a little more than 5 feet in the length and 10 in the width of the room. At one end of the room is the door, and a room for the sergeant of the section, which is about 14 feet long, 10 wide, and 12 high. At the other end is a narrow passage leading to a urinal and an ablution room, in which one basin is provided for every four men.

Such is the arrangement recommended for a single barrack room, and it is difficult to conceive a better plan, unless it might be suggested that an open verandah, never to be made into a corridor, should be placed on the south or west side. It would be a lounging-place for the men, and might also serve as a cleaning place for arms and accoutrements.

The room thus formed may constitute a single hut, but if space is a consideration, two such rooms are directed to be placed in a line, the lavatories being at the free ends. A house of this kind will accommodate half a company. The several houses are separated by an interval of not less than 25 feet. For the sake of economy, however, the houses will in future be frequently made two-storeyed, so that one house will contain a company in four rooms, and ten will suffice for a regiment.

In the French Army the amount allotted is 14 cubic metres (495 cubic feet) for cavalry, and 12 cubic metres (424 cubic feet) for infantry, per head, the air to be changed at least *once* an hour. In the German Army the allowance is 495 cubic feet (German measurement, which is nearly the same as English), the superficial space being 42 to 45 square feet.

In some of the latest barracks which have been built, the lavatory and urinals are placed in the centre of the building, near the head of the staircase: this is a retrograde step (fig. 125).

The three following plans of barracks show the arrangements which are adopted:—

1*st*, When there is a single storey, as at Colchester, and no staircase is required (fig. 126).

2*nd*, When there are two storeys, and a staircase must be introduced, as in the cavalry barracks at York (fig. 127).

3*rd*, When there are not only staircases, but the barracks must be extended in one long line, including many rooms, and when, therefore, the ablution rooms cannot be put at the ends of the rooms, but must be placed on the landings, as at Chelsea and Seaforth (figs. 128 and 129).

If ten houses are thus formed, and arranged so as to insure for each the greatest amount of light and air, the following area will be occupied by these houses alone. Each house (with walls) would measure about 140 feet long and 22 broad, and the space between the houses may be taken at 64 feet, or twice the height of the house. The external houses would, of course, have clear spaces on both sides like the others. The area of occupied and unoccupied space would be very nearly 12 square yards to a man.

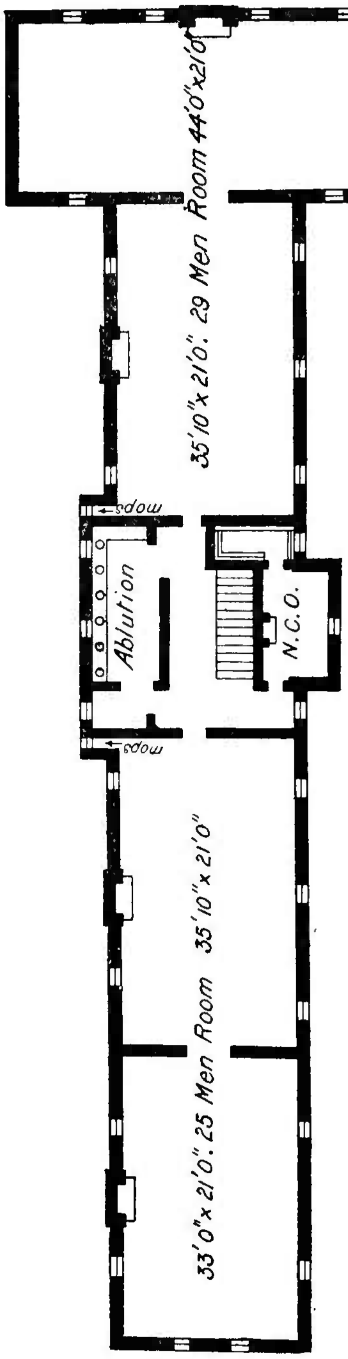


Fig. 125.

This density of population, although highly objectionable for a general urban community, is permissible in well-planned and ventilated barracks, situated in the open country.

Usually two such barrack rooms are placed in a line, the lavatories being placed at the free ends. A house will therefore contain a company in four rooms, if it is double storeyed, and ten such houses will suffice for a regiment. Each room is provided with two ventilating shafts, also inlets for fresh air between the windows and a ventilating fire-grate (Galton's).

As a rule, the number of windows is half as many as the number of beds; they are on opposite sides of the room, and carried up to within a few inches of the ceiling.

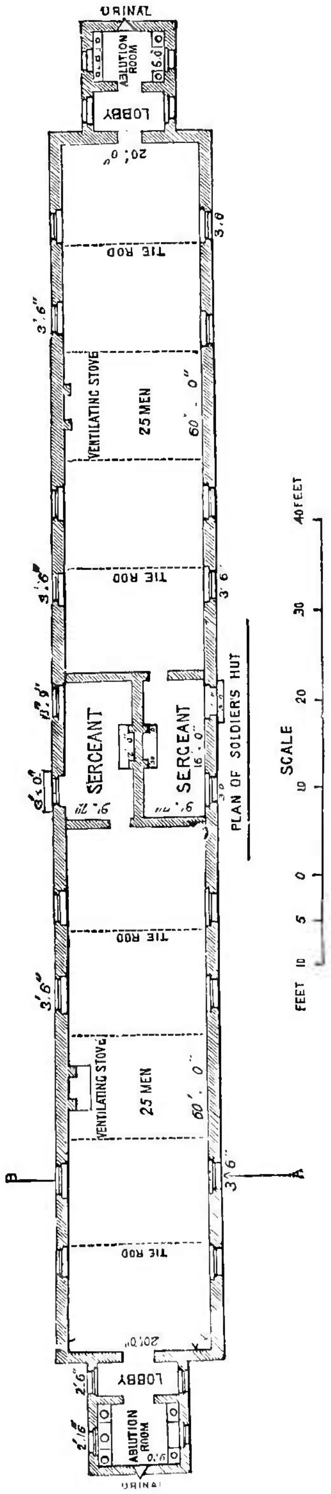


Fig. 126.

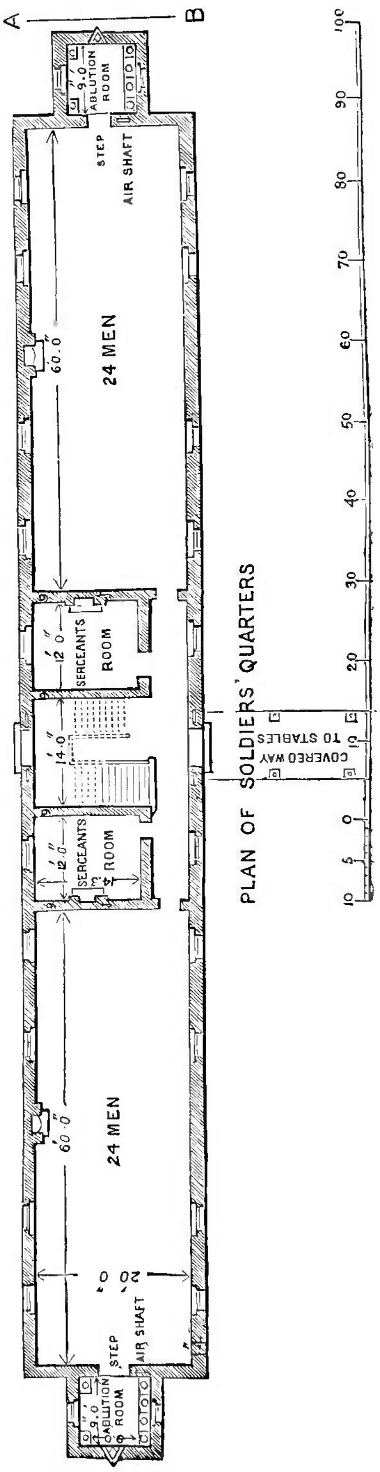


Fig. 127.

Non-commissioned Officers' Rooms.—Warrant officers and schoolmasters are entitled to two rooms and a kitchen. When possible their quarters will be separated from those of the non-commissioned officers and men. Married senior non-commissioned officers are entitled to two rooms; other sergeants have one room each. The rooms are about 14 feet long, 12 feet in breadth, and 10 feet high, giving, when empty, 1680 cubic feet.

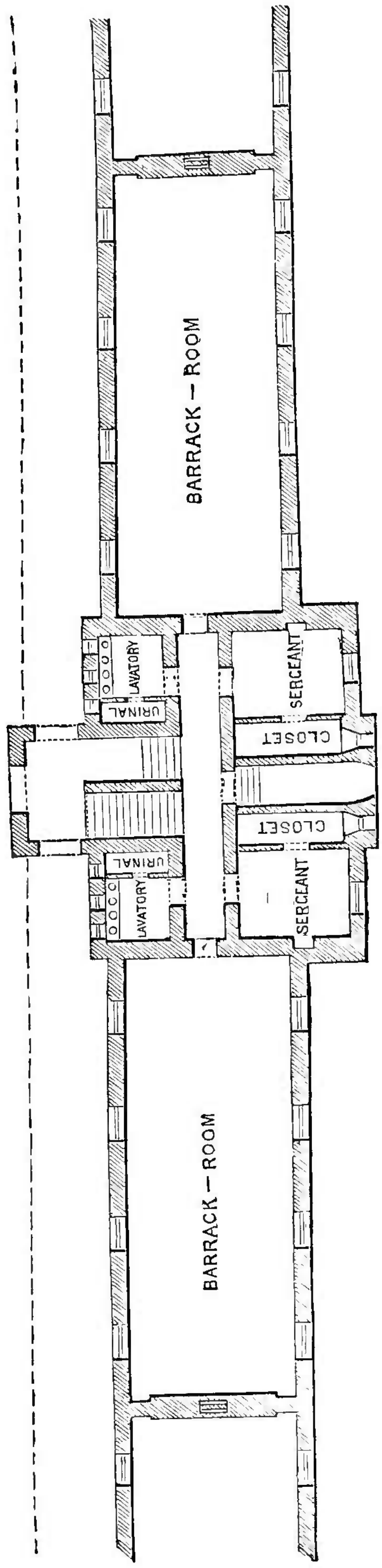


Fig. 128.

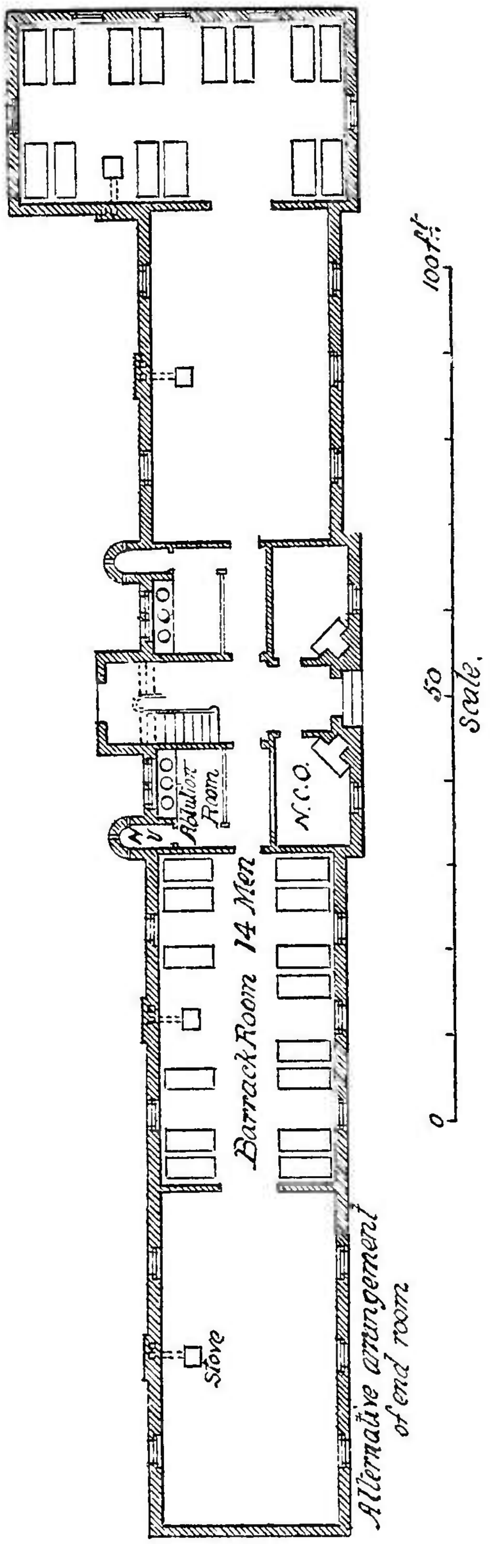


Fig. 129.

Married Soldiers' Quarters.—Each married soldier is entitled to one room 14 feet by 12 feet, giving 168 superficial and 1680 cubic feet of space. No man under the rank of sergeant is allowed to marry unless he has completed seven years service. With the present short service system the number of married soldiers is comparatively few, and generally there is no difficulty in providing them with two rooms each. There are also separate latrines provided for females, and a wash-house adjacent to their quarters.

Warming of Barrack Rooms.—The rooms are warmed by Galton grates in two ways—radiant heat from an open fire, and warm air, which is obtained from an air-chamber behind, heated by the fire. The external air is led by a pipe to this chamber, and then ascending enters the room by a louvre. The grates are of various sizes, according to the size of the room. Smallest —1 foot 3 inches of fire opening for rooms of 3600 cubic feet. Middle—1 foot 5 inches for rooms of 3600 and 7800 cubic feet. Largest—1 foot 9 inches up to 12,000 cubic feet. Large rooms have two grates. One grate is usually provided for twelve men.

The radiating power of the small barrack grate is aided by a well-arranged angle, and by a fire-clay back; as the fire is small, however, the radiating power is not great.

In the wards of Fort Pitt, with the largest size of grates, the mean rapidity of movement of warm air through the upper slits of the louvre, with a good fire, was found to be about 2½ feet per second, and the total cubic amount of warm air entering per hour through the whole louvre was (approximately) 4600 cubic feet per hour, with a mean temperature of 19° F. in excess of the external air temperature. No unusual dryness of the air is produced by the admission of this quantity of warm air, the relative humidity of the air being about 70.

The movement of air through the hot-air louvres is not regular; open doors and windows, which increase the pressure of the air of the room on the louvre, will sometimes delay the movement, and, if the air-chamber is not very hot, will even reverse it and drive the air down, as the rapidity of movement in these hot-air chambers is never very great; but in cold weather, when the doors and windows are shut, the action is tolerably regular.

Ventilation of Barrack Rooms.—In each barrack room ventilating shafts are provided to act as *outlets*, the sectional area of the shafts being dependent on the cubic contents of the room and by the number of inmates, but it is not made larger than 1 square foot; if more outlet is required, another shaft is put up. In a three-storeyed barrack, the rule is as follows:—

In rooms on the top floor a sectional area of 1 inch is allowed for every 50 cubic feet of room space, or for each man 10 square inches of area; for floors next below the upper floor a sectional area of 1 inch to 55 cubic feet of room space, or for each man 10·9 square inches; and when the barrack consists of three floors, the lower floors have a sectional area of 1 inch to 60 cubic feet of room space, or for each man 12 square inches.

The movement of air in these shafts is tolerably regular. Each shaft removes about 600 cubic feet per man per hour, the usual current at night being from 3 to 5 feet per second.

These foul-air shafts are carried from one angle of the ceiling to 4 or 5 feet above the roof, and are protected by cowls to prevent the air beating down. The shafts are usually made circular in form, of galvanised iron, perfectly smooth inside and free from angles or bends.

In addition to these shafts there is the chimney, which gives a section area per head of about 6 square inches. This removes about the same quantity of foul air as the ventilating shafts, so that each man is provided with from 16 to 18 square inches of outlet area, capable of removing 1200 cubic feet of air per man per hour.

Inlets for Fresh Air.—All inlets admitting air direct are placed near the ceiling. The form adopted is a perforated air brick of different sectional areas, according to the number of men the room is intended to contain. The sectional area adopted allows 1 square inch for every 60 cubic feet of contents of the room, but if warm air is admitted round the fire-grate and distributed, as will be presently described, 1 square inch to every 120 cubic feet of contents is sufficient.

The air is delivered into the room through valves either louvred or hopper-shaped. In the latter form the air is deflected towards the ceiling. The upper side of this valve may be formed of perforated zinc, the area of which is from six to eight times the area of the inlet from the outer air. Area of outer opening = 5 square inches per man.

The outlet and inlet shafts should be placed as far from each other as possible, to enable thorough diffusion of the inflowing air to take place. The best position for the foul-air shafts, however, is at one side or the other of the fire-place and not opposite to it.

Warm air is also provided for by the following plan. Air is admitted through a shaft from the external air to the air-chamber at the back of the fireplace. This shaft or tube should contain 1 superficial inch of sectional area for every 100 cubic feet of room space. Care should be taken to draw the air from a pure source. From the air-chamber the air is conducted into the room by a shaft and through a louvred opening placed as near the ceiling as possible; the louvres being bevelled upwards so as to cause the air current to impinge against the ceiling. Area of tube, 6 square inches per head; total inlet area = 11 square inches per man. By this system each room is ventilated by itself, and independently of any other room, and 1200 cubic feet of fresh air per man per hour in a room space of 600 cubic feet per man is provided.

The hospital system is precisely the same, only the dimensions are doubled. In the tropics and sub-tropical stations the sizes of the inlets and outlets are trebled: for example, there is 1 square inch of outlet for every 20 cubic feet of space, instead of 60 as at home.

Ablution Rooms.—These are now provided in every barrack, with clean water laid on and basins in the proportion of one to every four men. The basins are either of slate or enamelled iron. In many instances baths are also provided. The Barrack Commissioners recommended that one bath be provided for every 100 men.

Kitchens.—These should not be under the same roof as the barrack rooms, but at no greater distance than 100 yards, so as to allow the dinners to be brought hot to the men. Cooking is now frequently done by steam, but ovens are used when the rations are baked. The amount of coal used is generally about 10 ℔ per week for every seven men.

Guard-Room.—This room is about 24 feet long, 18 feet wide, and 14 feet high. Two rooms open out of it, capable of being overlooked from the guard-room—one for prisoners, the other for men who are awaiting trial. It affords 600 cubic feet per man, and is ventilated on the same principle as barrack rooms.

Cells.—The cells are ranged on one or both sides of a corridor. They are 10 feet long, 8 wide, and 10 high (= 800 cubic feet), with one window, 2 feet 9 inches wide by 1 foot 3 inches high, placed at the top of the wall, and guarded by iron bars. Fresh air is admitted through a grating opening from the corridor, which is warmed. The air enters below, or in some cases above; but the former arrangement is the best. A foul-air shaft runs from the top of the room. Two cells are provided for every 100 men.

Latrines and Urinals.—In all barracks urinals are now introduced; they are placed at the end of the passage beyond the ablution room. It is found by the men that this is inconvenient; the passage is often wet and cold. In some of the later barracks they are placed in the centre of the building.

Cesspits are now discontinued in all barracks, and water latrines are used. The latrines are placed at some little distance from the rooms, and are usually connected with them by a covered way; in almost all barracks they are Jennings' or Macfarlane's patents. These are metal or earthenware troughs, which are one-third full of water. Twice a day a trap-door is lifted, the latrine is flushed, and the soil flows into a sewer or tank at a distance. A hydrant is frequently placed close to the latrine; an india-rubber pipe can be connected with it, and the seats and floor of the latrine be thoroughly washed in this way twice daily. In many of the newer barracks, automatic flush tanks are in use.

Water-Supply.—By decision of the Secretary of State for War, every adult receives 20 gallons daily. For each child 10 gallons per diem is allowed.

Cavalry Barracks.—In many of the older barracks the men's rooms were placed over the stables. The supposed advantages gained by this arrangement were (1) increased cubic space; (2) less exposure to the men in passing to their stables, and greater convenience.

The Barrack Improvement Commissioners have, however, shown that it is impossible to ventilate satisfactorily a stable accommodating a large number of horses if anything beside the roof is interposed between the stable and the outer air, and that it is equally impossible to keep the air in men's rooms over stables pure and free from stable odour.

The new model troop stable is arranged for forty-eight horses. The length of the stable is 143 ft. 8 in.; breadth, 33 ft.; height of side walls to spring of roof, 12 ft.; total height, 20 ft. 6 in. Each horse is arranged to have 1605 cubic feet of air and 100 superficial feet of space. The stalls are 5 ft. 6 in. wide, 9 ft. 6 in. in length, and the width of the passage between the stalls is 14 ft. Over the head of each horse is placed a window 3 ft. 4 in. high by 2 ft. 6¾ in. wide; an air brick is placed between every stall 6 in. from the ground, and a course of air bricks is carried around the eaves of the building. The roof is open at the ridge by means of a louvre, which allows 4 sq. ft. of ventilating outlet per horse, and a continuous skylight is carried along on one side of it.

Inspection of Barracks.—The Regulations order the form in which reports on barracks shall be sent in. The report should include site, construction, external ventilation, internal ventilation, basements, and administration. It is then certain that no point will be overlooked; and, if nothing can be made out after going thoroughly through all the headings, it may be concluded that the cause of any prevailing sickness must be sought elsewhere. The site and basement should be especially looked at; every cellar should be entered, and the drainage thoroughly investigated. Little can be learned by merely walking through a barrack room, which is nearly sure to look clean, and may present nothing obviously wrong. With respect to ventilation, the statements of soldiers can seldom be trusted; they are accustomed to vitiated air, and do not perceive its odour. The proper time to examine the air of a room is about 12 to 3 A.M., and the medical officer might, with advantage, visit barrack rooms between midnight and 3 A.M. every now and then. The cisterns should be regularly inspected.

The walls and floors of the rooms should be carefully looked to. Walls are porous, and often become impregnated with organic matter. If there is any suspicion of this, they should be scraped and then well washed with quicklime. Care should be taken to see that the lime is really caustic; chalk and water does little good. Collections of dirt form under the floors sometimes, and a board might be taken up to see if this is the case.

Barracks in Forts and Citadels.—In fortified places it is, of course, often impossible to follow the examples of good barracks just given. Citadels may have little ground space; buildings must be compressed, guarded from shot, made with thick and bomb-proof walls, with few openings. Buildings are sometimes underground. Drainage is often difficult, or impossible; and if to all these causes of contamination of air we add a deficiency of water, which is common enough, it will not surprise us that the sickness and mortality in forts, in even healthy localities, are greater than should be the case. Both at Malta and Gibraltar there was for years too large a mortality from fever, and from the destructive lung diseases, which appeared in the returns as phthisis. The special difficulties of casemates are as follows: dampness, which is very common in all casemates, so that the moisture often stands in drops on the walls; a low temperature; a want of ventilation; and a want of light.

How these difficulties are to be met is one of the most difficult problems the military engineer has before him. Special means of ventilation must be provided when the defences close the usual openings; tubes must be carried up, and, if necessarily winding, an enlarged area might, perhaps, compensate for this.

It must be said, also, that it is quite certain that in our fortified places many of the arrangements are much worse than they need be, and that the sanitary rules deducible from home experience should be applied in every case when the defensive properties are not interfered with.

Barracks in Hot Climates.—The Indian Sanitary Commission have prepared standard plans suitable for different localities in India, and, while the detailed design is left to local officers, certain general principles are strictly laid down.

It will be desirable to refer here chiefly to the Indian barracks, but the same principles apply to all hot countries.

The *Indian Army Regulations* sanction the following scale of superficial and cubic space for European and native troops in India. *In the plains:* superficial space, 90 feet; cubic space, 1800 feet; height of room, 20 feet; width, 24 feet. The barracks to be two-storeyed, with a verandah 10 feet wide; not more than twenty-four men to be placed in one room. *In the hills:* 60 square feet, and 600 cubic feet per man; height of room, 10 feet; width, 22 feet.

The number of men to be placed under one roof is fixed at 40 or 50 (half-company barracks), except under exceptional circumstances; the number of men in one room is to be 16 to 20, and not to exceed 24; the barracks are to be two-storeyed in the plains, and one or two-storeyed in the hills, both floors being used for dormitories; single verandahs of 10 or 12 feet wide surround these rooms. There are to be only two rows of beds in the dormitories; the beds are to be 9 inches from the wall, and only two beds are to be in the wall space between two contiguous doors (or windows); in the plains each bed is to have 7½ feet of running wall space, in the hills 7 feet. The general arrangements of the building are based on the suggestions of the Royal Indian Sanitary Commission. At each end of the dormitory are closets and night urinals; the best plan is that which places these at the extreme end of the verandah, leaving a space between them and the dormitory.

The lower storey in the plains was intended to be used as a day-room, but this has not been found practicable, and both floors are now used as dormitories.

The married people's quarters are to be grouped in small one-storeyed blocks, each block holding the married people of a company or troop. Two rooms (16 feet × 14 feet and 14 × 10 feet) are provided for each family; verandahs, 12 and 10 feet wide, are provided.

In all these arrangements it will be perceived that the essential principles of the home barracks are preserved; long, thin, narrow lines of buildings, with thorough cross ventilation, with the sleeping rooms raised well off the ground, would certainly appear to be as good an arrangement as could be devised. A few more remarks on some of the points have to be made.

1. *Size of Houses.*—If there be no strong military reasons to the contrary, it seems certain that it is even more important in India than in England to spread the men over the widest available area, and not to place more than fifty men in a single block, and twenty-five men in a single room; and therefore the proposed plan is most desirable. There has been an objection raised, that small detached houses in the hot plains of India, not having any large space in shadow, get everywhere heated by the sun's rays, and become very hot. The objection is theoretical; it is the immense blocks of masonry used in the construction of large buildings which are to be avoided as much as possible, since, once heated, they take hours to cool.

2. *Arrangement of Houses.*—Broadside on to the prevalent wind, and disposition *en échelon*, as now adopted in India, is obviously the proper plan. The only exception will be when there are marsh or gully winds to be avoided, and then the houses should be placed end-on to the deleterious wind; and no windows should open on that side. But such a site would seldom be selected or retained.

If a barrack is built on a slope, and the ground is terraced, the Army Sanitary Committee have recommended that the barrack should be placed end-on to the side of the hill, and not nearer the slope than 20 to 30 feet: terracing should be avoided as much as possible.

3. *Breadth of Houses.*—As in England, it is important to have only two rows of beds in each room, and to keep the houses under 30 feet in width, so as to permit effective perflation. A single verandah is as good as a double one in keeping off the direct rays of the sun from the walls of a house, and two verandahs (one inner and one outer) add to the breadth to be ventilated. The width of the verandahs must be 10 to 12 feet; and on the southern and western sides wooden jalousies may have to be placed so as to occupy 3 or 4 feet at the upper part of the verandah.

Verandahs should be ventilated by openings at the highest part, so as to have a free movement of air through them; this is very important. If there are two storeys, the roof of the upper verandah should be double.

Materials of Building.—On this point there is little choice, for the risk of fire renders the use of wood undesirable for walls and roofs. And yet apart from this risk, loosely joined wood, or frames of bamboo, have the great advantage of allowing air to pass through the walls. Brick or stone has therefore to be used. In India, sun-dried brick (*kachā*), covered with cement, or faced with burnt brick, is often used. It is said to be a cooler material than burnt brick (*pakkā*), but it absorbs a great deal of moisture.

Iron barracks were sent out from England during the mutiny, but were hot, and were not found suitable: iron frames have been usefully employed, the intervals being filled up with unburnt bricks. There is, however, a very general feeling against the use of unburnt bricks, on account of the moisture they absorb and retain. The concrete walls now coming so much into use in England are particularly adapted for India, and have been used there for private residences; they are cheap and dry, and well spoken of.

Construction of the Building.—The three points to be aimed at are—avoidance of malaria and dampness of the ground, should there be any risk of this; insuring of coolness; provision of ventilation.

(*a*) *Employment of Open Arches for the Basement.*—The extraordinary diminution in the risk of malaria by elevating the building only a few feet above the ground, and allowing a current of air to freely circulate under the house, is illustrated by universal experience. But another great benefit is obtained; dryness and freedom from pent-up, stagnant, and often offensive masses of air are insured, so that, even when the soil is not distinctly malarious, buildings should be raised. In malarious countries the height of the lowest floor above the ground should be 8 or 10 feet; in non-malarious districts 3 or 4 feet are sufficient, but it should always be high enough to allow cleaning.

(*b*) *Walls.*—Very thick brick walls do not conduce to coolness, but if thoroughly heated during the day, are liable to give out heat all night. The direct rays of the sun should not be allowed to fall on any part of the main wall. This will be found one of the most important rules for insuring coolness. Double main walls, with an air space between and free openings above and below, so as to permit of a constant movement of air, is the coolest plan known. Considering the excellent ventilation which goes on in bamboo and wooden houses, it may be a question whether, in the warm parts of India, the walls might not be made, as far as possible, permeable; at any rate, above the heads of the men. Whitening the outside walls reflects the heat, but is dazzling to the eyes; almost as good reflection, and much less dazzling, is obtained by using a slight amount of yellow or light blue colour in the cement or lime-wash.

(*c*) *Floors.*—The materials at present used are flagstones (in Bengal), slates (in some barracks in the Punjab), greenstone (in some Madras barracks), tiles, bricks placed on end and covered with concrete, pounded brick and lime beaten into a solid concrete and plastered with lime, broken nodulated lime-stone or *kankar* (in places where the masses of kankar are found, as in Bengal), asphalt, pitch and sand, wood. Of these various materials, the asphalt gets soft and is objectionable; the cements and kankar wear into holes, produce dust, and have been supposed to cause ophthalmia (Chevers); wood is liable to attacks of white ants, &c.

On the whole it would seem that good wood (if there be a space below the barracks thoroughly ventilated) with brick supports is the best, and after this tiles.

(*d*) *Roofs.*—Double roofs of well-burnt tiles are now usually employed, and are made slanting, and not terraced. The terraced roofs, if made single (*i.e.*, with battens on the joists covered with kankar), conduct heat too freely, and crack during the hot weather; but if made double, with a good current of air, there is an advantage in giving a promenade to the men, and also, at some seasons of the year, the roof may be most advantageously used as a sleeping place: they are apt to leak, however, and are always a source of trouble on this account.

The sloping roofs are better adapted for ventilation. The coolest roof is made of tiles, covered with thatch; thatch is dangerous on account of fire, and harbours vermin and insects. If there is a good space between the two roofs, and if there are sufficient openings to permit a good current of air, two tile roofs are as cool as any.

(*e*) *Doors and Windows.*—These are now always made very numerous, and opposite each other, so as to permit perfect perflation. The official *Suggestions* order one window for every two beds. Five doors are recommended for each room of twenty-five men; and Norman Chevers gives a good rule: a light placed in the centre at night should be seen on all sides. Upper as well as lower windows—a clerestory, in fact—are useful; the lower windows should then open to the ground. In most of the stations in Northern India the windows must be glazed.

The Committee appointed to carry out the suggestions of the Indian Sanitary Commission have recommended that each window should consist of two parts—the upper portion, about 2 feet in depth, being hinged on its lower edge to fall inwards, so as to direct the currents of air towards the ceiling of the room.

Ablution Rooms.—In India every private house, and almost every room in a house belonging to a European, has its bath-room. Not only the luxury, but the benefit of this arrangement is so great, that bath-rooms should be considered essential to every barrack. For the usual purposes of ablution, the plan now used on home service is the best; but it is in almost every barrack supplemented by a plunge-bath. The supply of water is in most cases almost unlimited. In order that this may be efficiently given, the old plan of carrying water by hand must be given up; water in large quantity must be laid on in pipes, and cisterns should feed the ablution rooms and supply water for the urinals. So essential must baths be considered for health, that a large supply of water should be considered a necessary condition in the choice of site. The disposal of the water after use is a question for the engineer; but it must not be permitted to soak into the ground near the barracks; it might seem superfluous to notice this, if the custom of allowing the ablution water to run under the houses had not prevailed formerly at some stations.

Latrines.—The system of excrement disposal generally adopted throughout India is the "dry earth" system. The latrines are well kept and their contents regularly removed. The system answers well in barracks, but great care is required to see that the contents are disposed of properly. Iron receptacles generally receive the urine; these are frequently tarred and emptied at stated intervals. These receptacles are all emptied into closed carts twice daily; but the natives who perform this duty require careful watching, otherwise they are apt to deposit the contents of their carts on the surface of the ground in place of in trenches. The earth supplied for the purpose of deodorisation must be clean and absorbent. Sand is of little use for this purpose.

Ventilation of Tropical and Sub-tropical Barracks.—If barracks are not made too broad, and are properly placed, the same principles of ventilation may be applied to them as to barracks at home. The perflation of the wind should be obtained as freely as possible. The numerous doors and windows, however, render it unnecessary to provide special inlets; outlets should, as at home, be at the top of the room, either along the ridge, or, if of shafts, they should be carried up some distance; if they are made of masonry, and painted black, the sun's rays will cause a good up-current. The area of the shafts is ordered to be 1 square inch to every 15 or 20 cubic feet, with louvres above and inverted louvres below. In the lower rooms these shafts are built in the walls, while in the upper rooms they are placed in the centre of the ceiling.

In many parts of India, however, at particular times of the year, the air is both hot and stagnant; in such stations artificial ventilation must be employed, and the forcing in of air offers greater advantages than the method by aspiration. The wheel of Desaguliers was introduced into India many years ago by Rankine, and, under the name of "Thermantidote," is frequently used in private houses and hospitals. The great advantage of it is that the air is put not only in motion but can be cooled by evaporation.

The common punkah is a ventilator, as it displaces masses of air; the waves pass far beyond the building, and are replaced by fresh-air waves entering in.

Ventilation in most parts of India must be combined with plans for cooling, and often for moistening the air.

Cooling of Air.—When the air is dry, *i.e.*, when the relative humidity is low, there is no difficulty in cooling the air to almost any extent. If the air be moving, this is still easier. The evaporation of water is the great cooling agency. A drop of water in evaporating absorbs as much heat as would raise 967 equal drops 1° F., or, in other words, the evaporation of a gallon of water absorbs as much heat from the air as would raise $4\frac{1}{2}$ gallons of water from zero to the boiling-point. As the specific heat of an equal weight of air is $\frac{1}{4}$ that of water, it follows that the evaporation of 1 gallon or 10 ℔ of water will cool $(10 \times 4 \times 967)$ 38,680 ℔ of air, or 477,637 cubic feet of air 1° F.; or, to put it in another way, the evaporation of 1 gallon of water will reduce 26,216 cubic feet of air from 80° to 60° F. If thoroughly utilised, $1\frac{1}{2}$ gallon per head would be the allowance for twelve hours, but as the full work is never got out of any material, this quantity ought in practice to be doubled. In India the temperature of a hot dry wind is often reduced 15° to 20° F. by blowing through wet khus-khus tatties; merely sprinkling water on the floors has a perceptible effect on the temperature.

When the air is stagnant cooling is less easy. In India it is often attempted, in a still atmosphere, to insure coolness by creating currents of air either by the simple punkah or by thermantidotes; these act by increasing evaporation from the body, and they certainly do away with the oppressiveness of a still atmosphere. But evaporation of water must be also employed if the atmosphere is dry.

In the case of a thermantidote, thin wet mats made of khus-khus grass are suspended in a short discharge-tube, or ice placed in the channel, through which the heated air passes, will answer equally well.

Hut Barracks.—Of late years the use of wooden huts, both in peace and war, has greatly extended in several of the European armies. In peace, their first cost is small, and they are very healthy. In war, they afford the means of housing an army expeditiously, and are better adapted for winter quarters than tents.

The ground occupied by a hut should be cleared, levelled, and drained. The hut should be provided with ridge ventilation and projecting eaves to carry off the rain-water from the foundations; it should have the requisite number of windows, and should be raised sufficiently above the ground to allow a free current of air to pass underneath the flooring. In hot climates the roof and sides should be double, if these latter are not protected from the sun by verandahs.

Huts are best placed *en échelon*, so as to receive the full advantage of winds.

Ventilation is effected by openings in the ridge, or outlet shafts may be used, passing through the roof and terminating in louvres and inlets under the eaves.

Warming may be effected by the use of stoves or an open grate. The latter is preferable, as it assists in ventilation. The construction of huts depends on whether they are used for temporary purposes or whether they are intended to be of a more or less permanent character. In the latter case the sides are usually built of brick.

In the German Army the Döcker huts are largely used, and are said to answer well. They have recently been favourably reported on in this country. They are made of wooden or iron frames, covered with a special kind of felt, lined with canvas. They are very portable, and the fastenings are so arranged that they can be put together in a very short time. These huts are well ventilated by windows, cross louvres, and ridge ventilation, and can be easily warmed, if this is desired.

Lord Wolseley recommends that temporary huts on service should be constructed to hold twenty-eight men, and be of the following proportions: Length, 32 feet; breadth, 16 feet; height to eaves, 6 feet; height to ridge, 16 feet. The cubic space should be 400 cubic feet per man. Two such huts are placed end to end with one chimney between them.

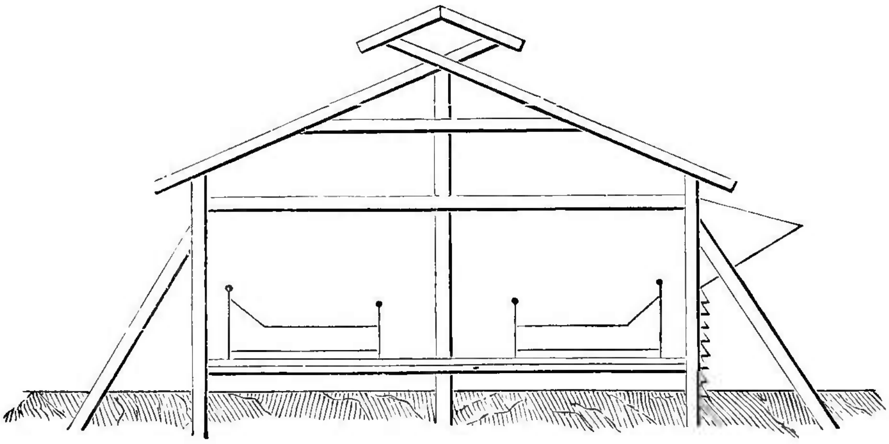


Fig. 130.

The roof may be made of felt or tarred calico, secured by strips of wood. In the tropics, if the rainfall is heavy, the roof should be made steep, to throw off the rain.

If the flooring is made of wood, it should be fastened by screws and not nails. This will allow the boards to be taken up, if necessary, and the space beneath cleaned. If the floor is of earth, a little of the surface earth may be removed occasionally and replaced by clean gravel. Ashes from wooden fires, well rammed down, make an excellent floor.

Trenches should be carried round huts as in the case of tents.

Fig. 130 shows a plan much used by the Germans in 1870–71 for temporary sheds; the crossing of the rafters permits thorough roof ventilation, and the raising from the ground where practicable is very important.

Bamboo was used in the Ashanti Expedition, on the north-east frontier of India, also at Suakim, and made excellent huts. In the Nile Expedition huts were built of sun-dried brick, which gave great protection from the sun.

The "Berthon" huts are portable and circular structures made on the same principle as the collapsible Berthon boats, with timbers radiating from an apex, and which extend two plies of waterproof canvas. The hut walls are composed of two thicknesses of board, with glass windows in each segment. The floor is made in segments of board, stained and thickly varnished. The ventilation in them is good, as fresh air enters between the double sides, and passing upwards between the two skins of the roof escapes by ventilators at the apex. These huts can be heated in the winter by a stove placed in the centre with a stove-pipe projecting through the apex, nowhere touching any wood or canvas. In extreme climates, additional warmth can be obtained by means of additional felt inner linings. As these huts can be readily taken down and removed, their employment on service, especially for hospital use, presents many advantages.

Tents.—A good tent should be light, so that it may be easily transported, readily and firmly pitched, and easily taken down. It should completely protect from weather, be well ventilated, and durable.

It is perfectly easy to devise a tent with some of these characteristics, but not to combine them all.

The tents used in our army are as follows:—

The Circular or Bell Tent.—A round tent with sides straight to 1 foot high, and then slanting to a central pole. Angle at apex, 70° Diameter of base, 12·5 feet; height, 10 feet; area of base, 123 square feet; cubic space, 492 feet; weight, when dry, including poles, about 72 lb. The canvas of the new pattern is made of cotton or linen. The ropes extend about 1½ foot all round. It holds from twelve to sixteen men; and in war time eighteen and even twenty have been in one tent. The men lie with their feet towards the pole, their heads to the canvas. With eighteen men the men's shoulders touch. Formerly, there was no attempt at ventilation; but afterwards a few holes were made in the canvas near the pole. Ventilation, however, is most imperfect, as the holes are so small that the movement of the air is almost imperceptible. There is little ventilation through the canvas, and none at all when it is wet with dew. The new circular tent is somewhat improved as regards ventilation.

The Hospital Marquee.—An improved hospital marquee was issued in 1866. It is in principle the same as the old marquee, but with improved ventilation. This tent is two-poled, with double canvas. It is made of a lower, almost quadrangular part, and an upper part, sloping from the top of the straight portion to the ridge. Length, 30 feet; breadth, 15; height of sides, 5; height to ridge, 15; area about 385 square feet; cubic space, 3336 cubic feet.

It is intended for sick, and can accommodate eight men. There are ventilators, and a large flap at the top can also be opened for ventilation, and the fly can be raised. The weight of this hospital marquee (including the valise) is about 512 lb. A waterproof sheet is supplied, to put on the ground, and this weighs 145 lb.

It is a good tent when care is taken with ventilation; but there should be a way of raising one whole side, so as to expose every part of the tent; and if the height of the upright part were 6 feet, it would be more convenient. These tents are used for hospitals on the lines of communication and at the base, but form no part of the movable field equipment: they are used when buildings or bell tents are not available.

This hospital marquee is cumbersome, excessively heavy, and difficult to pitch. It might advantageously be replaced by a smaller tent, known as the officers' marquee, and which weighs but 168 lb complete.

Circular Tents.—Two double circular tents, with higher walls and without lining, weighing about 75 lb and 85 lb, have been approved of for hospital purposes, into which four sick or wounded men are placed. These form part of the new field equipment. Five such tents accommodate twenty men well, whereas the marquee of the same weight only serves for eight, unless unduly crowded.

Shelter Tent.—There is no official shelter tent for the English Army on home service, but one was formerly issued for service at the Cape, and one is still occasionally issued on campaigns, weighing 11 ℔, for two or three men. Each man at the Cape carried a canvas sheet, made up of a quadrangular (5 feet 9 inches × 5 feet 3 inches) and of a triangular piece (2 feet 8 inches height of triangle × 5 feet 3 inches base). Buttons and buttonholes were sewn along three sides, and a stick (4 feet long, and divided in the middle) and three tent pegs and rope also were provided. Two or four of these sheets could be put together, the triangles forming the end flaps. A very roomy and comfortable shelter tent, 4 feet in height, was formed, which would, with a little crowding, accommodate six men, so that two sheets could go on the ground. The objection to this tent was its weight, viz., 6 ℔ 14 oz. per man. Lord Wolseley condemns the shelter tent as too heavy and not fulfilling its purpose. If a thinner material could be obtained, and if the size could be a little lessened in all directions, it would be a very good tent. A plan for making a shelter tent with blankets is given in the *Instructions for Encampments*, 1895, plate xviii.

The tents in use by the Indian Army are as follows:—

British Privates.—With two poles and ridge, double fly. Length, 20 feet; breadth, 16 feet; height of walls, 5 feet 6 inches; height to ridge poles, 10 feet 6 inches. Cubic space, 2373 cubic feet. This tent is used for inland service, and accommodates 16 healthy men or 8 sick.

Mountain Service.—With two poles and ridge. Length, 12 feet; breadth, 8 feet; height of walls, 10 inches; height to ridge poles, 8 feet. Cubic space 544 cubic feet. This tent is used for field hospitals to accommodate 4 sick.

General Service.—With three poles and ridge. Weight, 160 ℔; length, 14 feet; breadth, 14 feet; height of walls, 1 foot; height to ridge pole, 7 feet. Cubic space, 686 cubic feet. This tent is used for field service, and accommodates 16 British or 20 native soldiers, or 25 followers.

General Service (small).—With two poles and ridge. Weight, 80 ℔; length, 8 feet; breadth, 14 feet; height of walls, 1 foot; height to ridge pole, 7 feet. Cubic space, 392 cubic feet. This tent is used for field service, and accommodates 8 British or 10 native soldiers, or 12 followers.

French Tents.—In the French Army two chief kinds of soldiers' tents have been used.

1. The *tente-abri*, or shelter tent of hempen canvas, which was intended for three or four men. This is now given up, on account of its weight, except in campaigns beyond the confines of Europe.

2. *Tente de Troupe*, or *Tente Taconnet.*—This is a two-poled tent, with a connecting ridge pole; for sixteen men. It is considered cumbersome and unstable, and is now abandoned.

3. Two conical tents are now used, like the English bell tent; one (*tente conique*, also *tente turque*, or *à marabout*) a cone, and the other having an upright wall 16 inches high, and then being conical above (*tente conique et à murailles*). This last tent is ventilated at the top; a galvanised iron ring, 12 inches in diameter, receives the canvas, which is sewed round it. An opening is thus left of 113 square inches, which can be closed by a wooden top which rests on the top of the pole, and is buckled to the ring. Each tent holds sixteen men. The *tente conique* is the one now chiefly used. Its weight is 129 ℔, and its capacity 1059 cubic feet. Small tents, called *tentes de marche*, are now issued to officers, who formerly provided their own various forms.

French Hospital Tent.—This is constructed on Tollet's principle and consists of a metal frame with a double envelope, the outer casing being of linen, the inner of cotton. The framework is in seven pieces and tortoise-shaped. It measures 15 metres in length, is 5 metres broad and 5 metres high in highest part. It affords a cubic space of 200 cubic metres, which for 16 beds gives about 12 cubic metres for each sick person.

German Tent.—This is a conical tent, with a single pole, like the bell tent of the English Army; it is nearly 15 feet in diameter; the pole is 12 feet high: it holds fifteen men, and weighs 83 ℔ avoir. The floor space is 12 square feet, and the cubic space 70 cubic feet per head.

In the German Army bivouac tents are in use. The component parts of the tent poles and canvas are distributed among as many men (two at least) as are meant to be sheltered by it. The canvas part, which has the appearance of tanned waterproof flax, is rolled round the soldier's overcoat, which is strapped down on the top and sides of the knapsack, and in bad weather this tent section may be unrolled and worn as a watertight *poncho* by the bearer.

German Hospital Tent.—The ground floor of the tent is a rectangle 29½ feet long and 24½ feet broad; the tent is 13 feet 9 inches high; the area is 723 square feet, and the weight 952 ℔. It is divided by curtains into three parts, a central one for the sick, and two rooms for attendants, utensils, &c. The tents are made with a wooden framework, and there is a good hood for ventilation. Each tent could contain ten to twelve beds, but only six patients are placed in it. It stands on an area of 53 feet by 43 feet.

At the chief dressing stations, if no suitable building can be found, a bandaging tent is erected in which to perform operations. This is also rectangular in shape; length, 13½ feet; breadth, 11½ feet; height, 8 feet. It is very simply constructed, and has a single fly made entirely of waterproof canvas.

Russian Tent.—The infantry tent is quadrangular, 14 feet square and 7 feet high to the slope; there is a centre pole and four corner poles; it is intended for fourteen men, but only twelve are usually placed in it. Round the tent is a bench 1½ foot broad, and covered with straw mattresses and sheets (in the summer camps) for sleeping. A wooden rack round the centre pillar receives the rifles. The canvas can be partly or entirely lifted up. The officers' tents have double canvas.

United States Army.—Four styles of tent are issued:—

(1) Conical (modified Sibley), 16 feet 5 inches in diameter at base; wall, 3 feet; apex, 10 feet; floor, 212 square feet; air-space, 1450 feet; allowance, 20 infantry or 17 cavalry; comfortable for camp or slow march with half that number.

(2) Common ("I" or modified "A"), wall, 2 feet; base, 8 feet 4 inches × 6 feet 10 inches; ridge, 6 feet 10 inches from ground; floor, 57 square feet; air-space, 250 feet; allowance, 4 mounted or 6 foot men. Each infantry man would have 17 inches to lie in.

(3) Wall, 9 feet square × 3 feet 9 inches; to ridge, 8 feet 6 inches; floor, 81 feet; air-space, 500 feet; covered by fly or false roof.

(4) Shelter tent.

Hospital tents are larger wall tents (14 × 15 × 4½ feet wall, 12 feet to ridge), that may be opened at each end and thrown together in extension.

Camps.—The worst site for a camp is clay soil, or a clay subsoil coming near the surface. Such soils are retentive of water, and keep the atmosphere over them damp. They should therefore, if possible, be avoided. Ground immediately at the foot of a slope is apt to be damp and unhealthy, on account of receiving water from the higher levels. In tropical climates, localities exposed to winds blowing over low marshy ground are unsafe on account of malarial fevers; for the same reason elevated sites on the margin of steep ravines, up which malaria may be carried by air-currents, are apt to be unhealthy, as are also deep narrow valleys or gorges covered with dense vegetation.

Ground covered with rank vegetation, especially in the tropics, is unhealthy, partly on account of the amount of decaying matter in the soil, partly because the presence of such vegetation is in itself a mark of the presence of a high subsoil water or of a humid atmosphere. In hot climates, the banks of rivers, especially if the water is stagnant, marsh lands, lands subject to periodical floodings, and especially if covered with mixed salt and fresh water, are particularly unhealthy.

A porous subsoil, not encumbered with vegetation, with a good fall for drainage, not receiving or retaining water from any higher ground, and the prevailing winds not blowing over a marsh, will afford the best sites.

Regulations have been issued by the Quartermaster-General's Department, and the *Queen's Regulations* contain several orders which will be noticed hereafter. The Barrack Improvement Commissioners also lay down certain rules which must be attended to.

Encampments are divided into two kinds—those of position, which are intended to stand for some time, and incidental camps. The camps are arranged in the same way in peace and war, as a means of training the men; but, of course, in peace the war arrangements need not be adhered to.

In the *Regulations and Instructions* issued in 1895 by the Quartermaster-General's Department, the following points are laid down as of importance:—

1. The length of time troops are to occupy the camping-ground.
2. That order, cleanliness, ventilation, and salubrity are to be ensured.
3. That means of passing freely through the camp are essential.
4. That a straggling camp increases labour of fatigue duties, and impedes delivery of supplies and circulation of orders.
5. That the more compact the camp, the easier it is to defend.

Troops are ordered to be encamped in such a manner that they can be rapidly formed in a good position for action. This does not involve the necessity of encamping on the very position itself. Although purely strategical or tactical considerations are of the first importance before an enemy, yet sanitary advantages must always be allowed great weight, and will, in most cases, govern the choice of ground if military reasons permit. Cavalry and infantry camps are directed to be formed with such intervals between their troops or companies as circumstances may require, or the general commanding may direct. Open column is usually the most extended order used.

In front of an infantry camp is the battalion parade, the quarter-guard being in front of all. Behind the men's tents, on the left side, are the kitchens, and on a line to the right the tents of the officers; then come the waggons, horses, drivers, and bâtmen; next the ashpit and latrines, and on the boundary line the rear-guard. In fixed camps the latrines and kitchens may be pitched elsewhere, if found advisable.

The distances between different corps are, as a rule, to be 10 yards. Measurements in camps are made in yards: 5 yards = 6 paces.

Cavalry are encamped in columns of troops or squadrons, the horses being picketed between every second row of tents; 5 feet of space is allowed to each horse.

Artillery encamp with the guns in front, the waggons in two lines behind, and the horses and men on the flanks, the men being outside, the officers' tents being in rear.

There are 3,097,600 square yards in a square mile, and assuming that there are fifteen men to each bell tent, the following table gives the surface area per tent for different densities of population per square mile:—

No. of Square Yards per Tent.	No. of Tents per Square Mile.	No. of Troops per Square Mile at 15 Men per Tent.
50	61,953	929,280
100	30,976	464,640
200	15,488	232,320
400	7,744	116,160
800	3,872	58,080
1000	3,097	46,464

Assuming the strength as in column one, and using these measurements, the following table gives the density of population:—

	Strength.	Square Yards.	Acres.	Men per Acre.	Men per Sq. Mile.
Infantry battalion, full size,	1011	21,600	4·46	226	144,640
,, minimum,	1011	7,800	1·61	628	401,920
Cavalry regiment, full size,	630	34,000	7·02	89	56,960
,, minimum,	630	15,000	3·09	204	130,560
Battery, . .	154	11,200	2·31	67	42,880
Field company, R.E.,	182	7,500	1·54	118	75,520
Bearer company,	66	8,400	1·73	38	24,320
Field hospital,	145	11,200	2·31	62	39,680

The above tables show that a cavalry regiment encamped upon its maximum area is nearly as densely populated as Liverpool, which has a population density of 97·3 persons to an acre; and when occupying its minimum space would have as dense a population as the most crowded part of London, namely Whitechapel.

The compression of any camp must depend on the size of the ground and the nature of the service on which troops are employed, but these tables clearly show that camps in the most "open order," as laid down in regulations, are densely populated.

In laying out a camp, tents should never be arranged in double line; short single lines are best.

The tents in line should be separated from each other by a space at the very least equal to a diameter and a half of the tent, and the further the lines can be conveniently placed from each other the better.

The floor of a tent should never be excavated, with a view to increase the space; water is apt to lodge in the cavity; the space is nearly always damp, and the occupants are exposed to ground-air emanations. Men should never sleep below the level of the ground, but if possible above it.

To prevent the subsoil beneath the tent becoming saturated with filth, tents should occasionally be shifted to fresh ground within the same lines, so as to expose the vacated sites to sun and air. It is well known that tents occupying the same ground for a length of time become unhealthy.

The German regulations order that the soil underneath, if not absolutely clean and firm, should be dug out to the depth of one foot, and replaced by gravel, coal-dust, &c., slightly watered, and covered by a few boards until dry and hard.

Whenever possible, the floors of tents should be boarded, the boards being loose, so as to be easily removed. If boards cannot be obtained, waterproof sheets should be used; the soil should be beaten down, so as to render it less permeable; the surface scraped from time to time and replaced by clean gravel or ashes from the wood fires.

If straw is used for bedding, it is best to make it into mats of a triangular shape and two or three inches in thickness. These can be taken up during the day and exposed to the sun and air.

As there is almost no ventilation in tents, the sides should be raised during the day and to leeward at night. The tent door should never be closed.

Camp latrines should be placed to leeward of prevailing winds, and as far removed from the tents as is compatible with convenience. They should be dug deep and narrow, and their contents covered over every evening with several inches of fresh earth. Care should be taken not to place them near existing wells, nor to dig wells near where latrines have been placed. When the latrines are filled within two or three feet of the surface, earth should be thrown in and well raised so as to mark the site. It is well to screen off the latrines with any available material.

Horses or other animals should always be placed to leeward of the men's tents.

All refuse material that can be disposed of by burning should be got rid of in that way. If this cannot be done, it should be removed daily to some spot at a safe distance from the camp.

Dead animals and the débris from the slaughter-houses, &c., should be buried in dry earth at sufficient depth, and at a distance to leeward of the camp.

Military Hospitals.—In the construction of hospitals, the great points to be secured are: (1) purity of internal atmosphere; (2) abundance of pure air and sunlight within the building; (3) facility of administration and discipline. The realisation of these principles involves the selection of a healthy site for the building, simplicity of plan and construction, a sufficient number of wards properly placed, a certain arrangement of wards, proper ward proportions, a suitable number of offices, stores, &c., and easy means of communication throughout the building. The first of these conditions is met by placing the sick in detached buildings, with such an aspect as will afford the freest air and the greatest light; this is best effected in hospitals built on the pavilion plan, in which the sick can be treated in small detached and perfectly ventilated buildings, and where there is no possibility of the air of one ward passing into another.

The ventilation of wards in a military hospital is on the same plan as for barracks, except the dimensions are nearly doubled.

The ward unit is the foundation of the hospital plan, and the ward construction and proportions must be based on the number of cubic feet to be allowed per bed. In wards each man should have at least 90 square feet of superficial space and 1200 feet of cubic space. This is the amount allowed by regulations at home, but, if possible, a larger space should be given. In tropical climates (exclusive of India) 1500 feet of cubic space is allowed to each man, or an amount as may be specially authorised for each command.

The *Instructions for the Royal Engineer Department*, 1887, state the size and construction of hospital wards in the United Kingdom to be as follows:—

Ward.—Normal size for twenty-four beds, 87 ft. × 24 ft. × 14 ft. high.

Ward for two beds, 20 ft. × 13 ft. × 14 ft. high.

1. The regulations direct that the walls for hospitals shall be constructed on the same plan as those for barracks.

2. The bed space for two beds between two windows must not be less than 9 ft., or 3 ft. per bed and 3 ft. between them. The bed space between a window and an end wall should be 4 ft. 6 in. With the minimum distance between the windows, their maximum interval width should be 5 ft. 6 in., giving for each bed in the large wards a floor space of 7 ft. 3 in. × 12 ft., which, with a height of 14 ft., allows 1218 cubic feet.

The windows of large wards should face east and west. The windows should be 2 ft. 6 in. from the floor to the top of the stone sill, about 10 feet high, and should run up to within 12 inches of the ceiling; the inner sills to be bevelled to prevent accumulation of dust. Blinds should be provided to the windows of wards.

Doors to large wards to be 4 feet wide, hung in two, and glazed with a swing fanlight above.

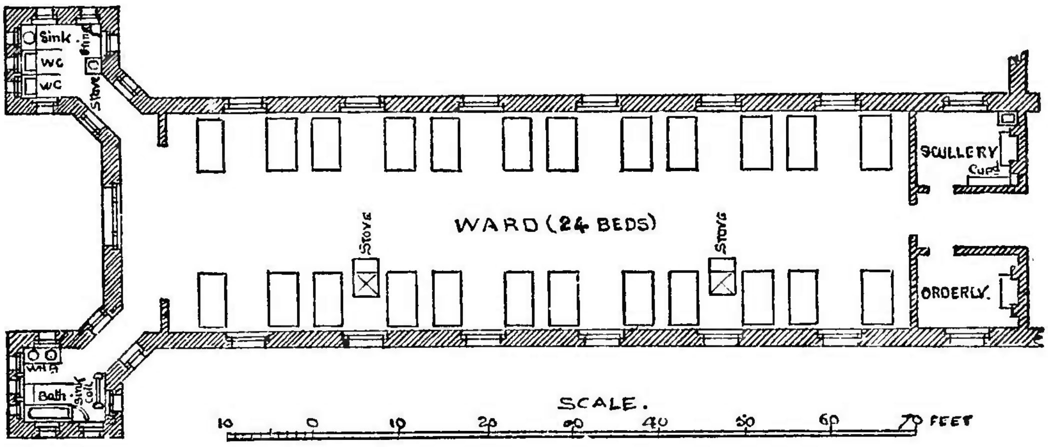


Fig. 131.

The arrangement of water-closets and urinals is a matter of the greatest importance. The best plan is to throw out from one end of the ward a building to contain the closets, and connect it to the ward by an intercepting lobby. This is the plan adopted in the Cambridge Hospital at Aldershot and in all the new station hospitals (see fig. 131).

The following plans show the general arrangements adopted in the construction of military hospitals.

The Herbert Hospital, Woolwich, consists of four double and three single pavilions of two floors each, all raised on basements. The administration is in a separate block in front. The wards are warmed by two central open fire-places with descending flues, round which are air-passages, so that the entering air is warmed. The floors are iron beams filled in with concrete and covered with oak boarding (fig. 132).

The Cambridge Hospital at Aldershot is much on the same plan, but the closets and lavatories are thrown out in separate turrets and connected by intervening lobbies (fig. 133).

Military Hospitals in India.—The *Indian Army Regulations* direct for each sick man from 102 to 120 square feet of superficial area, and from 1630 cubic feet of space (in the hills) to 2400 (in the plains).

Hospital Organisation, &c.—Military hospitals are classified as follows:—

I. *In Districts and Commands.*

(*a*) General Hospitals.
(*b*) Station Hospitals.
(*c*) Lunatic Hospitals.
(*d*) Hospitals on board ships conveying troops.
(*e*) Hospitals for soldiers' wives and children.

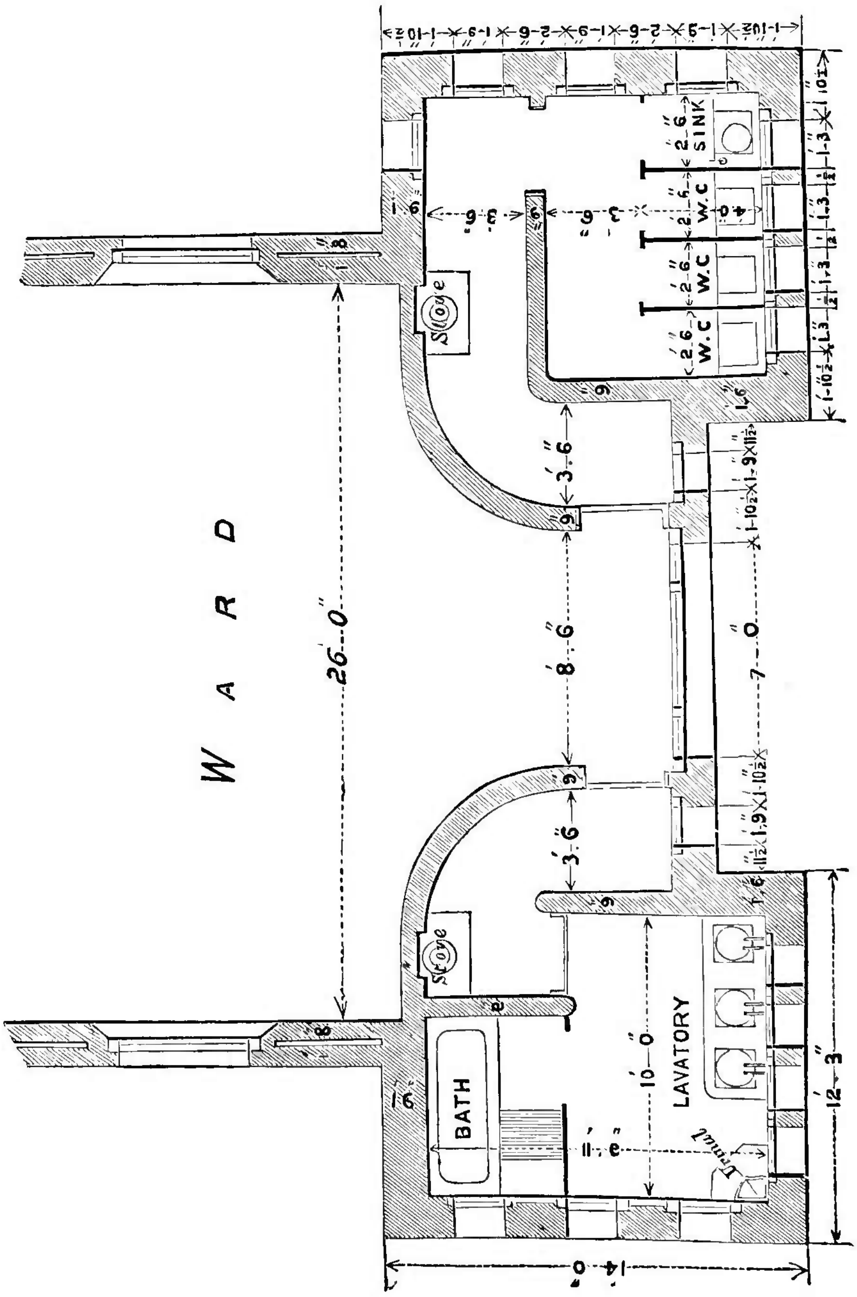


Fig. 132.

II. *With an Army in the Field.*

(*a*) General Hospitals.
(*b*) Hospital Ships.
(*c*) Hospitals on the lines of communication.
(*d*) Field Hospitals.

Subject to the officer commanding the district or station, the senior medical officer in charge of a hospital commands all officers of the Army Medical Staff, and soldiers of the Medical Staff Corps attached to the hospital, as well as all patients in hospital and officers and soldiers of other corps attached to the medical staff corps for duty. He is responsible for the discipline of the whole establishment.

The medical officer in charge of a military hospital is directly responsible for all the duties of the hospital: he will take care that all the instruments, medicines, hospital equipments, clothing, and stores held on inventory are in good condition, sufficient according to regulation, and kept in safe custody; that the supplies are of good quality, and that the cooking and distribution of the diets are properly carried out.

The nursing duties in general and station hospitals are carried out by nursing sisters, under the immediate supervision of the superintendent or acting superintendent: they receive orders and instructions relative to the nursing arrangements from the medical officers. Nursing sisters are responsible for the personal cleanliness of the patients in their wards and that all medicines, diets, &c., are properly issued. They also assist in training, as hospital attendants for nursing duties, the men of the medical staff corps.

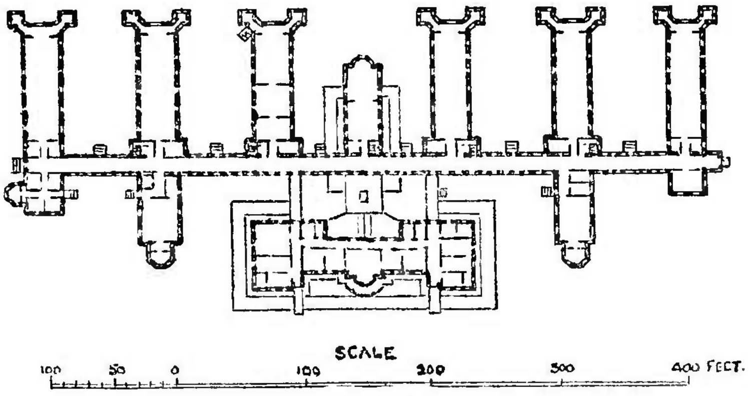


Fig. 133.

Field Organisation.—The organisation for the medical service for troops in the field consists of the following parts:—

1. To each infantry regiment, regiment of cavalry, horse or field artillery division of three batteries with ammunition column, and to each engineer company or troop, is attached a medical officer, to afford such temporary assistance to sick and wounded as may be required on the line of march, in camp, and in action. He will be furnished with a corporal and a private as orderly from the regiment, and the trained bearers of the corps, in the proportion of two men per company, will be placed at his disposal to render first aid to the sick or wounded soldier.

2. To each brigade of infantry and cavalry is attached a bearer company, consisting of three medical officers and sixty-four men of the medical staff corps. In action the bearer company is divided into (1) two stretcher sections, each of one sergeant and sixteen privates, and one of which is under a surgeon-captain; (2) a collecting station, under a sergeant; (3) the ambulances; and (4) a dressing station, under a surgeon-major, assisted by another medical officer.

The *collecting* station will be as close as possible to the fighting line, and, if possible, under shelter. The ambulances rendezvous here, and, as they are loaded with wounded, move off to the dressing station; having deposited them they return at once to the collecting station.

The *dressing* station is usually out of range of fire. Any available shelter may be used, and there should be a supply of water at hand; if no building is available a tent must be pitched. After the wounded are dressed, and beef-tea, stimulants, &c., given, they are moved in the ambulances of the second line to the field hospitals. Each bearer company is provided with ten four-horse ambulance waggons (when wheeled transport is available), of which four are intended to ply between the collecting and the dressing stations, and six between the dressing station and the field hospitals.

3. To each brigade is attached a field hospital of 100 beds, the *personnel* consisting of four medical officers, one quartermaster, and forty rank and file of the medical staff corps. This hospital is capable of being divided into two halves of fifty beds each. To each infantry division is attached, in addition, a field hospital in reserve, and an army corps has a field hospital as well for corps details. A cavalry division consisting of two brigades has the same provision as a division of infantry, one field hospital being for corps details.

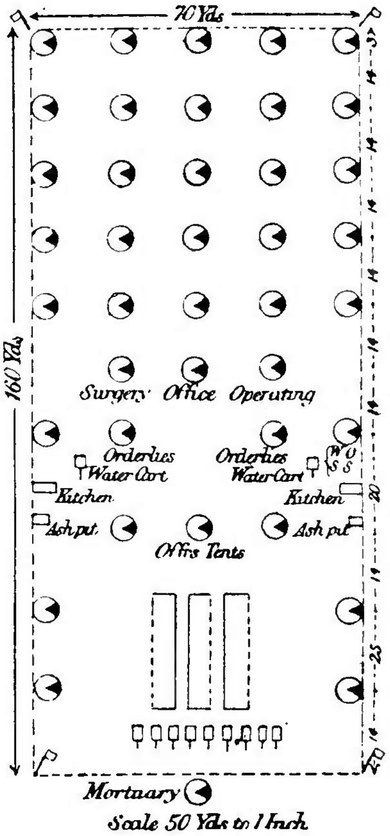


Fig. 134.—Camp for Field Hospital.

For an entire army corps of 35,110 of all ranks there are provided six field hospitals with the six brigades, a field hospital with each division, or three in all, and one other for the corps details, giving altogether ten hospitals, or 1000 beds for 35,000 men, or about 3 per cent. of hospital accommodation in the second line.

On the line of communication stationary field hospitals and general hospitals are established at as many points as may be considered necessary. On an assumed line of 100 miles in length, viz., 50 miles of railway and 50 miles of road, two stationary hospitals and two general hospitals would be required for a field force consisting of an army corps with a division of cavalry, and comprising in the field and at the base, and on the line of communications, a grand total of 41,815. There are provided 1000 beds in the field hospitals, 400 beds in the two stationary (200 each), and 1000 beds in the two general hospitals (500 each) on the lines of communication, and 1000 beds at the base—in all, 3400 beds for about 8 per cent. of the whole force.

Slight cases would be treated in the field hospitals, but all cases likely to be of a serious nature should be sent to the base. The hospitals in front should be kept empty as far as possible, in order to meet any emergency and to enable them to advance with the army; if encumbered with sick this is impossible.

A field hospital is a non-dieted hospital, *i.e.*, one in which no hospital diets are issued, but the sick have their ordinary field rations cooked for them; these are supplemented by such medical comforts as are required. Beds or stretchers form no part of the field hospital equipment.

Hospitals on the lines of communications form the third line of medical assistance. The site for these should be selected near canals, roads, or railways, for the ready removal of the sick and wounded to the base. Each hospital is for 200 patients. If possible, these hospitals will be established in buildings or wooden huts at any port of embarkation and in towns, villages, and farm-houses along the lines of communication. These hospitals, if possible, will be dieted.

General Hospitals at the Base.—These are dieted hospitals and are fully equipped. Nursing sisters form part of the establishment of these hospitals, which are organised in a manner similar to a general hospital in peace.

The hospitals at the base should never be the ordinary buildings of the country adapted for that purpose. Such buildings have always been found unhealthy. Churches should never be used, as they are not only cold, but are subject to exhalations from graves in their vicinity and from vaults placed beneath them.

Experience teaches that the best plan is to erect huts at the base or whenever hospitals are required for any length of time. In the war of the rebellion, the American Army discontinued converting old buildings into hospitals: huts were erected capable of accommodating fifty sick men with two rows of beds; the superficial area allowed per bed was 87 square feet, and the cubic space 1200 feet per man.

The hospital huts used at Suakim in 1885 were of wood, the upper halves of the walls being movable or provided with bamboo chicks or matting. The roof was of cork covered with Willesden waterproof paper, and ventilated by means of metal cowls. Each hut accommodated twelve men with 850 cubic feet of space per man. The floor was raised 16 inches above the ground. The Döcker hut (already described) is largely used in the German Army, and appears admirably adapted for their purpose.

Hospital Ships.—The floating hospital accommodation for an army corps consists of three depôt ships, each capable of receiving 200 sick. There are also relieving ships, capable of accommodating sixty sick, employed for the conveyance of those who may be invalided to England; and in addition despatch vessels fitted with thirty canvas cots for the removal of the less serious cases, which may be transported by mail packets on their way to England.

On these ships the Admiralty undertakes the lodging, victualling, and conveyance of the sick; the washing is also arranged for by them.

The War Office undertakes to furnish the medical and other attendance necessary for the proper treatment and nursing of the sick, and supplies all articles of personal and hospital clothing (but not bedding or ward equipments), medical and surgical appliances, and hospital utensils.

The fittings of a hospital ship should be as simple as possible and made of iron. Ample ventilation must be provided for, especially between decks; the method of receiving and removing the excreta of dysenteric or febrile patients must be carefully attended to; the supply of good water should be ample, and, if possible, a separate ship should be employed for washing linen, &c.; if the expedition is a large one it would not be difficult to convert a small ship into a laundry. Every possible plan should be adopted to keep the ship as dry, well ventilated, and pure as a hospital on shore.

THE FOOD OF THE SOLDIER.

The *Regulations for the Army Medical Services* direct medical officers to examine from time to time into the quality of the various articles of food; the cooking, to ascertain whether it is sufficiently varied; and likewise the amount and quality of the drinking water supplied to troops. With an army in the field the principal medical officer will give his advice with reference to rations, clothing, shelter, and all other points affecting the health of the men.

It will be thus seen that a medical officer may at any time be called upon to give his opinion on the quality of the food supplies tendered, on the composition of men's diet, and whether these are sufficiently varied and in proper quantity, and on their cooking and preparation.

The rations of the chief armies are as follows:—

British Soldier on Home Service.—The British soldier obtains his food supplies from the following sources:—

1. From the Government, 12 ounces of meat and 1 ℔ of bread "free."
2. By stoppage from his pay (usually 3½d. per diem) he is provided with his "grocery ration." This sum is at the disposal of the various companies in a regiment; it is expended on the purchase of extra bread, potatoes, milk, vegetables, tea and sugar, &c.
3. In addition to these there are certain individual purchases the soldier makes at the canteen, all articles being supplied to him at cost price. It is easy to calculate the amount he receives from the first two sources of supply, but how much he buys it is impossible to say. The sales at various canteens show that cheese, bacon, preserved meats, and fish are the articles most in demand.

The accessory foods are rather deficient in the soldier's food, and vinegar especially should be used. Robert Jackson very justly insisted on the importance of vinegar as a digestive agent and flavourer, as well, no doubt, as an anti-scorbutic. He remarks on the great use of vinegar made by the Romans, and possibly the comparative exemption which they had from scurvy was due to this.

Nutritive Value in Ounces (avoir.) of the Free Ration and of the Grocery Ration.

Articles.	Quantity taken daily in Ounces and Tenths of Ounces.	Water.	Nitrogenous Substances.	Fat.	Carbo-hydrates.	Salts.	Water-free Food.
Meat,	12 oz., of which one-fifth is bone.	7·20	1·44	0·81	...	0·15	2·40
Bread,	24	9·60	1·92	0·36	11·81	0·31	14·40
Potatoes,	16	11·84	0·32	0·02	3·36	0·02	3·72
Other vegetables (taken as cabbage),	8	7·28	0·14	0·04	0·46	0·06	0·70
Milk,	3·25	2·82	0·13	0·12	0·16	0·02	0·43
Sugar,	1·33	0·04	...	...	1·29	...	1·29
Salts,	0·25	...	...	...	...	0·25	0·25
Coffee,	0·33	...	...	...	...	...	...
Tea,	0·16	...	...	...	...	...	...
Total quantity,	65·32	38·78	3·95	1·35	17·08	0·81	23·19

Calculating this by the table given at page 268, it would give :—

Nitrogen,		276 grains.
Carbon in proteids,	837	4588
Carbon in fats,	454	
Carbon in carbo-hydrates,	3297	
Hydrogen in proteids,	32	97
Hydrogen in fats,	65	
Sulphur in proteids,		32

In this ration the nutrient value of the bones, which form one-fifth of the meat ration, is omitted; these, if crushed and boiled with vegetables, make an excellent and nutritious soup. The grocery ration may be taken as a minimum of what is supplied, and is no doubt far short of what might be afforded with good management of the messing money.

What really can be accomplished with this has been shown by General Burnett. He considers that under former systems of messing there has been considerable waste, and in his regiment the bones, which formerly were thrown away, are used to make soup, being supplemented by the coarser parts of the ox (head, &c.), and with the addition of peas, lentils, &c., make a palatable and very nutritious soup.

The Committee on Soldiers' Dietary (1889) came to the conclusion that the Government free ration, supplemented by a daily messing contribution of from 3d. to 4d., is under proper management sufficient to provide an ample diet, and that the chief defects in the soldier's diet are due to insufficient interest being taken in the subject. The meat they consider to be, as a rule, of good quality. The quantity is judged to be sufficient: in support of this they quote the instance of Pearce's dining and refreshment rooms—an institution supplying 30,000 meals daily to the industrial classes—where the average amount of meat, without bone, supplied to each man for dinner was 5 ounces, uncooked, yielding when cooked about 4 ounces; whereas at Aldershot, where 1232 cooked rations were weighed, the average amount of cooked meat supplied daily was 7 ounces 1 drachm, exclusive of bone and dripping. When frozen meat is issued they recommend that 10 per cent. increase should be allowed as there is a greater loss of nutriment when cooked.

The Committee also recommend that the bread should be baked in 2 ℔ loaves, and patent yeast used in place of brewer's yeast: the smaller loaf ensures a proper proportion between the crust and crumb.

British Soldier in India.—The constitution and nutritive value of the Indian ration is as follows:—

	Quantity taken daily.	Water-free.	Proteids.	Fats.	Carbo-hydrates.	Salts.
	Ounces.	Ounces.	Ounces.	Ounces.	Ounces.	Ounces.
Meat with bone,	16	3·2	1·92	1·08	...	0·2
Bread,	16	9·6	1·29	0·24	7·84	0·2
Potatoes,	16	3·72	0·32	0·02	3·36	0·02
Rice,	4	3·6	0·20	0·032	3·38	0·032
Sugar,	2·5	2·42	...	...	2·41	0·012
Tea,	0·71	0·7	...	...	...	...
Salt,	0·66	0·66	...	...	...	0·66
Total,	55·87	23·90	3·73	1·372	16·99	1·124

In this diet there is—

	Grains.
Nitrogen,	256·5
Carbon,	4503

The bread and meat are a free issue: the remainder are supplied by the Commissariat for a stoppage of 9 pies (about 1d.) per diem. In India, as at home, there are also individual purchases consisting of extra bread, tinned meats, fish, eggs, &c., but on the whole the amount does not appear to exceed the standard diet necessary to maintain health. The deficiency appears to be in vegetables, which are very difficult to get during the hot weather.

The diet of the soldier on foreign stations, other than India, does not differ greatly from that which he receives when on home service; the chief difference is an issue of an extra ¼ ℔ of meat.

British War Rations.—In the time of Edward VI. the English soldier's rations during war were—meat 2 ℔, bread 1 ℔, wine 1 pint (Froude).

On active service in the field a special scale is fixed by the Secretary of State, according to the climate and the circumstances of the expedition: the following scale is adopted, as far as possible:—1 ℔ fresh, salt, or preserved meat; 1¼ ℔ bread, or 1 ℔ biscuit, or 1 ℔ flour; ⅙ ounce tea; ⅓ ounce coffee; 2 ounces sugar; ½ ounce salt; $\frac{1}{36}$ ounce pepper; ½ ℔ fresh vegetables when procurable, or 1 ounce compressed vegetables: also ½ ounce lime juice with ¼ ounce sugar, and 2½ ounces rum, when ordered by the general commanding, on recommendation of the principal medical officer.

The war scale should be very liberal, and every article ought to be issued by the Supply Department. It would be probably a good plan to have the supply under two headings, the "usual" and the "extra" articles, the latter being intended for special occasions, such as forced marches, rapid movements far from the base of supplies, &c. The usual ration ought not to contain less than 375 to 400 grains of nitrogen. The following is suggested as a liberal and varied war ration, which could be easily supplied under ordinary circumstances:—Bread, 1¼ ℔; fresh meat (without bone), 1 ℔; peas or beans, 3 ounces; potatoes and green vegetables, 1 ℔; cheese, 2 ounces; bacon, 2 ounces; sugar, 2 ounces; salt, ½ ounce; pepper, $\frac{1}{20}$ ounce; ground coffee, 1 ounce; tea, ½ ounce; red wine, 10 ounces, or beer, 20 ounces. No spirit ration to be given, except under orders from the generals of divisions. The nutritive value of this diet is:—Proteids, 5·6 ounces; fats, 3·43; carbo-hydrates, 16·6; salts, 1·37, equal to 410 grains of nitrogen and 5000 of carbon.

The "extra" articles would be kept in readiness by the Supply Department for occasional issue, viz., tinned Australian or New Zealand meat, Chicago corned meat, or the best market article of the kind, Liebig's extract of meat, pea and beef sausages, biscuits, flour, meat biscuits, rice, lime juice, preserved vegetables, brandy or rum, and vinegar.

This plan supposes that the "usual" scale of diet would be issued to the troops, and the "extra" articles under certain conditions, and under order of the general of the division.

Steam baking ovens have been used in the autumn manœuvres, and have been found very good. Field ovens can also be built by iron hoops fixed in the ground. Lord Wolseley gives the following plan:—Take a barrel (with iron hoops, if possible), knock out the head, lay it on its side, after scraping a bed for it; cover it with a coating of 6 or 8 inches of thick mud, except at the open end; pile up sand or earth to a thickness of 6 inches over the mud; arrange a flue at the end distant from the open part, through the mud and earth, of 3 inches diameter, to increase the draught when the fire is burning. Form an even surface of well-kneaded mud at the bottom of the barrel; light a fire in the barrel, and keep it alight until all the wood is burnt; there will then be a good oven of clay, supported by the iron hoops. When heated for baking, the mouth is closed with boards, or a piece of iron or tin. These ovens were used in the Red River Expedition, and answered admirably.

Bread (which should be well-baked) should be issued as long as possible; and if biscuit is issued for more than a week, flour or rice should be added to it. Salt meat should never be issued for several days in succession, especially with the excellent supply of preserved meat now available.

When fresh vegetables cannot be obtained, preserved vegetables may be substituted for them: 1 ℔ of uncooked preserved potatoes are equal to 3½ ℔ of fresh potatoes. Preserved vegetables are in every way superior to compressed vegetables. Owing to the high pressure to which the latter have been subjected, a very large proportion of their salts, with part of their albumin, has been expressed and little remains beyond cellulose (Morache); on this account their anti-scorbutic power is not very great. Preserved vegetables require to be well soaked in water before being used, otherwise they are apt to cause diarrhœa.

The issue of a spirit ration on service has been the subject of much discussion; the whole experience of recent wars is against its issue. There is perhaps no point on which there is a more unanimous opinion than that there should be no daily issue of a spirit ration. Brydon long since pointed out that there was nothing more inimical to the acclimatising process in India than the habitual use of alcohol. But although the daily issue of rum as a ration should be avoided, there are cases in which a ration of alcohol has been found to be productive of the greatest service, even where alcohol in the form of rum and beer may be productive of much evil. The advantage which light red wines possess cannot be passed over. These, well diluted, are most refreshing drinks in hot climates: they should of-course be used in moderation, and for young and "unseasoned" soldiers, probably total abstinence would be better. After a fatiguing march, red wine may be given with advantage: it has a recuperating effect, and may possibly be a preservative against disease. Alcohol should never be allowed before or during a march, but at the end, and then only in the form already indicated. It was formerly supposed to be a preservative against malaria; that this is not so is now abundantly proved by the experiences gained in India and South Africa. There is no evidence to show that the issue of a daily ration of rum has been productive of any good, and in many cases it has certainly done much harm. It is certainly contraindicated in all cases where cholera and enteric fever are likely to occur. On the other hand, light red wine may be given with advantage, as it contains a large amount of salts and tannin, the latter possibly precipitating and rendering innocuous any organic matter in the water.

For rapid expeditions, when transport has to be reduced to the minimum, the use of concentrated and cooked foods is all-important. The men can carry enough for seven or eight days, and are then independent of all base of supply.

Pea and flour sausages, meat biscuits, and dried meat are the best to use; and the issue of cheese and bacon fat, if it can be obtained with these, gives a diet which is fairly nutritious and not disagreeable. The following would be the weight of food which would last a man a week, and render him independent of the Supply Department during that time:—Biscuit, 2 ℔; pea or flour meat sausages, 4 ℔; dried meat, 2 ℔; sugar, ¾ ℔; tea, ¼ ℔; cheese, 1 ℔;—total, 10 ℔. That is to say, a weight of 10 ℔, which would be lessening day by day, would, if properly used by the men, carry them through a week's labour, and although, of course, a meagre diet, would yet enable them to do their work. A special emergency ration has been long under consideration, while the chief facts connected with those at present available have already been detailed on page 358.

In war the supply of food is often difficult, but as an army "fights on its belly," the importance of food at critical movements cannot be overrated. The uncertainty of the time of supply, and the difficulty of cooking, often cause the men to be without food for so many hours as to exhaust them greatly, and not a few actions have been lost or have remained without good result from this cause. This can only be avoided by regimental transport of condensed and ready-cooked food, which may be used on such emergencies, and given in addition to the usual rations issued by the Supply Departments. The colonel of a regiment would then always be sure that he had the means of keeping up the strength and vigour of his men. The Austrians have tried a plan of cooking, which is intended to obviate one difficulty on the march. A Viennese engineer (Herr Beuerle) has altered Papin's digester in such a way as to make it a convenient cooking utensil, and it is now in use in the Austrian ambulances. It is a conical iron pot covered with a lid, and capable of standing the pressure of five atmospheres; the lid is fastened by screws, and a layer of felt or india-rubber is between it and the rim of the pot, so as to exclude air; in the lid is a ventilating opening, weighted to 2·5 ℔ (Austrian = 3·1 ℔ English), so that it opens when the pressure exceeds one atmosphere. The meat, salt, vegetables, &c., are put into this digester, and it is filled up with water till about three fingers' breadth from the top. The amount of water is 1 pint (English) to 1 ℔ of meat (English). This makes so strong a soup that it has to be diluted. The pot with the lid screwed down is put on the fire (three iron supports from which the pot hangs, like a gipsy's kettle, are provided for the field), and as soon as steam is developed, which is known by opening the ventilator a little, the fire is moderated. In an hour and a half the soup is ready. Pots to cook from eight to twenty-five rations are made, and special arrangements are available for cooking potatoes, &c. The plan is, in fact, in principle similar to Warren's compressed-steam boilers, now used in our army, but is simpler.

One advantage in active service of this plan is, that if the troops are surprised, and have to move off their ground before the soup is ready, the pot is simply thrown into the waggon, and at the end of the march the soup is usually found to be ready.

Rations of the French Soldier.—Under the present Regulations in time of peace the Government furnishes the meat for the soldiers' rations at about 35 per cent. under market price. This has proved a great advantage for the soldier. The State also furnishes bread (*pain de munition*) and fuel; the white bread (*pain de soupe*), as well as other articles, are bought from the funds of the *ordinaire*, or common fund of the company, battery, or squadron.

If biscuit is issued, 550 grammes (or 19·4 ounces) are given in place of bread. If salt beef is used, 250 grammes (8·8 ounces) are issued, or 200 (7 ounces) of salt pork. Haricot beans form the chief part of the dried vegetables. The following is the authorised scale:—

	Grammes.	Ounces avoir.
Munition bread,	750	26·4
White bread for soup,	250	8·8
Meat (*uncooked*),	300	10·6
Vegetables (green),	100	3·5
,, (dried),	100	3·5
Salt,	15	0·5
Pepper,	2	0·073 = 31 grains.
Total,	1417	53·373

Analysed by the table for calculating diets, and deducting 20 per cent. from the meat for bone, the water-free food of the French infantry soldier is, in ounces and tenths—

	Water.	Proteids.	Fats.	Carbo-hydrates.	Salts.	Water-free Food.
Meat,	6·30	1·26	0·70	...	0·13	2·09
Bread,	14·15	2·82	0·53	17·25	0·45	21·05
Vegetables (taken as cabbage), .	3·19	0·01	0·00	0·21	0·02	0·24
Vegetables dried (as peas),	0·16	0·24	0·02	0·58	0·02	0·86
Salt,	...	...	...	...	0·50	0·50
Total,	23·80	4·33	1·25	18·04	1·12	24·74

In Algiers the ration of bread is also 750 grammes, or 26·5 ounces, and 8·8 ounces for soup, or biscuit 643 grammes. The meat is the same; 60 grammes of rice and 15 of salt are issued, and, on the march, sugar, coffee, and ¼ litre of wine.

In time of war discretion is given to the Minister of War and the general commanding, by the decree of 26th October 1883, to fix and modify the soldiers' rations, so as to suit the circumstances and places where war may be carried on. By the decree of 16th December 1874, soldiers on board ship receive the same rations as the sailors of the navy, which are much more liberal than those allowed by the military regulations.

Rations of the German Soldier.—The rations in time of peace are divided into the smaller and the larger victualling rations; the former for ordinary use in garrison, the latter for use in camps and in field manœuvres.

	Smaller Ration, in ounces avoir.	Larger Ration, as supplied for Camps, Marches, &c., in ounces avoir.
Bread,	26·47	35·30
Meat (raw),	5·30	17·65
or Bacon, . .	4·41	6·00
or Smoked Meat (only in war time),	...	8·82
Rice,	3·18	6·00
or Groats or Grit,	4·24	6·00
or Peas or Beans,	8·12	12·00
or Potatoes,	53·00	71·00
Salt, . .	...	0·88
Roasted coffee (exceptionally only in war time),	...	1·41
Brandy,	...	3·53
or Beer,	...	35·30
or Wine,	...	17·65
Butter,	...	1·76
Tobacco,	...	1·41

The nutritive value of these diets is as follows:—

Kind of Ration.	Proteids.	Fat.	Carbo-hydrates.	Salts.
Smaller Ration,	3·79	0·77	17·27	0·47
Larger Ration,	4·76	0·95	18·81	0·50

Troops, when travelling by railway or steamer, receive an additional pay of 25 pfennings (= 3 pence) per man for refreshments. Should the travelling last longer than sixteen hours, the additional pay is doubled.

In Time of War.—The supply of rations for the Germans during the Franco-German War was thus conducted:—

1. During the marches in Germany the men were billeted, and money was paid for their food.
2. Supplies were drawn from the magazines.
3. Supplies were obtained by requisition when the troops entered France.

This last plan was a bad one, as was especially shown in the march to Sedan, where the Germans passed over a country previously nearly exhausted by the French. The principal defect was the great uncertainty and irregularity of the supplies; some corps received too much, others too little, and the hospitals especially, which had not men to send out to get supplies, were particularly badly off. The quality of the food was also often bad; the inference being that, as far as the health of the troops is concerned, the system of supplies by requisition should be as little used as possible. It must be noted, however, here, that the Germans did not pay ready money, which might, perhaps, have attracted better supplies than the system of written vouchers. The magazine supplies were excellent, but occasionally failed in certain articles, such as fresh meat, as a substitute for which the celebrated pea-sausage was issued. But it was found that if the pea-sausage was used too exclusively the men disliked it. In fact one of the greatest objections was the too great uniformity of the food. To do away with this, bacon, preserved and smoked meat, peas, and white beans, and potatoes, when possible, were issued as a change of diet.

The want of knowledge of cooking was very great, and the addition also of articles to give flavour, as vinegar and spices, would have been much prized. Roth strongly recommended the establishment of a school for cooking, like that at Aldershot. The bread, owing to the long time it was on transport, was sometimes mouldy.

The daily war ration is now as follows :—

Bread,	26·50 ounces.
Fresh, or raw salt meat,	13·25 ,,
or Smoked beef, mutton, ham, bacon, or sausage,	8·82 ,,
Rice or ground barley,	4·41 ,,
or Peas, beans, or flour,	8·82 ,,
or Potatoes,	53·00 ,,
Salt,	0·90 ,,
Coffee roasted,	0·90 ,,
or Raw coffee,	1·00 ,,

This affords from 4·37 to 5·44 ounces proteids, from 0·71 to 3·71 fat, and from 19·61 to 22·41 of carbo-hydrates.

Rations of the Austro-Hungarian Soldier.—The peace ration consists of the following :—

Bread,	30·88 ounces.
or Biscuit,	17·65 ,,
Meat,	6·71 ,,
Suet,	·62 ,,
Wheat flour,	6·57 ,,
or Legumes,	2·47 ,,
or Groats,	4·94 ,,
or Millet,	5·29 ,,
or Pearl barley,	4·02 ,,
or Potatoes,	19·77 ,,
or Rice,	3·71 ,,
Sauer kraut,	5·54 ,,

This contains proteids, 4·34 ounces; fat, 1·74 ounce; carbo-hydrates, 17·33 ounces, and 0·53 ounce of salts.

The war ration consists of—

Biscuit,	3·53 ounces.
Flour,	25·20 ,,
Beef,	9·88 ,,
or Salt meat,	6·00 ,,
or Bacon,	6·00 ,,
Peas,	5·29 ,,
or Groats,	4·94 ,,
or Potatoes,	8·82 ,,
or Sauer kraut,	5·54 ,,
Suet,	1·06 ,,

The nutritive value of this, with beef, is proteids, 5·15 ounces; fat, 1·66 ounce; carbo-hydrates 22·77 ounces; with bacon, proteids, 3·85 ounces; fat, 4·76 ounces.

Wine, brandy, beer, and coffee are also given.

Rations of the Russian Soldier.—These dietaries are as follows:—

	Peace Ration, in ounces avoir.	Smaller War Ration, in ounces avoir.	Larger War Ration, in ounces avoir.
Rye-bread,	43·35	36·15	36·15
or Biscuit,	28·91	...	...
Flour,	32·65	...	...
Meat,	7·24	14·44	21·67
Groats,	4·80	4·80	4·80
Butter or Tallow,	...	1·34	2·72

The nutritive value of these diets is:—

Kind of Ration.	Proteids.	Fat.	Carbo-hydrates.
Peace Ration,	5·86	0·99	24·74
Smaller War Ration,	3·67	2·58	18·36
Larger War Ration,	5·79	4·13	18·36

Rations of the Italian Soldier.—The peace ration of the Italian soldier is as follows:—

	Ounces avoir.
Bread,	32·40
Meat,	7·06 to 10·59
Bacon, .	0·53
Rice,	5·30
Salt,	0·53
Sugar, .	0·71
Roasted coffee,	0·53
Wine,	8·82

The nutritive value of this diet is:—proteids, 3·99 ounces; fat, 1·34 ounce, and carbo-hydrates, 21·64 ounces.

Rations of the Belgian Soldier.—This ration consists of:—

Munition bread,	26·47 ounces.
White bread,	0·7 ,,
Meat with bone,	8·82 ,,
Potatoes,	35·3 ,,
Butter,	0·7 ,,
Lard,	0·35 ,,
Salt,	1 ,,
Coffee,	0·9 ,,

The nutritive value of this ration is 264 grains of nitrogen and 5920 grains of carbon.

Rations of the Spanish Soldier.—During peace this soldier receives daily 46 centimes, out of which he spends 36 centimes on his food. In addition the State gives him 24 ounces of bread. On service, he either receives extra pay, varying from 12 to 24 centimes daily, or receives a special issue in kind.

Rations of the United States Soldier.—The daily ration in the United States Army is as follows:—

Fresh meat, 20 ounces, or salt beef,	22·00 ounces.
or Pork or bacon,	12·00 ,,
Bread or flour,	18·00 ,,
Potatoes,	16·00 ,,
Peas or beans,	2·40 ,,
Rice,	1·60 ,,
Sugar,	2·40 ,,
Coffee (raw),	1·60 ,,
Salt,	0·25 ,,

Rations of the Indian Sepoy.—This dietary cannot be laid down with any exactitude, as the native soldier is drawn from various races, having varying caste prejudices. The rations issued in the Afghan War, 1878–1880, may be taken as a type of the native soldier's war ration; atta or rice, 2 ℔; ghi, 2 ounces; dhal, 4 ounces; salt, ¾ ounce; also meat and condiments on payment. In some later expeditions, onions and amchur have been issued.

Rations of the Japanese Soldier.—The daily ration in peace consists of 6 go of rice (5½ go = 1 litre) or about 36 ounces in bulk, and 6 cents (or sen) for the purchase of beef, chicken, pork, or fish, and vegetables, tea, pepper, mustard, and miso, a kind of pea flour.

The daily field ration consists of:—

Rice,	36 ounces.
Chicken, beef, pork, or fish,	5 ,,
or Preserved meat,	2½ ,,
or Dried meat,	3¾ ,,
Vegetables, fresh,	5 ,,
or Dried vegetables, .	1⅞ ,,
Spice, made from daikon or other vegetables,	1⅞ ,,
or Preserved plums,	1½ ,,
or Salt,	⅜ ,,
Soy, miso, tea,	sufficiency.

CLOTHING.

In former times a sum of money was granted to colonels of regiments to cover the cost of clothing: this system was not found to answer, and since the Crimean War the Government has taken the supply into its own hands.

The various articles of clothing for the army are prepared, under Government supervision, at the clothing depôt at Pimlico, and every care is taken to test the materials tendered by contractors. All clothing for soldiers is now issued in accordance with the *Regulations for the Supply of Clothing and Necessaries.*

The recruit on enlistment receives a free kit: some of the articles the Government replaces as they become unserviceable, others he is obliged to make good at his own expense, but these are sold at cost price, and a careful man can keep his kit in good order at an annual cost of about £1. The following are the articles of kit supplied to an infantry recruit:—

Clothing.

2 frocks.
2 pairs of trousers.
2 pairs of mitts.
2 pairs of ankle boots (one pair every six months).
1 forage cap.

Necessaries.

- 2 flannel shirts.
- 3 pairs of socks (worsted).
- 1 pair of braces.
- 1 hair-comb.
- 1 knife and fork.
- 1 spoon.
- 1 mess-tin and cover.
- 2 towels.
- 1 soap (piece).
- 1 sponge (pipe-clay).
- 1 razor and case.
- 1 hold-all.
- 1 tin of blacking.
- 1 blacking-brush.
- 1 brass-brush.
- 1 cloth-brush.
- 1 polishing-brush.
- 1 shaving-brush.
- 1 button-brass.
- 1 kit-bag.

The kit is divided into the personal and the public kit. The former, consisting of a frock, a tunic, a pair of trousers, a pair of boots, and all necessaries. The public clothing consists of a great-coat with cape, a helmet or other head-gear, a pair of leggings, and a haversack.

Certain articles are also issued free of expense at stated intervals. For the particulars of these, reference must be made to the *Regulations*, where they are stated in detail. The following are the articles issued to the infantry soldier of the line at home:—

1 helmet and bag,	Quadrennially.
1 tunic,	Biennially.
1 frock (undress), .	Annually.
1 pair tweed trousers,	Annually.
1 pair tweed trousers, .	Biennially.
2 pairs of boots, one on 1st April and one on 1st October,	Annually.
1 Forage cap, . .	Annually.
1 silk sash for warrant officers and staff sergeants,	Biennially.
1 worsted sash for sergeants,	Biennially.
1 greatcoat,	Every five years.
1 pair mitts,	Triennially.

In India and other tropical stations light clothing of different kinds is used—drill trousers and jackets, or in India complete suits of the khaki, a native grey or dust-coloured cloth, or tunics of red serge and very light cloth. The English dress is worn on certain occasions, and during the cold weather season, or in certain stations.

For other stations abroad, soldiers are supplied before embarkation, if possible, with any new articles of personal clothing that may be necessary owing to differences of climate, pattern or scale. Similarly, before proceeding on active service the soldier is supplied with additional articles of clothing according to the circumstances of climate and season.

In selecting the material for soldiers' clothing the chief points to be considered are, its permeability, durability, and the property it has of conducting and absorbing heat.

Cotton is durable, does not shrink when washed, is non-absorbent of moisture, conducts heat rapidly away, and has the effect of chilling the body if perspiration is present. Hence it is not the material for the dress or undergarments of soldiers. It is also non-permeable to air, possessing little more than half the porosity of flannel.

Linen, like cotton, is a good conductor of heat but a bad absorbent of moisture; it soon soaks up the moisture from the skin, and this evaporating so cools the body as to cause chills. In many respects, however, it is inferior to cotton for underclothing.

"Cellular" cotton has of late years been introduced as a substitute for cotton and linen. In the process of manufacture interspaces for air are left in the texture. Air being a bad conductor of heat, the cellular cotton is warmer than cotton clothing.

Wool is by far the best material for underclothing; it has very large absorbing properties for moisture, conducts heat very slowly, and thus prevents cooling of the surface of the body after exercise; it is nearly twice as permeable to air as cotton; for these reasons woollen garments are best adapted for ensuring an equable temperature round the body, and should be invariably used on military service. In all campaigns it has been found the best material and the best preservative against illness. The non-conducting properties of wool may be in part due to the fibres, which contain a proportion of fatty matter, as well as to the large amount of air entangled in the interspaces.

Jægers' woollen underclothing is so woven that it is not irritating to the skin, and the arrangement of the constituent hairs provides for the escape of moisture. It is largely used in the German Army.

The disadvantages of woollen clothing are, that the material becomes hard and shrinks on washing, and thus loses in part its absorbing properties. This can, in every case, be obviated by using a soap free from any excess of alkali. The alkali acts on the natural oil of the wool, and materially injures it. The addition of a little paraffin to the soap is said to facilitate the removal of dirt.

Soldiers' shirts, made at Pimlico, are manufactured from a mixture of cotton and wool: this material is lighter and cheaper than pure wool, and is said to be more durable; it does not shrink in washing: there should not be more than 30 per cent. of cotton in the mixture.

The colour of the material has an important bearing on the hygienic value of the clothing, and in regard to the absorption of heat exerts more influence than the material itself. The results of experiments made at Aldershot show that white possesses very slight absorptive power compared to other colours, and, next to this in the scale, grey or pale yellow gives the best results: grey is the best colour for soldiers' dress on service, white is least suited for the field, as it soils so quickly; the khaki drill used in India appears to answer well, and, as regards absorption power, corresponds very closely with grey.

All clothing should be made to fit loosely, so as to allow free movement of every part of the body, otherwise mechanical work is increased. In the British Army the underclothing consists of shirts, stockings, and flannel belts. The shirts are made of a mixture of wool and cotton. In hot climates all wool would probably be found a better material; but the collar band should be made of linen to avoid shrinkage, and consequently tightness round the neck. Drawers find no place in the soldier's kit: they are cleanly, and necessary to provide warmth for the legs and lower part of the abdomen. Many soldiers provide themselves with these articles.

Socks are made of worsted. The number supplied is too small, and, as there is often excess of perspiration, they should be frequently washed. It is probable that sore feet are frequently due to this cause. A good sock, kept clean, is a protective against sore feet. Flannel belts are useful to protect the abdomen from chill. A watch must, however, be kept to see that men wear them, especially in hot climates. It is astonishing to find the number of men who neglect to do so.

The tunic—the coat worn by the British soldier—is close fitting, and to some extent compresses the muscles, and interferes with the free movement of the chest. If loosely made, it does not give the same appearance of smartness to the men. For active service the tunic is made looser, and generally of some thin material (this will depend on the climate); but serge is always preferable to cotton. A loose Norfolk jacket is the pattern usually adopted in India, and this seems to meet all necessary requirements.

Trousers should be large over the lower part of the pelvis. Parkes recommended the "peg-top" shaped trousers as being the best pattern, and if "putties" are worn with these, they make a most serviceable dress. The putties give support to the leg, and protect it from the bites of insects.

Braces are preferable to a belt round the waist. They form a better means of support, and do not compress any part, which a belt invariably must do. This latter is also said to predispose to hernia.

The greatcoat and cape is issued in three sizes, and weighs from 5 ℔ 8 oz. to 6 ℔ 3 oz. They are all made double-breasted, but seldom long enough. The cloth is excellent, but it is rather heavy, absorbs a large quantity of moisture, and is difficult to dry. It would be an advantage if the greatcoat could be made of a lighter material, and waterproof.

For service in the field a waterproof sheet is an imperative necessity, to protect against rain or ground moisture. The waterproof sheet should always be used to lie on unless employed to form a temporary *tente d'abri.*

Cloth may be made waterproof by the following simple plan:—Make a weak solution of glue, and while it is hot add alum in the proportion of 1 ounce to 2 quarts; as soon as the alum is dissolved, and while the solution is hot, brush it well over the surface of the cloth, and then dry. It is said that the addition of 2 drachms of sulphate of copper is an improvement. Hiller describes a useful method of waterproofing porous materials, as cloaks, &c., by dipping them alternately in a solution of sulphate or acetate of alumina and of soap.

Such articles as sheepskin coats, hoods, gloves, &c., issued for protection against very severe cold, are necessary, and are fully justified by the results following their use.

The head-dress is an important article of the soldier's kit. The essentials of a good head-dress are that it should be light, durable, and comfortable; that it does not press unduly on any part, nor fit too closely on the head. It should admit of a limited amount of ventilation, and its shape should not only serve as a protection to the head, but it should afford as little resistance as possible to the wind.

Helmets are now issued to infantry regiments, artillery, and engineers, and also to departmental corps.

Bear-skin caps are worn by the Guards, Highland bonnets and shakoes by Highland regiments, and a seal-skin cap by Fusilier regiments.

The infantry helmet weighs 14½ ounces. It is made of cork covered with cloth. The weight of the bear-skin is 37 ounces.

In the cavalry and horse artillery, helmets are also worn, but of a slightly different pattern. They are of excellent shape, but rather heavy. In the Guards and Heavy Dragoons the helmet is of metal, and is partly intended for defence. The weight of the Life Guard's helmet is 55 ounces, and that of the Dragoon Guards 39 ounces. Were the helmet made of aluminium, these weights might be considerably reduced. The Lancer cap weighs 29½ ounces, the Hussar 28½ ounces.

In India the same head-dress is worn by all the different branches of the Service. Helmets made of bamboo or cork, covered with cotton and provided with puggeries, are now used; they are very light—13 ounces—and afford good protection from the sun.

The "Tuson helmet" has lately been adopted by some regiments in India. It consists of two bodies, one within the other, forming a complete air-chamber, not only in the crown but in the brim, thereby completely protecting the temples and the nape of the neck. The weight with chin strap and button is only 11½ ounces; with chin strap and spike, 14 ounces.

In the French Army a shako, made of pasteboard and covered with leather, is worn. It is very hot.

Leggings are now used by all dismounted branches of the Service: they are made of leather, and reach from the ankle nearly to the knee. The great advantage of leggings is that at the end of a march they can be at once taken off and cleaned. In India, "putties" are used for the same purpose, and are found most comfortable, affording protection and support. They are worn by the mounted branches also.

The boots are supplied from the clothing depôt at Pimlico, and are in thirty-two sizes, made right and left, and weigh about 40 ounces. The sole is wide and the heel low and broad. The leather has to be of a certain quality, and a number are always cut up and examined before a contract is passed. There must be eight stitches per inch for the upper leather, and the thread must be of a certain strength and well waxed. The great fault of this boot is its hardness and the rough way in which it is finished. Once it is moulded by wear to the shape of the foot, it is an excellent boot. In the Russian Army boots made of a soft and pliable leather are issued, and foot-soreness is said to be unknown: the Russians appear fully to understand the advantages gained by this.

The English boot seems to require some other means of fastening it. The number of eyelet-holes cause waste of time in fastening, and the thong is liable to break. The "Elcho" boot is worn by officers on service: it is a long boot with a slit down the centre: it may be worn under the trousers or outside, as the slit opens and can be laced. There is no difficulty in taking off this boot when wet, as was so frequently the case with the old pattern.

For service in the field, boots should, if possible, be made impermeable to wet. Parkes recommended the following receipt, which he tried and found effectual. Take half a pound of shoemaker's dubbing, half a pint of linseed oil, half a pint of solution of india-rubber. Dissolve with gentle heat (the mixture is very inflammable), and rub on the boots. This will last for five or six months, but it is well to renew it every three months. Army orders direct (1) that soldiers' boots are to be blackened with three coats of ordinary blacking instead of other substances. (2) Boots or shoes in store are to be dubbed, or have neat's-foot oil applied to uppers at least once in four months.

Weights of the Articles of Dress and Accoutrements, and on the Modes of Carrying the Weights.—The following tables give the weights of all the articles carried by the light cavalry and the infantry of the line. The weights carried by the artillery are much the same as those of the cavalry. The weights of the helmets of the life and horse guards have been already mentioned. The cuirass weighs 10 ℔ 12 oz.; it rests a little on the sacrum and hip, and in that way is more easily borne by the man. With these exceptions, the weights may be considered nearly the same as those of the heavy dragoons.

Cavalry.—The weight of the accoutrements and equipment is in great part carried by the horse. The cloak, when not worn, is carried in a roll over the shoulder, or sometimes round the neck, or in front on the horse.

The following weights for *light* cavalry will serve to indicate what a horse has to carry on active service :—

	st.	℔	oz.
The rider (say),	10	4	0
Clothes on rider, viz., flannel shirt, drawers, socks, braces, head-dress, tunic, pantaloons, boots, spurs, gloves, and flannel belt,	1	1	11
Arms, &c., belts and sword,	0	7	0
Carbine,	0	7	7
Ammunition, 30 rounds,	0	4	8
Saddlery, viz., saddle and bridle complete, breastplate, wallets, shoe cases, numnah, head rope and carbine bucket	2	9	11
Small blanket under saddle,	0	2	0
Kit of rider, viz., clothes brush, stable sponge, oil-bottle, pot of grease, horse-rubber, pocket-ledger, field-dressing, horse brush, curry-comb, flannel shirt, drawers, socks, towel and piece of soap, hold-all with needles and thread, kit scissors, fork, spoon, comb, and forage cap,	0	7	5
One day's reserve rations (sausage), say,	0	0	12
Cloak and waterproof sheet,	0	9	8
Mess-tin and strap,	0	1	4
Haversack, water-bottle, and pocket-knife,	0	1	12
Hoof-picker, nose-bag, picket-peg, heel-rope, and shackle,	0	4	1
Hay net, corn-sack,	0	3	12
A fore and hind shoe with nails,	0	1	14½
Balance of man's rations, &c. (say),	0	1	0
Balance of horse's forage, &c. (say),	0	6	0
Mallet (when carried),	0	2	0
Total,	18	5	9½

Infantry.—The articles of the infantry soldier's kit have been already noted. This kit may be divided into the service and the surplus kit, the latter being always carried for, and not by, the man. The service kit consists of the clothes he wears, and of some duplicate articles and other necessaries.

The following are the weights of the 1888 valise equipment in different "Marching Orders" :—

1. *Service Marching Order.*

	℔	oz.
1 Valise,	1	8½
1 Pair of braces and chapes,	0	13½
1 Waist-belt,	0	12½
2 Pouches,	1	3
1 Haversack,	0	9½
1 Mess-tin, cover, and strap,	1	11
1 Water-bottle and carrier,	1	0
2 Coat straps,	0	5
1 Frog for side-arm,	0	3½
1 Greatcoat,	4	6
1 Cape,	2	0
1 Rifle and sling (magazine),	9	8
1 Bayonet and scabbard,	1	1
1 Magazine pouch,	0	4
1 Spade,	2	9¾
Total,	27	15¼

2. *Home Marching Order.*

	lb	oz.
2 Pouches,	1	3
Haversack,	0	9½
Water-bottle and carrier,	1	0
Greatcoat and cape, with slings,	6	11
Mess-tin, cover, and strap,	1	11
Valise,	1	8½
Pair of braces and chapes,	0	13½
Rifle and sling,	9	8
Bayonet, scabbard, and frog,	1	4½
Waist-belt,	0	12½
Total,	25	1½

3. *Light Service Order.*

	lb	oz.
Same as service marching order,	27	15¼
But without valise, braces and chapes,	2	6
	25	9¼
Add waterproof sheet,	4	4
Total,	29	13¼

Additional Weight carried on Service

	lb	oz.
Field kit,	5	6
Rations,	2	0
Water (in bottle),	1	8
Ammunition (magazine),	6	4
Waterproof sheet,	4	4
Total,	19	6

In the cavalry the weight carried appears to be too great: the weight of his clothing and equipment is equal nearly to the man himself. It is a mistake to overweight the horse; the long and rapid marches cavalry have to make tell especially on the horse when he is overpowered by such a weight as 19 stone, and it is of no less importance to keep the horse effective as it is his rider.

In the case of the infantry soldier, who carries the weights himself, the greatest care is necessary in their arrangement so as not to detract from his efficiency or to injure his health. Whenever possible, his kit, as far as he can dispense with it, should be carried for him, with the exception of his armament and water-bottle. The advantage of transporting a soldier's knapsack for him is well recognised in India, where longer marches, greater endurance, and efficiency are found to result from this practice.

The chief points to attend to are to so adjust the weights that when carried they fall as near the centre of gravity as possible, and not outside; there must be no compression of the chest, so as to interfere with perfect freedom of respiration, or with the circulation by pressure on the arteries or veins. The weight should be distributed as far as possible, so as to avoid fatiguing one set of muscles.

Soldiers should be taught to carry weights, so as to dispose of them comfortably, and then cease to carry them, unless absolutely required to do so.

The present equipment is partly based on the plans recommended by the late Sir T. Trowbridge, but there have been many improvements since it was first introduced. The principle is to use the point of the shoulders and the sacrum on which to distribute the weight. The old framed knapsack has been abandoned, and a valise equipment substituted.

The present valise equipment (pattern 1888) possesses the great advantage that it is light and very simple. In a few seconds the soldier can change from "marching" to "service" order by merely detaching the valise from the remainder of the equipment. The pouches are so constructed that whilst the ammunition can be easily reached, liability to loss is provided against. Greater freedom of action is allowed, as the straps under the arms are dispensed with. This valise costs less than the former patterns. It is made of japanned canvas and is carried on the back of the shoulders, and is so arranged that it adapts itself to the width of the soldier's shoulders.

The valise holds the following articles:—Emergency ration; towel and soap; clothes-brush; hold-all complete; housewife, fitted; pocket ledger; one pair of socks; canvas shoes; and cape carried under the flap.

The ammunition is carried in two pouches; the right hand is the "expense" pouch containing thirty rounds, the left being the "reserve" holding forty rounds.

The mess-tin is carried on the top of the greatcoat or under the coat, when this is carried on the shoulders, or it may be fastened to the waist-belt; in each case it can be detached without interfering with the rest of the equipment.

The German soldier carries his kit in a cowskin knapsack, which is encircled by the rolled greatcoat, and to the back of it a camp kettle is strapped.

The ammunition is carried in the two front pouches. The haversack, to which a drinking flask is attached by a clip, is worn at the right side; on the left an entrenching spade is strapped, the bayonet hanging over it. The total weight carried is about 70 ℔.

The helmet is of polished leather with spike and ornaments of brass; it is low, fits tightly on the head, and is rather heavy. His arm is the "Mannlicher" repeating rifle. The ammunition is made up in magazines holding five cartridges in each: these fit into the pouch. The following weights are carried by the German infantry soldiers:—

	lb.	oz.
Clothing on the person (with gloves), not including helmet, . .	23	8
Armament and equipment, including helmet, water-bottle (full), coffee-mill, and entrenching tools,	42	8
Sundries,	1	13
Rations,	5	12
Total,	73	9

Some of the articles are not always carried by the same man, such as the coffee-mill, hatchet, and spade, so the weight may be lessened to 67 ℔—average weight carried, 67 to 71 ℔. His rifle weighs 10 ℔ and the bayonet 1 ℔ 8½ oz.

In the French Army the soldier wears his coat rather long, but has the skirts buttoned back; his trousers are usually turned up at the bottom over shoes and leggings. His kit is carried in a cowskin knapsack round which a blanket and portions of a shelter tent are strapped, the whole surmounted by a camp kettle. Two pouches carry his ammunition—one in front and the other in rear of the waist-belt. A flask and drinking cup hang at the right side, and a canvas haversack at the left. His "képi," or shako, is made of leather or pasteboard, and to make it as light as possible, it is divested of all unnecessary ornaments. His arm is the "Lebel" repeating rifle, in which nine cartridges are placed, and can be discharged in succession without reloading. The total weight carried by the French infantry soldier is nearly 67 ℔.

The Austrian soldier carries his kit in a cowskin knapsack, around which is strapped his overcoat, and on the back a camp kettle. The whole can be immediately detached by withdrawing a pin in the right shoulder strap. Two pouches in front contain the ammunition, and an additional supply is carried in a cartridge box of the same material as, and immediately under, the knapsack. The drinking flask is suspended at the left breast. A brown canvas haversack hangs at the left side, and the entrenching spade is strapped to it, over which again hangs the short sword-bayonet by a frog from the waistcoat. For parade purposes he is provided with a tunic and shako, but on service in the field he wears a loose blouse, with pockets, and a field cap, with flaps, which can be unbuttoned when necessary.

His arm is the same in every respect as the German soldier. The total weight carried on service in the field is about 60 ℔.

The Russian soldier's equipment consists of two large waterproof canvas satchels slung over each shoulder; that on the right side contains clothing and necessaries, while the left one is used as the ordinary haversack. The greatcoat is rolled and worn round the body; to the middle of it, at the back, a case containing a spare pair of boots is affixed, and below that the man's portion of a shelter tent. To the coat-ends a copper camp kettle is fastened by its handle. A water-bottle hangs over the left haversack, and an entrenching spade is strapped by its blade to the waist-belt. The ammunition is carried in two pouches in front. His present rifle is being replaced by the French Lebel rifle. In the field his head-dress is a forage cap made of black cloth with coloured band. Total weight carried is about 74 ℔.

The Italian soldier carries his equipment in a knapsack made of cowskin: round it is the greatcoat, and his camp kettle is strapped at the back. The waist-belt is worn under the tunic, the skirts of which are buttoned back in front to allow the ammunition pouch to protrude. A water-bottle is worn on the right side, the haversack and sword-bayonet at the left side. In the field a white cover is worn over the ordinary shako. His arm is the Vitali repeating rifle. The weight carried is about 75 ℔.

Weights are most easily borne when the following points are attended to:—

1. They must lie as near the centre of gravity as possible. In the upright position the centre of gravity is between the pelvis and the centre of the body, usually midway between the umbilicus and pubis, but varying of course with the position of the body; a line prolonged to the ground passes through the astragalus just in front of the os calcis. Hence weights carried on the head or top of the shoulder, or which can be thrown towards the centre of the hip bones, are carried most easily, being directly over the line of the centre of gravity. When a weight is carried away from this line the centre of gravity is displaced, and, in proportion to the added weight, occupies a point more or less distant from the usual site; until, perhaps, it is so far removed from this that a line prolonged downwards falls beyond the feet; the man then falls, unless, by bending his body and bringing the added weight nearer the centre, he keep the line well within the space which his feet cover.

In the distribution of weights, then, the first rule is to keep the weight near the centre; hence the old mode of carrying the soldier's greatcoat, viz., on the back of the knapsack, was a bad one, as it put on weight at the greatest possible distance from the centre of gravity.

2. The weights must in no case compress the lungs, or in any way interfere with the respiratory movements and the elimination of carbon dioxide, or hinder the transmission of blood through the lungs, or render difficult the action of the heart.

3. No important muscles, vessels, or nerves should be pressed upon. This is self-evident; an example may be taken from the old Regulation pack, the arm-straps of which so pressed on the axillary nerves and veins as to cause numbness, and often swelling of the hands, which has been known to last for twenty-five hours.

4. The weights should be distributed as much as possible over several parts of the body.

If we consider the means made use of by those who carry great weights, we find the following points selected for bearing them:—

1. The top of the head. The cause of this is obvious; the weight is completely in the line of centre of gravity, and in movement is kept balanced over it. Of course, however, very great weights cannot be carried in this way.

2. The tops of the scapulæ, just over the supra-spinous fossa and ridge. At this point the weight is well over the centre of gravity, and it is also diffused over a large surface of the ribs by the pressure of the scapula.

3. The hip bones and sacrum. Here, also, the weight is near the centre of gravity, and is borne by the strong bony arch of the hips, the strongest part of the body.

In addition, great use is always made of the principle of balancing by those who have to carry great weights. The packman of England used to carry from 40 to even 60 ℔ easily thirty miles a day by taking the top of the scapula for the fixed point, and having half the weight in front of the chest and half behind. In this way he still brought the weight over the centre of gravity. The same point, and an analogous system of balance, is used by the milkmaid, who can carry more weight for a greater distance than the strongest guardsman equipped with the old military accoutrements and pack.

These points must guide us in arranging the weights carried by the soldier. The weight on the head is, of course, out of the question. We have, therefore, only the scapulæ, the hip, and the principle of balance to take into consideration when carrying weights.

WORK OF THE SOLDIER.

The work of the soldier mainly depends on the branch of the service to which he belongs, and, therefore, it cannot be brought under one general description.

The artillery have the hardest work, which comprises mostly cleaning horses, guns, carriages, and stables; the cavalry have very nearly the same amount of work to get through, although their stable duties consist nearly altogether in looking after their horses, but their movements on parade are more rapid, and the distances they cover are greater than the artillery. The infantry duties are mostly confined to drills, marches, and fatigue work in barracks.

All these duties, when not excessive, have a beneficial effect, but when severe and violent work has to be done hurriedly, the soldier is not placed in the same favourable condition to carry out the work as the ordinary mechanic would be; this is due to the movement of his body being limited owing to his being burdened, more or less, with the weight of his accoutrements and his clothes.

With a view to assist in the physical development of the soldier, every recruit is ordered to have a three months' course of gymnastic training. The exercises last for one hour daily and are in addition to his ordinary drill. The training is superintended by a medical officer, who is responsible that it is done properly, and who has the power to discontinue the exercises, if there is any evidence of their acting injuriously, the symptoms indicating the necessity for rest being hurried or difficult respiration, and smallness, inequality, or irregularity of the pulse. The infantry soldier goes through this course every year, but in the cavalry fencing and sword exercise are substituted for it.

During the training the men are carefully examined from time to time and measurements taken to ascertain what effect it has on their physical development. The *Regulations* lay down that each man's weight must be taken at the beginning and end of each course and oftener if there is any reason to believe that a loss in body weight is taking place, care being taken that the weight is recorded under the same conditions, as far as possible, each time. Men should be weighed in their trousers only; the early morning and before breakfast is the best time.

Most medical officers consider that, as regards chest measurements, the extent of mobility is of more practical value than the actual maximum and minimum measurements of the chest walls, for it is expansion that shows capacity for sudden or sustained effort. As a rule, also, the growth of muscle follows on gymnastic training. Measurements should be taken when the muscle is relaxed and when tense also, over the thickest part. Much of the success due to gymnastic training is due to the instructor: if he has patience and the men are not urged to repeated exertion, but sufficient rest allowed between the exercises, and the work constantly varied, there is little danger of any undue strain on the heart or blood-vessels. The ordinary duties of barrack life may be said to consist in drills, fatigue duties, and marches; in the drills the position is more or less strained, and the nature of his dress and equipment adds to the work which the soldier is called upon to do.

Drills and Marches.—In all drills and marches the movements are to a certain extent stiff. The position of "attention" is not a secure one, as the basis of support is small, and muscular action is necessary to maintain the equilibrium. It is not desirable to keep men long in this attitude, and they are told to "stand at ease." In this position the heels, in place of being together as at "attention," are further apart, and afford a broader basis of support.

In marching, the attitude is stiff; the centre of gravity is constantly shifting from one foot to the other in a constrained way; the lateral movement which is made in ordinary walking is limited; it is certainly more fatiguing than ordinary walking. For this reason, whenever practicable, the order is given to "march at ease," in which there is more gradual and not nearly so much loss of muscular strength.

In walking, the heel touches the ground first, and then rapidly the rest of the foot, and the great toe leaves the ground last. The soldier, in some countries, is taught to place the foot almost flat on the ground, but this is a mistake, as the body loses in part the advantage of the buffer-like mechanism of the heel. The toes are turned out at an angle of about 30° to 45°, and at each step the leg advances forward and a little outward; the centre of gravity, which is between the navel and the pubis, about in a line with the promontory of the sacrum (Weber), is constantly shifting. It has been supposed that it would be of advantage to keep the foot quite straight, or to turn the toes a little in, and to let the feet advance almost in a line with each other. But the advantage of keeping the feet apart and the toes turned out is that, first, the feet can advance in a straight line, which is obviously the action of the great *vasti* muscles in front of the thigh; and second, when the body is brought over the foot, the turned-out toes give a much broader base of support than when the foot is straight. The spring from the great toe may perhaps be a little greater when the foot is straight (although this is doubtful, and there seems no reason why the gastrocnemii and solei should contract better in this position), but there is a loss of spring from the other toes. Besides this, it has been shown by Weber that when the leg is at its greatest length, *i.e.*, when it has just urged the body forward, and is lifted from the ground, it falls forward like a pendulum from its own weight, not from muscular action, and this advance is from within and behind to without and before, so that this action alone carries the leg outwards.

The foot should be raised from the ground only so far as is necessary to clear obstacles. Formerly, in the Russian Imperial Guard, the men were taught to march with a peculiar high step, the knee being lifted almost to a level with the acetabulum. The effect was striking, but the waste of power was so great that long marches were impossible, and this kind of marching is now given up. The foot should never be advanced beyond the place where it is to be put down: to do so is a waste of labour.

In the English Army the order is as follows:—

Length and Number of Steps in Marching.

Kind of Step.	Length.	No. per Minute.	Ground Traversed per Minute.	Ground Traversed per Hour without Halts.
	Inches.		Feet.	Miles.
Slow time,	30	75	187½	2·1
Quick time,	30	116	290	3·3
Stepping out,	33	110	303½	3·4
Double,	33	165	453¾	5·157
Stepping short,	21	...	...	...
Side step,	13½	...	...	...
Or when				
Forming four deep,	24	...	...	...
Stepping back,	30	...	...	...

The length of the step of an average soldier is 27 inches. It is of great importance not to lessen the length too much, and it would be very desirable to have some well-conducted experiments on this point. The steps must be shorter if weights are carried than without them; a little consideration shows how this is: When a man walks, he lifts his whole body and propels it forward, and in doing so the point of centre of gravity describes a circular motion, in the form of an arc about the foot. The less the body is raised, or, in other words, the shorter the versed sine of the arc, the less of course the labour. In long steps the arc, and of course the versed sine, or height to which the body is raised, are greater; in short steps, less. Weber, however, has shown that the angle at which the body is bent, and, consequently, the coefficient of resistance, are not affected by the length of step, provided the velocity remains the same. It is probable, that with the weight the soldier carries (60 lb), the step of 30 inches is quite long enough.

From some very careful observations by Lawson, during a march of the 47th Regiment from Boyle to Naas, the length of pace was found to average 30·41 inches, the number per minute being 116 or 117, and the rate of marching 3·34 miles per hour. The paces were frequently counted, and found to range between 112 and 120 per minute: the length was sometimes as much as 31·38 inches. The circumstances of the march were favourable, but the men were in heavy marching order, carrying 60 rounds of ball cartridge.

In the German Army the step is 31·2 inches, there are 112 per minute, and the ground traversed is over 3 miles an hour. In the Austro-Hungarian Army the men take 120 steps per minute, each step being 29 inches; this is equivalent to a distance of from 3·2 to 3·6 miles per hour. In the Italian Army the step is practically the same. A Russian soldier covers 28 inches at each step, at an average rate of 120 per minute, or at a speed of 2⅔ miles per hour.

In the French Army the march is commenced at 120 steps per minute; then accelerated to 125 or even 135 steps; during the last half-hour 120 steps are returned to. Four kilometers (= 2½ miles) per hour is considered a good general average (Laveran).

The soldier, in this country, when he marches in time of peace in service order, carries his valise, containing his kit, two pouches, haversack, water-bottle, greatcoat, gaiters, mess-tin, rifle, and ammunition. In India he does not carry his valise or greatcoat.

There is a very general impression that the best marchers are men of middle size, and that very tall men do not march so well.

Length of the March.—In "marching out" in time of peace, which is done once or twice a week in the winter, the distance is 8 or 10 miles. In marching on the route or in war, the distance is from 10 or 12 miles to occasionally 18 or 20, but that is a long march. A forced march is any distance—25 to 30, and occasionally even 40 miles being covered in twenty-four hours. In the French Army the length of march is from 20 to 25 kilometres (12½ to 15 miles). In the German Army the usual march is 14 miles (English); if the march is continuous, there is a halt every fourth day. Anything beyond this is rarely achieved, except occasionally by small bodies of men.

Conditions rendering Marches Slower.—The larger the body of men the slower the march; 14 miles will be covered in six or seven hours by two or three regiments, but not under eight or nine hours by 8000 or 10,000 men. A large army will not go over 14 miles under ten hours usually. A single regiment can do 20 miles in eight hours, but a large army will take twelve or fourteen, including halts. Head winds greatly delay marches; a very strong wind acting on a body of men will cause a difference of 20 to 25 per cent., or only 4 miles will be traversed instead of 5. Snow and rain, without head wind, delay about 10 to 15 per cent., or 4½ miles are done instead of 5.

During marches, regular halts are necessary in order to rest the muscles, and to relieve them from continuous tension. Lord Wolseley recommends a halt of five to ten minutes every hour, and when the march extends for 10 or 12 miles, to halt for thirty minutes when half-way; and this appears to be a true economy of labour.

Frequent short halts allow the muscles to rest, and there is economy of force with less fatigue by working for a short period with a short period of rest, than by working for a long period with only one period of rest.

In tropical countries the time of marching should be so arranged that, if possible, the sun should not fall on the backs of the men. This can usually be avoided by using the early morning hours for the march.

Night marches should rarely be resorted to. In the tropics the soldier cannot sleep during the day in tents, and marching at night destroys the only rest available. All experience shows that night marches sap men's strength and fill the hospitals: this time should be utilised for the purpose for which nature intended it. The early morning hours are the best: men appear to traverse the ground easier and to feel the fatigue less.

When the distance covered is over 15 or 16 miles, men should halt for dinner, and have an evening meal on reaching camp. Marches should not be too long prolonged, especially at first; regular halts should be arranged for, and at least on one whole day during the week, with a short march on one other day. The other rules are simple: ample food, good water, and lighten and adjust the loads a man has to carry in every possible way. No spirit ration is necessary, and none should be allowed.

If a malarious tract of country has to be crossed, this should be done in a temperate climate in the daytime, and in the tropics in the afternoon. The danger of malaria is greater in the very early morning than at any other time, and when the march can be accomplished without a halt this should be done. If the distance is too great, and a halt is necessary, a dose of quinine may be given, and the men cautioned against exposing themselves to the early morning air more than is necessary. Before leaving camp the men should have a good ration of bread, with coffee or cocoa. The men should start on the march at "quick time," and in the most open order, for if the ranks close up the temperature mounts up, and the air is vitiated with the products of respiration and transpiration.

If the march is a continuous one and in a tropical country, men should be allowed to unbutton their coats, and be relieved from all superfluous weight. Good water or cold tea should be provided, as any deficiency in the supply of fluids will obviously diminish perspiration, and the temperature of the body will rise. The effete matters removed by free perspiration will be retained, and a condition favouring heat-stroke established.

On the march in a tropical climate, the heat developed within the system must be dissipated by transpiration and respiration in order to preserve the normal temperature of the body. The soldier starts at a disadvantage: he is loaded with his kit and armament, so that in addition to the muscular fatigue and extra work done in carrying these, the result of exercise under such conditions is that he is bathed in perspiration, which actually causes a loss of water from the system, without a commensurate lowering of body-heat. If the atmosphere is moist, this further interferes with evaporation; or the want of water to replace that lost by excessive perspiration may cause the skin speedily to become dry. From this we see that the suppression of evaporation consequent on a deficient water-supply causes the temperature to rise and favours the occurrence of heat-stroke.

For the same reason on the march the order should be "open order." Nothing fatigues men more than keeping "close order"; evaporation is checked, the temperature in the ranks goes up, and with it the body temperature. Without ventilation through the ranks the air becomes foul, owing to the giving-off of organic matter and watery vapour.

At the end of a march men should be dismissed from parade as soon as possible, so as to avoid inducing further fatigue. On being dismissed, they should wash their feet and change their socks: this is the best preventative against footsoreness.

Duties of Medical Officers during Marches.—Before commencing the march, order all men with sore feet to report themselves. See that all the men have their proper kits, neither more nor less. Every man should be provided with a water-bottle to hold not less than a pint. Inspect halting-grounds, if possible; see that they are perfectly clean, and that everything is ready for the men. In India, on some of the trunk roads there are regular halting-grounds set apart. The conservancy of these should be very carefully looked to, else they become nothing but foci for disseminating disease. If there are no such places, halting-grounds are selected. It should be a rule never to occupy an encamping ground previously used by another corps if it can be avoided; this applies to all cases. Select a position to windward of such an old camp, and keep as far as possible from it. The encampments of the transport department, elephants, camels, bullock carts, &c., must be looked to,—they often are very dirty: keep them to leeward of the camp, not too near, and see especially that there is no chance of their contaminating streams supplying drinking water. If the encampment is on the banks of a stream, the proper place for the native camp and bazaar will always be lower down the stream. A medical officer, if he can be spared, should be sent forward for this purpose with an executive officer. Advise on length of marches, halts, &c., and draw up a set of plain rules to be promulgated by the commanding officer, directing the men how to manage on the march if exposed to great heat or cold, or to long-continued exertion, how to purify water, clean their clothes, &c. If the march is to last some time, and if halts are made for two or three days at a time, write a set of instructions for ventilating and cleaning tents, regulation of latrines, &c.

Inspect the breakfast or morning refreshment; see that the men get their coffee, &c. On no account approve of the issue of a morning dram, either in malarious regions or elsewhere. Inspect the water-casks, and see them properly placed, so that the men may be supplied; inspect some of the men, to see that the water-bottles are full. March in rear of the regiment so as to take cognisance of all the men that fall out, and order those who cannot march to be carried in waggons, dhoolies, &c., or to be relieved of their packs, &c. The medical officer with a regiment should always be in the rear.

Special orders should be given that, at the halt, or at the end of the day's march, the heated men should not uncover themselves. They should take off their pack and belts, but keep on the clothes, and, if very hot, should put on their greatcoats. The reason of this (viz., the great danger of chill *after* exertion) should be explained to them.

At the end of the march inspect the footsore men. Footsoreness is generally a great trouble and frequently arises from faulty boots, undue pressure, chafing, riding of the toes from narrow soles, &c. Rubbing the feet with tallow, or oil or fat of any kind, before marching, is a common remedy. In the late war the Germans found tannin very useful,—they used an ointment of one part of tannin to twenty parts of zinc ointment. A good plan is to dip the feet in very hot water, before starting, for a minute or two; wipe them quite dry, then rub them with soap (soft soap is the best) till there is a lather; then put on the stocking. At the end of the day, if the feet are sore, they should be wiped with a wet cloth, and rubbed with tallow and spirits mixed in the palm of the hand (Galton). Pedestrians frequently use hot salt and water at night, and add a little alum. The German soldiers use *Pulvis salicylicus cum Talco* (German Pharmacopœia); this is salicylic acid 3 parts, wheaten starch 10 parts, talc 87 parts; mix to a fine powder; it is applied daily on the march; in garrison every two or three days. Sometimes the soreness is owing simply to a bad stocking; this is easily remedied. Stockings should be frequently washed, then greased. The German troops use no stockings, but rags folded smooth over the feet. The French use no stockings, but this is not a good plan. Very often soreness is owing to neglected corns, bunions, or in-growing nails.

Frequently men fall out on the march to empty the bowels; the frequency with which men thus lagging behind the column were cut off by Arabs led the French in Algeria to introduce the slit in the Zouave trousers, which require no unbuckling at the waist, and take no time for adjustment.

At a long halt, if there is plenty of water, the boots and stockings should be taken off and the feet well washed; even wiping with a wet towel is very refreshing. The feet should always be washed at the end of the march and dry stockings put on.

Occasionally men are much annoyed with chafing between the nates or inside of the thighs. Sometimes this is simply owing to the clothes, but sometimes to the actual chafing of the parts. Powders are said to be the best—flour, oxide of zinc, and, above all, it is said, fuller's earth. Absolute cleanliness is here of the first importance.

If blisters form on the feet the men should be directed not to open them during the march, but at the end of the time to draw a needle and thread through; the fluid gradually oozes out. All footsore men should be ordered to report themselves at once.

Sprains are best treated with rags dipped in cold water, or cold spirit and water with nitre, and bound tolerably tight round the part. Rest is often impossible. Hot fomentations, when procurable, will relieve pain.

Marches, especially if hurried, sometimes lead men to neglect their bowels, and some trouble occurs in this way. As a rule, it is desirable to avoid purgative medicines on the line of march, but this cannot always be done; they should, however, be as mild as possible.

Robert Jackson strongly advised the use of vinegar and water as a refreshing beverage, having probably taken this idea from the Romans, who made vinegar one of the necessaries of the soldier. It was probably used by them as an anti-scorbutic; whether it is very refreshing to a fatigued man seems uncertain.

There is only one occasion when spirits should be issued on a march: this is on forced marches, near the end of the time, when the exhaustion is great. A little spirit, in a large quantity of hot water, may then be useful, but it should be used only on great emergency. Warm beer or tea is also good; the warmth seems an important point. Ranald Martin and Parkes tell us that in the most severe work in Burmah, in the hot months of April and May, and in the hot hours of the day, warm tea was the most refreshing beverage. Travellers in India, and in bush travelling in Australia, have said there was nothing so reviving as warm tea. Chevers mentions that the juice of the country onion is useful in lessening thirst during marches in India, and that in cases of heatstroke, the natives use the juice of the unripe mango mixed with salt.

Music on the march is very invigorating to tired men. Singing should also be encouraged as much as possible.

The Effects of Military Service.—The influence of the various conditions of military life is shown by the records of sickness and mortality, and these should be noted in the various stations.

The recruit having entered the ranks, begins his service at home, and he is kept at his depôt for some time. He should not go on foreign service until he has completed his twentieth year of age. We should suppose his life would be a healthy one It is a muscular, and, to a certain extent, an open-air life, yet without great exposure or excessive labour; the food is good, the lodging is excellent, and the principles of sanitation of dwellings are carefully practised. There is a freedom from the pecuniary anxiety which often presses so hardly on the civil artisan, and in illness the soldier receives more immediate and greater care than is usual in the class from which he comes.

There are some counterbalancing considerations. In a barrack there is great compression of the population, and beyond a doubt the soldier has greatly suffered, and even now suffers, though to a far less extent than at any previous time, from the foul air of barrack rooms. This is a danger greatly lessening, owing to the results of the work of the Barrack Improvement Commissioners, and, as is proved by the experience of some convict jails, can be altogether avoided.

Among the duties of the soldier is some amount of night-work; it is certain that this is a serious strain, and the Sanitary Commissioners, therefore, inserted in the *Regulations for the Medical Services* an order that the number of nights in bed should be carefully reported by medical officers. Lord Roberts has called marked attention to the injurious effects of night duty and "sentry-go." Commanding officers should be informed how seriously the guard and sentry duties, conducted as they are in full dress, tell on the men if they are too frequent. One guard-day in five is quite often enough, and at least four nights in bed should be secured to the men. Exposure during guard, and transition of temperature on passing from the hot air of the guard-room to the outside air, are also causes of disease. The weights and accoutrements are heavy, but the valise equipment recently introduced has removed the evil of the old knapsack.

The habits of the soldier are unfavourable to health; in the infantry, especially, he has much spare time on his hands, and *ennui* presses on him. *Ennui* is, in fact, the great bane of armies, though it is less in our own than in many others. It is said to weigh heavily on the German, the Russian, and even on the French Army. Hence, indeed, part of the restlessness, and one of the dangers of large standing armies. We avoid it in part by our frequent changes of place, and our colonial and Indian service; but not the less, both at home and abroad, do idleness and *ennui*, the parents of all evils, lead the soldier into habits which sap his health. Not merely excessive smoking, drinking, and debauchery, but in the tropics mere laziness and inertia, have to be combated. Much is now being done by establishing reading-rooms, trades, industrial exhibitions, &c., and by the encouragement of athletic sports to occupy spare time, and already good results have been produced.

The establishment of trades, especially, which will not only interest the soldier but benefit him pecuniarily, is a matter of great importance. It has long been asked why an army should not do all its own work; give the men the hope and opportunity of benefiting themselves, and *ennui* would no longer exist. In India Lord Strathnairn did most essential service by the establishment of trades; and the system, after long discussion and many reports, is now being tried in England.

One of the proofs of ability for command and administration is the power of occupying men, not in routine, but in interesting and pleasant work, to such an extent that rest and idleness may be welcomed as a change, not felt as a burden. Constant mental and much bodily movement is a necessity for all men; it is for the officers to give to their men an impulse in the proper direction.

The last point which probably makes the soldier's life less healthy than it would otherwise be is the depressing moral effect of severe and harassing discipline. In our own army in former years it is impossible to doubt that discipline was not merely unnecessarily severe but was absolutely savage. An enlightened public opinion has gradually altered this, and with good commanding officers the discipline of some regiments is probably nearly perfect, that is to say, regular, systematic, and unfailing, but from its very justice and regularity, and for its judiciousness, not felt as irksome and oppressive by the men.

It is by no means easy to say whether soldiers enjoy as vigorous health as the classes from which they are drawn; the comparison of the number of sick, or of days' work lost by illness by artisans, cannot be made, as soldiers often go into hospital for slight ailments which will not cause an artisan to give up work. The comparative amount of mortality seems the only available test, though it cannot be considered a very good one.

ARMY STATISTICS.

These are intended to show the effect of military life and the influence of service in various countries and under different conditions of climate.

Statistics of army disease and mortality were first commenced after the close of the Peninsular War, but these were issued at long and irregular intervals. They gave much information with regard to the topography and climate of various stations, but the advent of the Crimean War put a stop to any further issue for a time.

In 1859 they were again published, and since that year have been issued annually. These returns show the amount of loss the army incurs annually from disease, not only for the army as a whole, but for each particular arm of the service, as well as for each station or command at home and abroad.

In order that the results may be compared with those taken from the civil population as well as those given in previously published medical statistics, it is necessary that the classification shall be as far as possible uniform; for this purpose the official *Nomenclature of Diseases*, prepared by the Royal College of Physicians of London, is adopted for the British Army Returns.

Unfortunately, owing to different classifications being adopted in different countries, it is not always possible to compare the sickness and mortality for special diseases occurring in different armies. The Committee on International Military Medical Statistics, which recently (1894) met at Buda-Pesth, have formulated a scheme which it is hoped will be adopted by the various Governments and which will overcome in a great measure the difficulties army statisticians have hitherto had to contend with. This scheme will undoubtedly lead to a common basis for comparison being adopted and will be the means of affording a large amount of information hitherto not available. But little information is gained by recording the statistics of disease *as a whole*: the most important factor dealing with army statistics is *age*, for unless the mortality is given by age-groups it is impossible to compare the effects of military service with those relating to the civil population. The special points to be determined with reference to Army Statistical Reports are as follows:—

(1) The number of admissions to hospital as compared with the number of persons furnishing the sick.

This is obtained by taking the numbers of the body furnishing the sick (the strength of the regiment or command) and the sick, and reducing both to a comparable standard: thus a regiment 1080 strong furnishes 23 sick in a week; reduce this to a percentage,

$$\frac{23 \times 100}{1080} = 2 \cdot 13 \text{ per cent., or } 21 \cdot 3 \text{ per } 1000.$$

Of course the numbers furnishing the sick are constantly reduced by the sick entering hospital; as a rule, an equivalent number usually leave hospital; if the numbers are very different, a calculation must be made to equalise them.

It is always desirable to express what would be the admissions in a year into hospital, supposing that the strength remained the same, and furnished every week the same number of sick. This result is obtained by taking the daily admission per 1000 and multiplying by 365. In this case $= 1109$ per 1000. Therefore, the whole regiment, or what would be equivalent to it, would pass through the hospital if 23 men were admitted weekly.

There are here, of course, 3 variables—

(*a*) The successive days or weeks.

(*b*) The strength of the regiment.

(*c*) The number of sick.

But to simplify matters, it is sufficient to take the first and last, and to leave out the varying strength, unless this is considerable.

The admissions into hospital are advantageously considered from the point of view of age, to show whether the younger or the older men are suffering most. For this we require to know the number of men in the regiment at every age:—

18 to 20 years.
20 ,, 22 ,,
22 ,, 24 ,,
24 ,, 26 ,,
26 ,, 28 ,,
28 to 30 years.
30 ,, 35 ,,
35 ,, 40 ,,
40 ,, 50 ,,

Then reduce to a comparable standard.

As the number of men at a given age are to the number of sick at that age, so is 1000 for example. Supposing that between the ages of twenty to twenty-two there are 163 healthy men furnishing 22 sick in one week, while between the ages of twenty-six to twenty-eight there are 115 men furnishing 7 sick, then,

$$\frac{22 \times 1000}{163} = 134 \cdot 9 \text{ per } 1000,$$

and

$$\frac{7 \times 1000}{115} = 60 \cdot 8 \text{ per } 1000;$$

therefore, the younger men are more than twice as sickly as the older ones.

(2) The deaths in hospital must be considered, as compared with the number of cases treated. In a given time we have to state—How many persons have been treated? How many have died? and then to reduce this to a comparable standard. To get the number of persons treated, we may adopt several ways.

(*a*) Take half of the cases admitted and discharged. Supposing in one week 40 cases were admitted and 10 discharged, then $40 + 10 = 50 \div 2 = 25$, the average number treated.

(*b*) This same result may be obtained in another way. Supposing we have in hospital—

30 Remained,	call that R
40 Admitted,	,, A
60 Remaining,	,, L
10 Died or discharged, .	,, D

Then to get the average sick treated in the time, add half the remained to the admissions and deduct half the remaining :—

$$A + \frac{R}{2} - \frac{L}{2} = \text{number treated},$$

$$A = 40 + \frac{30}{2} = 55 - \frac{60}{2} = 25\,;$$

or, deduct from the discharged half the remained and add half the remaining :—

$$10 - \frac{30}{2} + \frac{60}{2} = 25.$$

Then reduce the mortality to a comparable standard. Supposing in a hospital 557 are admitted and 237 are discharged in a given time, say 63 days, then $557 + 237 = 794 \div 2 = 397$ cases treated in the time in which the mortality is to be calculated. Then supposing that the mortality has been 15, reduce this to a percentage :—

$$\frac{15 \times 100}{397} = 3{\cdot}78 \text{ per cent., or } 37{\cdot}8 \text{ per } 1000.$$

To make this still more intelligible, let us reduce it to a uniform time, say, as given above, 63 days; then if the mortality continued, let us see what it would be in a year :—

$$\frac{365 \times 37{\cdot}8}{63} = 219 \text{ per } 1000\,;$$

that is, if instead of 397 men only, 1000 had been in hospital constantly, 219 would have died in a year if the mortality had been the same as in the 63 days.

Instead of the cases treated, the *sick population* may be taken; that is, the number of patients in hospital on each day as an average.

To get the sick population add the numbers put down as remaining on each day or on each week and divide by the number of days or weeks. This gives the average number in hospital on any one day.

The mortality may be calculated on the sick population, by dividing the deaths by the sick population and reducing to a uniform standard of time, say one year.

(3) The next point is to determine the number of days a patient is in hospital.

(*a*) Add all the days together and divide by the cases treated; or,

(*b*) Multiply the sick population by the number of days over which the return extends and divide by the cases treated. For example, say the sick population is 23, number of days 7, and the cases treated 39, then $\frac{23 \times 7}{39} = 4{\cdot}1$. Each patient was therefore in hospital rather over four days.

If in any individual case we wish to know the number of days we must, of course, have the dates of admission and discharge of the individual. A rough estimate may at any moment be made by remembering that if in the above example the sick population and the cases treated had been equal, each man must have been seven days in hospital. If the sick population had been, as above, 23, but the cases treated 46, each man would have been half a week in hospital, or 3·5 days.

The returns required to be furnished by the medical officer in charge of a station or general hospital are as follows :—

1. *Daily Return.*—This is a daily state of the numbers admitted, discharged, remaining in hospital, or died. It is sent to the officer commanding

the station for his information. A return of the men admitted and discharged is also forwarded to the officer commanding each corps.

2. *Weekly Return.*—This return contains the details for seven complete days, including the average strength by corps, the admissions to and discharges from hospital, the numbers remaining in hospital, the deaths, remarks on all important cases, also on any infectious diseases, and on the sanitary condition of the station. All deaths occurring during the period have to be briefly noted, as well as any important cases under treatment. This return is furnished by all hospitals except those for soldiers' wives and children, hospitals on board ship, and hospitals in the field.

3. *Annual Return.*—This return is completed and forwarded by each officer who is in medical charge of a hospital on December 31. It includes all the details given in the weekly returns, and, in addition, the average number of daily sick, the average sick time to each soldier, and the average duration of each case of sickness is given. It must include the statistics of all the sick of the regular forces who have been admitted during the year. With this return is attached a report in manuscript of medical transactions, and prevailing diseases, which should show the bearings of sanitary arrangements thereon.

An annual report is also furnished by the officer in charge of the hospital for soldiers' wives and children.

4. *Special Returns.*—During the prevalence of epidemics, special weekly returns are furnished.

5. *Returns on Board Ship.*—The statistics of the following classes of troops are required:—

(*a*) Troops proceeding on service abroad.
(*b*) Troops returning home from abroad.
(*c*) Troops proceeding from one station to another.
(*d*) Invalids returning home.

6. *Returns of Troops on Active Service in the Field.*—These include (*a*) daily state of sick and wounded, (*b*) special return of officers and men who have received wounds or injuries in battle, specifying as tersely and accurately as possible the kind of wound or injury and the degree of severity. Weekly returns are also required for hospitals in the field.

The mortality of the army has undergone an enormous diminution during later years. This is probably due in some measure to a closer selection of the men enlisted, to the lesser difficulty in invaliding under the short-service system, and to the comparative youth of the army taken as a whole. But there can be little doubt that this result is also the outcome in a large measure of the sanitary improvements which have of late years been introduced, and which have lessened the death-rate and invaliding both at home and abroad.

The following table shows this decrease:—

Mortality per 1000 *in the United Kingdom.*

		From all causes.
Mean of 10 years	1861–70,	9·45
,, ,,	1870–79,	8·18
,, ,,	1878–87,	6·52
Mean of 7 years	1886–92,	5·24
1893,		5·13

This gross mortality must now be compared with that of the civil male population at the soldier's age:—

	Mortality per 1000 of population.
From 20 to 25 years of age,	5·4
,, 25 ,, 35 ,,	7·4
,, 35 ,, 45 ,,	12·8

The soldier's mortality, taken as a whole, is therefore under that of the civil population, but this is not taking into account the invaliding, for which some addition should be made.

As regards the influence of age on mortality, statistics show that between the ages of twenty and thirty-four the mortality is in favour of the soldier; after thirty-five years the proportion is reversed, and the civilian mortality is lower.

The inference which must be drawn is that military life, if prolonged, has an injurious effect—probably, in some measure, the result of climate and of personal habits acquired in it.

Causes of Mortality.—As regards the causes of mortality the disease which is most fatal is phthisis: the number of cases invalided during the year 1893 was 1·60 per 1000, and the average ratio per 1000 from 1886 to 1892 was 1·75: the mortality being 2·72 per 1000 for each period—making a total loss by death and invaliding during 1893 of 4·32 per 1000, and for the seven years 1886 to 1892 an average of 4·42 per 1000 annually.

The mortality is only slightly below the whole male civil population at the soldier's age, and must be considered excessive when we remember that the soldier is especially selected and undergoes a strict examination before he is enlisted. The diminution over former years is exceedingly large, and there is still evidence of further decrease, so that we may reasonably hope for still further improvement in this direction.

Heart disease and diseases of the circulatory system come next in order of frequency. The mortality is about the same as that of the civil population. There is here also a considerable improvement over former years, due to the close attention given to the dress of the soldier and to the careful distribution of the weights he has to carry, which are now arranged so as not to press unduly on the chest walls. Excessive smoking has also been assigned as a possible cause, as well as the excessive use of alcohol. The real cause of the "soldier's heart" appears, however, to be due to sudden and violent exertion, undertaken by lads of immature growth under unfavourable conditions of food and clothing.

The next most fatal forms of disease are those referred to the digestive system; from these soldiers suffer in about the same ratio as the civil population. Diseases of the nervous system are also in about the same ratio as the civil population; this class includes apoplexy, meningitis, paralysis, mania, &c., and accounts for 3·4 per cent. of the total deaths.

Acute diseases of the lungs come next in order. It is extremely difficult to say whether in military life these are more common than among the civil population, but from the crude information we possess, the mortality appears to be less than in civil life.

The next group are the continued fevers. Practically, the mortality from these is nearly all due to enteric fever. The mortality is about one-half that of the civil population.

Other diseases, such as diphtheria, scarlet fever, diabetes, &c., account for nearly 23 per cent. of the total deaths which take place yearly.

Although there has been great improvement in the health of the army during recent years, still much remains to be done. Tubercular diseases, those of the circulatory system, and "fevers," all more or less preventible, are still excessive in the mortality returns.

Loss of Strength from Invaliding.—In 1893 the invaliding at home was 15·70 per 1000: this is lower than the decennial average rate by 1·50; for the whole army it was 13·30 per 1000, the decennial average, 1883 to 1892, being 15·54. During the seven years 1860–67 there were invalided 37 per

1000, and a total loss by death and invaliding from disease nearly 46 per 1000. Thus the loss by invaliding has been reduced more than one-half compared to what it was in former years. The chief reason for this reduction is the system of short service. Circulatory diseases account for about one-fifth, phthisis and respiratory diseases, in round numbers, account for about one-sixth, and nervous diseases for about one-eighth of the invaliding.

Loss of Service from Sickness.—On an average, 1000 soldiers furnish from 700 to 800 hospital admissions: the seven years 1886–92 gave 777; 1893, 751·6.

The cavalry of the line and the artillery furnish the largest number, whilst the household cavalry and engineers give the least number; in the latter, many of the men are married, and when admitted to hospital are deprived of their working pay, so they seldom seek admission until compelled to do so. The cavalry of the line and artillery are also subject to accidents incidental to the nature of their work.

A very large number of admissions are the result of venereal disease, of which there is no immediate prospect of any considerable decrease. It is not possible to compare the loss occasioned by sickness with that occurring in other armies, as the conditions of service are not the same.

Causes of Sickness.—*Venereal Diseases.*—This class of disease causes a large amount of inefficiency in the army. It is impossible to compare the numbers who are affected in the military and naval services with those in the civil community, as there are no morbidity statistics relating to the latter. We have, however, no reason to believe that the civil population is exempt from these diseases in a greater degree than the military and naval services are.

The large amount of inefficiency in the army and navy caused by venereal disease was brought prominently to notice shortly after the systematic issue of the *Army Medical Department Reports* in 1859. In 1864 the first Act of Parliament was passed which had for its object the prevention of these diseases, and caused those females who were the sources of its diffusion to be subjected to medical treatment in hospital while they were in a state capable of communicating it.

The first Act passed was found to be more or less ineffectual, and this was amended by the Acts of 1866 and 1869, which remained in force until May 1883, when compulsory examination was abolished by a resolution of the House of Commons, at which time the Acts practically ceased.

These Acts gave rise to much controversy, and there has been a wide-spread and active opposition to them. Apart, however, from the saving of much misery and suffering which they were the direct means of averting, they were no doubt useful as affording a wholesome influence on the class subjected to them, and were the means of raising the moral tone of those towns which were placed under them. It is not likely that these Acts will ever be passed in the same form again, but it is not unreasonable to hope that the time is not far distant when venereal diseases will be included in the list of those of which notification is required, and that men and women suffering from this objectionable disease shall be placed under supervision and control. The prevalence of venereal diseases in armies has recently been the subject of a communication to the Academy of Medicine in Paris by Commenge. He shows how prevalent these diseases are, and especially so in the British Army. In 1892 out of 196,336 soldiers, 52,155—that is to say, upwards of a quarter of the entire British Army—were admitted to hospital on account of venereal disease.

The following tables show the relative prevalence of venereal disease in the British, French, and Russian Armies, the figures giving the cases per 1000 of strength:—

	England.	France.	Russia.
1889,	217·1	45·8	40·7
1890,	212·4	43·8	43·0
1891,	197·1	43·7	41·5
1892,	201·1	44·0	44·6

The following table shows the comparative prevalence of syphilis alone:—

	England.	France.	Russia.
1889,	35·7	9·1	12·9
1890,	37·3	9·1	13·4
1891,	32·2	8·9	12·2
1892,	33·8	9·2	13·7

Commenge states that venereal diseases are always far more numerous in countries where there is free trade in prostitution than in those where regulations are in force.

On the other hand, it cannot be denied that since the abolition of the Acts there has been a progressive diminution in the admissions from these diseases in the army at home, and this has been used as an argument against their reinforcement by those who are opposed to any legislation on the subject. But that this occurred in former years before the introduction of the Acts must also be admitted, although the reason for this being the case is not apparent. The following table shows the admissions for venereal diseases for five years before the introduction of the Acts:—

Year.	Ratio per 1000.
1859,	422·0
1860,	368·9
1861,	353·8
1862,	329·9
1863,	306·8

A similar diminution in the admissions for all venereal diseases during the decennial period 1884–93 has also taken place, as shown in the following table:—

Year.	Admissions for	
	Primary Syphilis.	All Venereal Disease.
1884,	125·2	270·7
1885,	127·4	275·4
1886,	118·8	261·1
1887,	107·5	252·9
1888,	93·2	224·5
1889,	83·5	212·1
1890,	69·1	195·8
1891,	63·1	183·4
1892,	66·7	188·8
1893,	56·9	177·0

There is some evidence that during later years a diminution has occurred among the civil population, and the death-rate during the last quinquennial period, 1890–94, shows a large decrease over previous years. The following table is compiled from the Registrar-General's returns for England and Wales:—

Years.	Deaths per 1,000,000.
1865–69,	90
1870–74,	90
1875–79,	97
1880–84,	94
1885–89,	85
1890–94,	80

There is no doubt that, as shown by the above tables, there has been a decline in the prevalence of these diseases since 1885.

The last twenty years has seen many changes in this country. Since the passing of the Education Acts, when school attendance was made compulsory, there has been a gradual but increasing improvement in the moral character of the whole population, and the various sanitary Acts have in no small degree assisted to bring this about. It is evident also that the Contagious Diseases Acts have, of themselves, been beneficial, inasmuch as they proved to individuals the necessity for medical treatment when diseased, and inculcated the benefits to be gained from cleanly habits. It is seldom that the same abandoned class of prostitutes are to be seen in garrison towns that formerly frequented them, and there is every reason to believe that this is due to the general social improvement of the masses, and not to the abolition of the Acts, which served their time and purpose, and were in no small measure instrumental in bringing about this change.

On the contrary, we are justified in believing that this diminution in venereal disease would have been greater had the Acts remained in force and their sphere of usefulness been more widely extended. The advantages gained by the passing of these Acts at a time when education was neglected and few sanitary Acts dealing with the surroundings of the working classes were in existence, is shown in the following table, which gives the admission ratio per 1000 in fourteen stations under the Acts, and fourteen stations not under the Acts, since 1860.

Year.	14 Stations under the Acts.	14 Stations not under the Acts.
1860–63,	129·8	120·6
1864–69,	87·1	133·9
1870–73,	86·0	107·9
1874–79,	38·7	97·4
1880–82,	75·6	175·9
1883–84,	123·9	174·0

In India, where the same rapid advance in sanitary progress has not been possible, and where the education of the natives has been narrowed by caste prejudices, and especially of the female population, which has always been relegated to an inferior position in that country, there have not been the same influences at work; and consequently we find that the suspension of the Acts has had a directly opposite effect to what has taken place in this country.

The following table shows the comparison between the year 1866, before the Contagious Diseases Acts were imposed, the year 1884, while they were in force, and the years 1891–92–93, when the Acts had been abandoned, the figures giving the cases per 1000 of strength.

Presidency.	Average Strength.	1866.	1884.	1891.	1892.	1893.
Bengal,	42,304	217·7	290·6	303·8	315·0	357·8
Madras,	13,440	231·1	307·7	322·0	333·0	414·8
Bombay,	12,903	206·6	291·6	354·6	321·6	386·9

The history of the subject in Calcutta is even more convincing. The Acts were put in force in that city in 1869; they were suspended in part of the city in November 1881, and in the entire city in March 1883. The following figures show the results of this change:—

Cases of Venereal Diseases.—Ratio per cent. of Garrison.

Year.	Primary Syphilis.	Venereal of all Kinds.
1868,	10·0	25·06
1869,	9·0	25·08
1870,	6·0	14·4
1871,	2·7	8·1 New regiment.
1872,	5·7	13·9
1873,	1·4	7·4
1874,	1·4	9·4 New regiment.
1875,	1·3	10·3 ,, ,,
1876,	2·3	12·6 ,, ,,
1877,	4·3	10·7
1878,	4·0	11·7 New regiment and drafts.
1879,	2·7	9·3
1880,	1·7	12·8 New regiment.
1881,	3·1	8·7
1882,	3·7	14·5 New regiment.
1883,	10·9	28·0
1884,	30·2	58·1 New regiment.
1885,	15·1	31·6 ,, ,,

From these figures it is apparent that syphilitic disease had sunk from a high ratio, 10 per cent. in 1869, to a low one, 1·7 per cent. in 1880, and for two years it had only been 1·4. In 1883 it rose to 11 per cent., and in 1884 to 30 per cent., while 58 per cent. of the garrison were admitted to hospital for one form or other of venereal disease.

CHAPTER XX.

MARINE HYGIENE.

Marine Hygiene may be defined as the application of the principles of general hygiene to the conditions and exigencies of sea life. These conditions, so far as they affect life and health, contrast markedly with the corresponding circumstances on land. The importance of the subject, and the extent of the interests involved, will be apparent from a consideration of the following statistical facts.

Nature and Extent of the Marine Population.—The total population afloat belonging to this country may be stated in round numbers as being not less than 400,000 persons. It may be divided conveniently into (*a*) that belonging to the mercantile marine, including the crews of fishing-boats registered under both the Merchant Shipping Act and under the Sea Fisheries Act, and (*b*) that constituting the *personnel* of the Royal Navy.

According to the *Annual Statement of the Navigation and Shipping of the United Kingdom* issued by the Board of Trade, the number of persons employed in the mercantile marine of the United Kingdom in the year 1894 was as follows:—

Mercantile Marine.	Britishers.	Lascars.	Other Nationalities.	Total.
In sailing-ships,	62,915	79	11,857	74,851
In steamships, . .	120,318	26,096	19,193	165,607
In fishing-boats (approximate),	104,761	...	...	104,761
Total,	287,994	26,175	31,050	345,219

The table on page 980, prepared from the same source as the foregoing, shows the number and tonnage of sailing and steamships belonging to and registered in the United Kingdom, with the distribution of the mercantile marine population in ships of different sizes.

In the Royal Navy, the total force afloat, corrected for time in the year 1893, was 60,120 officers and men, of whom 33,940, or 56·45 per cent., were between the ages of fifteen and twenty-five; 18,430, or 30·65 per cent., were between the ages of twenty-five and thirty-five; 6820, or 11·34 per cent., were between the ages of thirty-five and forty-five; and 930, or 1·54 per cent., were above forty-five years of age.

Marine Sanitary Regulation and Supervision.—From the foregoing statement of the diverse composition of the general population afloat it will be apparent that the subject of Marine Hygiene is by no means simple, and it is further complicated by the fact that the health of the seafaring community is committed to the care of a variety of departments acting under the authority of different Acts of Parliament.

Classification of Tonnage.	Sailing.			Steam.		
	Vessels.	Tonnage.	No. of Crew per Ship.	Vessels.	Tonnage.	No. of Crew per Ship.
Under 50 tons, . .	3672	129,742	3·6	1,002	24,857	6·2
Of 50 and under 100 tons,	3614	258,479	4·4	652	44,413	9·0
,, 100 200 ,,	878	127,889	5·8	353	53,115	13·9
,, 200 ,, 300 ,,	184	44,109	8·0	211	52,854	18·0
,, 300 ,, 400	62	21,250	10·0	222	77,945	19·6
,, 400 500	65	30,092	12·2	263	118,263	19·6
,, 500 ,, 600 ,,	52	29,160	13·6	227	124,213	22·0
,, 600 ,, 700	53	34,663	15·3	218	141,690	21·1
,, 700 ,, 800	92	69,486	16·7	234	175,407	20·0
,, 800 ,, 1000	170	152,306	18·0	454	406,584	23·0
,, 1000 ,, 1200	187	207,994	21·3	498	546,623	24·0
,, 1200 ,, 1500 ,,	336	452,208	23·7	724	978,312	28·4
1500 ,, 2000 ,,	406	704,042	28·1	813	1,409,526	33·8
,, 2000 2500 ,,	186	411,329	31·4	349	773,385	55·8
,, 2500 ,, 3000 ,,	48	130,380	34·5	175	473,975	76·0
,, 3000 and upwards,	6	19,096	37·0	141	492,898	120·3
Totals,	10,011	2,822,225	74,851	6,536	5,894,060	165,607

Thus, the Board of Trade have the control of the mercantile marine, including both passenger and emigrant services, and, by virtue of the Merchant Shipping Act, 1894, are able to require that certain provisions as to cubic space, lighting, and ventilation shall be made on all British vessels. Under other portions of the same Act, the food to be supplied to seamen *may* be inspected by medical inspectors appointed for that purpose by the Board.

The Commissioners of Her Majesty's Customs apply such of the clauses of the Quarantine Act, 1825, as now remain in force; while the Local Government Board make Regulations dealing with cholera and other infectious diseases by authority of section 130 of the Public Health Act, 1875, and by the Public Health (Ships, &c.) Act of 1885 can apply sections 120, 121, 124, 125, 126, 128, 131, 132 and 133 of the Act of 1875 to ships. These sections are, by Local Government Board Orders made in pursuance of section 287 of the same Act, enforced by Port Sanitary Authorities (see also page 912, *et seq.*).

The *personnel* of the Royal Navy is controlled in all matters bearing on the province of naval hygiene by the Queen's Regulations and Admiralty Instructions.

The Seaman or Sailor.—If we accept the definition given in section 742 of the Merchant Shipping Act, 1894, the term seaman or sailor includes every person (except masters, pilots, and apprentices duly indentured and registered) employed or engaged in any capacity on board any ship; and further, if we take into consideration their numbers, and the peculiar nature and importance of their calling, the personal hygiene of these men is of exceptional importance to the country. The careful attention paid to hygiene in the Royal Navy testifies to the appreciation of this fact now shown by those officially responsible for the efficiency of that service. The same can hardly be said of the mercantile marine; the seamen of that service are a somewhat variable body, especially in respect of their antecedents. "The sea is too often the last resort of the idle, the careless, and the ne'er-do-well." Why this should be, is difficult to say; but it is probably the effect of a variety of causes, more particularly official and national apathy, want of organisation among owners, and general economic causes.

The seaman should have a good *physique*, though height, apart from good development, is of no advantage. Excepting it be a somewhat faulty examination of masters and mates as to ability to distinguish colours, there are no physical tests of fitness for service demanded by the Board of Trade in respect of those desirous of entering the mercantile marine. It is otherwise in the navy, where every man or boy desirous of joining is submitted to a rigid physical examination by one or more medical officers. None but promising lads are accepted for the training ships, while persons of whatever class or age, found to be labouring under any of the under-mentioned physical defects or deformities, are, by Article 1154 of the Admiralty Instructions, considered unfit for Her Majesty's Navy:—

(*a*) A weak constitution, imperfect development, or malformation or physical weakness, either hereditary or acquired.

(*b*) Skin disease, temporary or trivial; marks of cupping, leeching, blistering, or of issues.

(*c*) Malformations of the head, deformity from fracture, impaired intellect, epilepsy, paralysis or impediment of speech.

(*d*) Blindness or defective vision; imperfect perception of colours or any chronic disease of the eyes or eyelids.

(*e*) Impaired hearing, or any discharge from or disease of either ear.

(*f*) Disease of nasal bones or cartilage, and nasal polypus.

(*g*) Disease of throat, palate, tonsils or mouth; cicatrices of neck, whether from scrofula or suicidal wounds; unsound teeth, or seven teeth deficient or defective.

(*h*) Functional or organic disease of the heart or blood-vessels. Deformity of chest, phthisis, bronchitis, hæmoptysis, asthma, dyspnœa, chronic cough, or any evidence of lung disease or tendency thereto.

(*i*) Undue swelling or distension of abdomen; disease of liver, spleen, or kidneys; hernia or tendency thereto, incontinence of urine, syphilis or gonorrhœa.

(*j*) Non-descent of either or both testicles, hydrocele, varicocele, or any other disease or malformation of the genital organs.

(*k*) Fistula of anus, hæmorrhoids, or any disease of stomach and bowels.

(*l*) Paralysis, weakness, or impaired motion or deformity of either extremity, including varicosity of veins and distortion or malformation of hands, feet, fingers, or toes.

(*m*) Distortion of the spine, of the bones, chest, or pelvis, no matter whether from injury or disease, or from constitutional defect.

Artificers, over 18 years of age, when first entered, are not to be less than 5 ft. 4 in. in height, with a chest measurement of at least 32 inches. For stokers the same standard of height is required, with the following chest measurements:—Between 18 and 19, not less than 32 inches; between 19 and 20, not less than 33 inches; over 20, not less than 34 inches (Article 348).

The Vessel or Ship.—Section 742 of the Merchant Shipping Act, 1894, defines the term "vessel" as including any ship or boat, or any other description of vessel used in navigation. Similarly, "ship" includes every description of vessel used in navigation not propelled by oars. Boyd, quoted by Armstrong, says that "the criterion as to whether a vessel falls under the category of ship, is whether the vessel be one whose real habitual business is to go to sea; if so, though propelled by oars as well as sails, it is a ship within the meaning of the Act. If she does not go to sea at all she is not a ship in this sense."

The simplest classification of ships is into (*a*) men-of-war, (*b*) merchant ships. These classes can be further divided into groups according as to whether they are either wooden or iron ships, or whether they are steamships or sailing-ships.

Men-of-war, in the present day, are practically all iron ships and also steamships; they comprise battleships of the first, second and third class;

first, second and third class cruisers; sloops; gunboats; torpedo-boats; torpedo-boat destroyers; troopships; storeships; and stationary harbour ships.

Merchant ships are naturally divided into steamers and sailing-ships. Steamers may be further classified into passenger ships, trading or cargo ships, trawlers or fishing vessels, whaleships, cattleships, and colliers. The majority of these are built of iron and propelled by steam.

Sailing-ships, in the present day, are practically limited to the conveying of cargoes only, or to the carrying out of special industries, such as fishing, sealing, or whaling. Any precise classification of sailing-ships is founded primarily upon their rig. For example, we have full-rigged ships, brigs, brigantines, barques, barquentines, schooners, topsail schooners, cutters, yawls, barges, luggers, ketches and other small vessels.

A full-rigged ship has three masts, each fitted with topmast, topgallant-mast and royal mast, all being square-rigged.

A barque is a three-masted vessel, the two foremost being square-rigged as above, the hindmost, or mizzen, having only topmast with gaff sail.

The barquentine resembles the barque in having three masts, but only one of them (the foremast) is square-rigged.

A brig is a square-rigged two-masted vessel.

The brigantine has also two masts, but only one, the foremast, is square-rigged, the other or aftermast carrying a mainsail or boomsail, with topmast and gaff topsail.

A schooner may be either three or two masted; the lower masts being long with short topmasts and no yards, and carrying mainsails and gaff topsails only.

The topsail schooner is a two-masted vessel with long lower masts, the foremast having a loose square foresail, the aftermast having mainsail and topmast, &c., as in a brigantine. Some topsail schooners have three masts; in them the foremast is the same as in the foregoing, the two aftermasts having mainsails and gaff topsails.

A cutter is one-masted with running bowsprit, carrying jib, foresail and boom-mainsail.

Sailing and steam ships may also be classified according to their build or arrangement of decks. Thus we may speak of one, two, or three decked vessels; or, if lightly built, of spar-decked ships. Other terms in common use are flush-decked, well-decked, hurricane-decked, shade-decked, awning-decked or shelter-decked; all these expressions have reference to the character of the decks and the structures upon them.

While the *rig* of a ship has practically no relation, beyond that of general size, to its general hygienic character, it is far otherwise with the *build* or construction. Ventilation becomes more and more complex in proportion to the number of compartments into which the ship is divided either vertically or horizontally, transversely or longitudinally. These conditions vary considerably according to the material of which the vessel is constructed. Ships are built either wholly of wood or metal, such as iron or steel; or they are composite, that is, composed partly of wood and partly of metal. The principal facts connected with the construction of both wooden and iron ships demand some detailed reference.

Construction of Wooden Ships.—The frame or skeleton of a wooden ship consists principally of the following parts:—keel, keelson, stem, stern-post, timbers, planking, beams and stanchions.

The *keel* may be regarded as the back-bone of a ship and runs the entire length of the bottom of the vessel. It is usually, in wooden ships, made of elm, square in section, and consisting of a number of segments connected together by a joint or splice. The keel in front terminates in the *stem*, with which it forms an angle of from 80 to 100 degrees; behind it joins the *sternpost*, to which is attached the rudder. To the keel at regular intervals, and curving outwards like the ribs of an animal, are fixed the *timbers;* those in the front or bow of the ship are called "cant timbers," those aft of the cant timbers are the frames. To the timbers are attached the inner and outer *plankings;* these generally run horizontally the entire length of the ship. These inner and outer plankings constitute the "skins" or walls of the ship. Between the skins in the intervals of the frames is a space in the

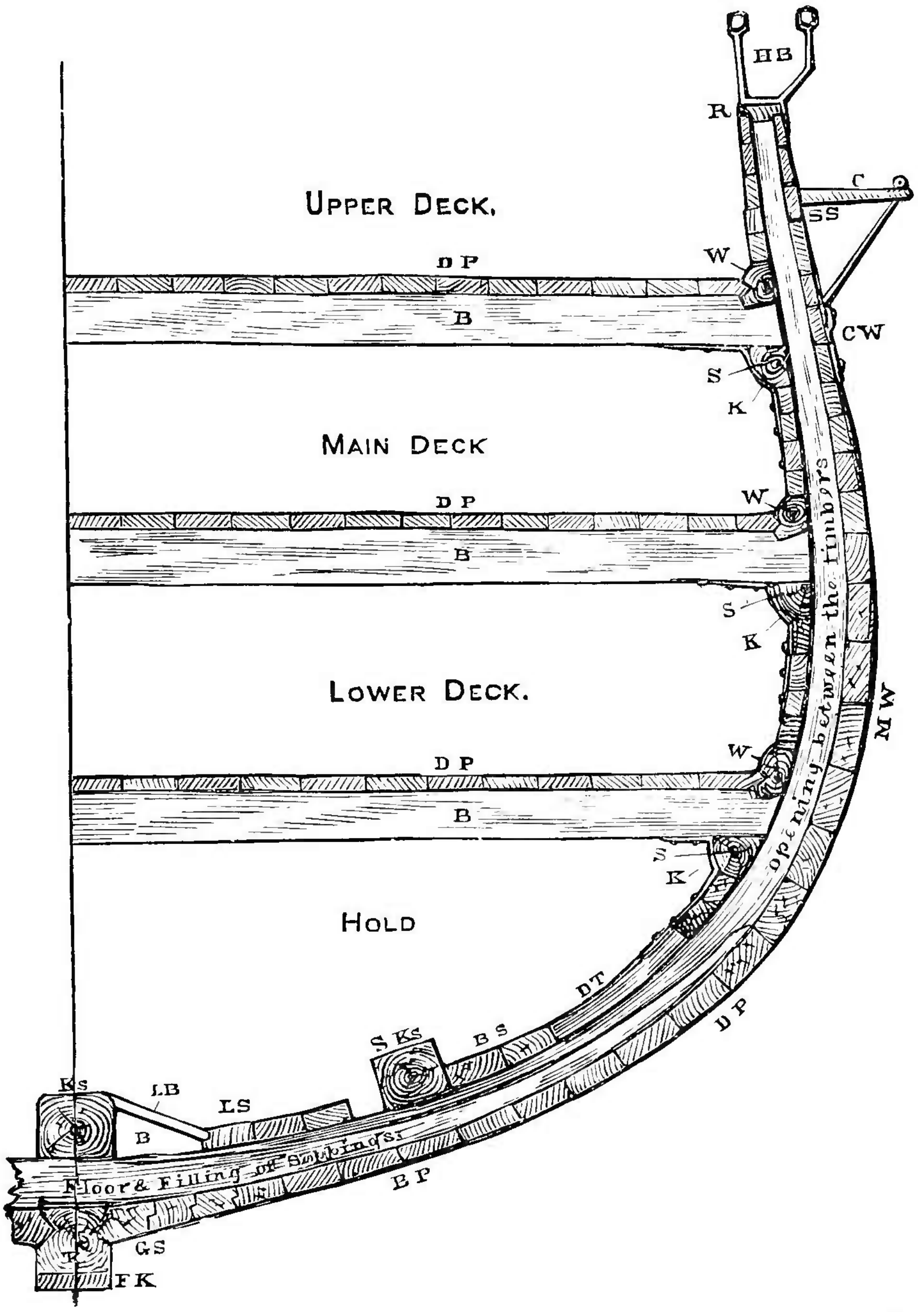


Fig. 135.—F.K., False keel; K.S., Keelson; B., Bilge; L.B., Limber board; L.S., Limber strake; S.Ks., Sister keelson; B.S., Binding strakes; D.T., Diagonal trusses; G.S., Garboard strake; B.P., Bottom planking; S., Shelf-piece; W., Waterway; D.P., Deck planking and diminishing plank externally; K., Iron knee; B., Beam; R., Rough tree rail; H.B., Hammock berthing; C., Channel; S.S., Sheer strakes; C.W., Channel wales; M.W., Main wales.

walls, closed at the top by a covering board and extending downward to the bottom of the vessel, where it ends in the *limber* or *bilge*, a longitudinal channel parallel to, and one on each side of, the *keelson*—a kind of inner or upper keel. In order to strengthen the walls, the "skin spaces" are often occupied by "fillings" of seasoned wood, first introduced by Seppings and often called after his name. The outside planking of a ship's wall is known by certain technical names, varying with different parts of the vessel. Thus, the term "garboard strake" is applied to those planks next to the keel; the planks from the garboard strake to the bulging portion of the ship's side are called the "bottom planking"; the name "main wales" is given to the planks at the water line; those near the main deck are called the "channel wales," while those on the bulwarks are spoken of as the "sheer strake." These technical terms and parts of a ship's structure will be readily understood by a reference to fig. 135, which gives a midship section of an ordinary wooden ship.

In addition to the foregoing special structures, the framework of a wooden ship is made up of *beams* or substantial pieces of timber running horizontally across the vessel from timber to timber. These are secured to the timbers above and below by structures known respectively as *waterway-pieces* and *shelf-pieces*, and which run from end to end of the ship, forming a kind of internal horizontal strengthening band. The waterway-pieces are similar in structure to the shelf-pieces, and are so called because their upper and inner surfaces are so shaped as to form gutters to receive the drainage of the decks. The *decks* practically consist of planking laid across the beams in a fore-and-aft direction. In the middle line of the ship the beams rest upon *stanchions* or pillars, the lower deck stanchions springing from the keelson, while the upper ones rise from deck to deck.

Construction of Iron or Steel Ships.—These vessels have more or less the same essential structures as wooden ships, but all are made of metal. In general principles the construction of an iron ship is the same as that of a wooden one, but there is this essential difference, that in iron ships the keel and ribs are not such prominent structures as in wooden vessels, and that the strength of the whole ship depends as much upon the quality of the metal and upon the rigidity with which the various parts of the framework or shell are secured together as upon the strength of such individual parts as keel, ribs, beams, &c.

Perhaps the most conspicuous feature of iron and steel ships is the subdivision of their hulls into a number of watertight compartments and the provision of cellular double bottoms or water-ballast tanks. These arrangements are obviously great safeguards against accident, and are met with in all modern men-of-war as well as in the better class of mail and passenger steamships. In purely cargo vessels, watertight bulkheads are not very generally provided, as they interfere with the loading and unloading and the storage of bulky articles; the greater number of such vessels, however, have double-bottom compartments, which serve not only as a safeguard against flooding in the event of the shell being penetrated, but also as water-ballast tanks when the vessel is empty or loaded with a light cargo.

Interior Economy of Ships.—With regard to the comparative salubrity of the different kinds of ship, there is much to be said both for and against sailing and steam ships or in respect of wooden and iron or steel vessels. Sailing-ships appear to be more liable than other vessels to accidents by loss of men overboard and the general dangers of the sea. On the other hand, accidents connected with machinery, scalding, &c., and the sickness resulting from continuous work in high temperatures, are characteristic of steamships. From a mere health point of view, the substitution of iron or steel for wood in the construction of ships has rendered easier the cleansing and disinfection of vessels, but has made it more difficult to maintain a suitable temperature in cold weather and to prevent excessive heat in the tropics; to these disabilities of metal ships must be added the disagreeable effects of condensation on metal surfaces from moisture-laden air between decks.

When compared with vessels of the merchant service, men-of-war have both advantages and disadvantages. Though the crews of men-of-war are, in most respects, exceedingly well cared for, the proportionately large numbers of men on board and the general construction of the ships imply crowding and defective ventilation. Of late years, in the mercantile marine, the tendency has been in the direction of undermanning, with of course an attendant increase of cubic space per head. The forecastles of these ships are, as a rule, more easily and possibly better ventilated than the crew's quarters in a battleship. Passenger and emigrant ships are quite a class of their own, and vary largely from the magnificent liners, with full accommodation and every luxury, to the dark, dirty, overcrowded emigrant ships characterised often by discomfort and cheerlessness. Of this latter kind of vessel the most objectionable are the few carrying both emigrants and cattle. The same difficulties met with in these ships occur sometimes in naval transports carrying cavalry.

From a sanitary point of view, the most important features of the interior economy of ships which demand special reference are the *bilge*, the fore and after *peaks*, the *stokeholds*, the *lavatories*, the *closets*, the *forecastle*, *deck-house*, *cabins* and *general accommodation* for crews and passengers, the *ventilation* and the *heating*.

The Bilge.—In marine language this term has a double meaning. By a shipbuilder it is applied to the curved part of the outside and bottom of the vessel, below the waterline, which bulges. By a sailor it is applied to that cavity or cavities in which offensive liquid, known as bilge-water, collects. In this latter sense only is it used in this article, and constitutes, therefore, that part of a ship to which all internal drainage gravitates. From what has been detailed already regarding the construction of ships, it is apparent that, in wooden vessels and such iron ones as have a keelson, the bilge is a double channel. In men-of-war and other iron vessels without a keelson the bilge is merely that portion of the upper surface of the inner skin about the median line on which drain fluid naturally collects. Closely connected with the bilge is the *main drain;* this is a large pipe running nearly the whole length of the ship and may be placed either above or beneath the inner bottom of the vessel. This pipe receives the drainage from the bilge, and is further connected with the bilge-pumps, and also receives any water which may have gained access to the bunkers.

Fore and After Peaks.—These are spaces right forward and right aft; and next to the bilges, perhaps, the most insanitary parts of a ship. These places are separated from the hold, &c., by bulkheads; but are frequently in a most foul condition, and in the case of the fore-peak in small ships materially affect the air of the lower forecastles, where the crew are housed, and through which alone entry is gained to it. The hatch rarely fits tightly, in spite of the Board of Trade's regulation, which requires it to be fastened down on to a ring of rubber or other elastic material, hence any effluvium passes readily into the crew space. Where there is sufficient beam for the purpose, the forecastles should be separated by a passage-way leading to the fore-peak hatch, and any spare space so left utilised as a store for oilskins or other wet clothing, which it is obviously desirable to keep out of the forecastle. Where the beam of the vessel will not admit of this arrangement, the hatch might be placed in the middle line and a corresponding hatch placed in the top-gallant deck; these two hatches being connected by means of a wooden casing.

Stokeholds.—In steamships the engine-room and boilers are usually placed amidships, extending downwards to the floor, and separated from the hold between decks by bulkheads, thus preventing the free circulation of air from end to end of the vessel below deck. From a health point of view, important parts of such ships are the stokeholds. These places are situated at the bottom of the ship, deeply below water, and from them the furnaces are coaled. In the smaller vessels there is only one stokehold, but large ships have two or more. In these parts of the ship the heat may be and is often excessive. For economy of space, the stokehold is rarely made wider than is absolutely necessary, often not more than from 8 to 10 feet; the stokers, therefore, have to work in a sort of deep well, exposed to great heat from the furnaces, and from which they are unable to withdraw whilst on duty. The air at the bottom of the stokeholds tends to become very foul, while the temperature not unfrequently recorded is from 115° F. to 140° F. In a properly ventilated stokehold this should not be the case; in fact, if sufficient air be supplied for the combustion of the furnaces there will be a constant and rapid current, and the atmosphere be actually purer than in other parts of the ship.

Engine-rooms and stokeholds should be supplied with fresh air by means of large ventilators carried from above deck and fitted with cowls turned to the wind. In other cases, windsails may be found of advantage.

In the Royal Navy, where everything is of necessity protected, and where forced draught is the exception, the question of the ventilation of the engine-rooms and stokeholds becomes a very difficult matter. In the majority of vessels of this kind fresh air is of necessity supplied by special apparatus, such as fan-blasts, &c. As may be readily imagined, firemen as a class are unhealthy, the effect of the stokehold on its occupants being detrimental to a high degree.

Lavatories.—In every ship proper provision should be made to enable men to keep themselves clean. There is no need for any elaborate arrangement, but there are few vessels where space cannot be spared for a reasonable lavatory and bath-room, while there is abundant evidence to show that seamen greatly appreciate and make good use of such accommodation. As a general principle, everything provided for the use of seamen should be of the simplest and strongest description possible. A comparatively small space will provide all that is required; water can be supplied by means of a tap, and in steamers there should be no difficulty in arranging for a hot supply. A few basins can be readily fixed, with galvanised iron buckets provided for the washing of clothes. A galvanised iron bath of sufficient size and depth should be provided also. It is not necessary that this should be of sufficient length for a man to lie down, as thorough cleansing can be carried out in a squatting position provided the bath be deep enough for the purpose. The floor of such a lavatory should be covered with sheet lead, carried up the side for a short distance, and efficient means of drainage provided.

While this question of provision for the personal cleanliness of seamen and others in the mercantile marine is not specifically laid down either in

Regulations of the Board of Trade or by schedule in the Merchant Shipping Act, it is otherwise as regards the Royal Navy. In that service there is a daily issue of fresh water every morning for personal cleanliness; moreover, by Article 531 of the Admiralty Instructions, the captain of every ship is directed to take care that all officers and men have ample opportunities to avail themselves of the special fittings provided in the ship for personal washing, and that bath-rooms when so fitted are kept supplied with both hot and cold water, and also kept open for the use of those who desire it every evening after quarters. All commanding officers must see that proper times are appointed for washing the person, so that it may be a part of the daily routine. Special facilities are given in the Navy to stokers and firemen for personal cleanliness, and in the larger ships special bath-rooms with an unlimited supply of fresh water are at the disposal of these men. The consumption of fresh water in the Navy for personal washing averages about one gallon daily per man.

Article 529 of the Admiralty Instructions directs that bedding be aired once a week when the weather will permit, each article being exposed separately to the air by being tied up in the rigging or upon girt lines. Twice in every year the blankets must be washed with soap in warm water; and once a year the bed tickings are to be washed, and the hair beaten and teazed. Hammocks are usually washed every fourteen days; the allowance of fresh water for the washing of clothes and bedding in the Royal Navy is about two gallons weekly per man.

Closets and Removal of Excreta.—On ships, closets should be of the simplest description, as any complicated apparatus is certain to go wrong when used by the ordinary seaman. They should be provided on every vessel, and in the case of steamships can be always furnished with an efficient water-flush. The floor of the closet should be impermeable, the surface being finished with a good fall outwards. The structure should be of sufficient size for a man to stand upright in, and should be provided with ample light. The ventilation should be free and secured by louvred panels or simple holes in the door, with a scuttle out-board. The best form of apparatus is a short hopper made of galvanised iron attached to an iron soil-pipe, the apparatus being open to the air beneath. If the seat be made to lift up, the closet may be used as a urinal, thus obviating the necessity for what is always a source of trouble on ships. Passenger ships and the better class of vessels are usually provided with valve closets flushed with water from a cistern, and having a valve fitted to the lower end of the soil-pipe so as to prevent the entrance of sea-water. In these vessels the latrines for the crew are ordinary trough closets. In many of the small cargo-boats, the *pail* is the only form of convenience in use. In small yachts and some fishing-boats special kinds of closet are in use, especially where these conveniences must be placed below the water line and where the ordinary discharge by gravity is impossible. In these closets the flush-water is drawn directly from the sea by the user pulling the handle of a pump at his right side; the contents of the basin are discharged by a valve opened by a handle near his left hand. Any quantity of water may be used for flushing, and with ordinary care these closets answer their purpose well.

The soil-pipes of all ships' water-closets should discharge at a proper distance from the deck and out of sight. Where possible, closets should be in the after part of ships, so that the soil-pipe may shoot over or through the counter near the sternpost.

The closets for the crew should be near the men's quarters, but not so close as to cause any nuisance. Where a closet actually adjoins a forecastle, the bulkhead, if wooden, should be doubled with a layer of felt between the two thicknesses, and extra ventilation arranged for.

The proportion of privies or closets on passenger and emigrant ships required by the Board of Trade in their *Instructions as to Survey of Passenger Accommodation, Masters' and Crew Spaces*, 1895, is at the rate of two for twenty of crew. Under the eleventh schedule of the Merchant Shipping Act, 1894, every passenger or emigrant ship must be provided with at least two privies, and with two additional privies on deck for every 100 passengers; and in ships carrying as many as fifty female passengers with at least two water-closets under the poop or elsewhere on the upper deck for the exclusive use of women and young children. The privies must be placed in equal numbers on each side of the ship, and need not in any case exceed twelve in number. All such privies and water-closets must be firmly constructed and maintained in a serviceable and cleanly condition throughout the voyage, and may not be taken down until the expiration of forty-eight hours after the arrival of the ship at the final port of discharge, unless all the steerage passengers quit the ship before the expiration of that time. In ships, other than emigrant ships, when lying in dock, the usual regulation is that the closets should be cleaned and kept fastened, the crew, if remaining on board, going on shore for accommodation.

In the Royal Navy the usual form of closet for officers is that known as the "Duplex valve closet." The outlet of the pan is closed by two metal valves so arranged that while one is open the other is shut, and *vice versa*. The outlet of the soil-pipe is further protected by an automatically acting leather or metal valve. The escape of compressed or pent-up air in the soil-pipe is provided by means of a vent delivering outside the bulwarks. In torpedo-boats, where the closet is below the water line, the special form of closets already described are provided. For seamen and the crews of warships ordinary trough closets or latrines are supplied at the rate of three for every hundred seamen and marines. These latrines are usually placed forward on one or both sides of the forecastle, and completely disconnected therefrom. Urinals are commonly put on the opposite side of the deck to the latrines. Closets for officers are placed either on the upper deck or on the fore part of the main deck.

Accommodation for Crew.—In merchant ships the crew are berthed either in forecastles or deck-houses. Forecastles are of two kinds, according to situation. The upper or top-gallant forecastle is placed upon the upper deck, right forward; it has side lights or scuttles and is entered by a doorway. Lower forecastles are found only in small vessels. They are below deck, and are entered by a hatch, measuring usually 2½ feet square and sometimes covered with a scuttle. Leading from the hatch into this forecastle is a ladder or flight of steep steps. This lower forecastle is a most unsatisfactory lodging, and one which it is scarcely possible to keep in a sanitary condition. The top-gallant forecastle is far preferable, but the ideal accommodation for seamen is undoubtedly the deck-house, now met with on the better class of British vessels, but most frequently seen on Danish and Norwegian merchantmen.

Deck-houses are placed amidships, and have the sanitary advantages of light, air, accessibility, and possibilities for the greater convenience and comfort of their occupants. Even on small sailing-vessels it is found that the erection of deck-houses does not materially interfere with the working of the ship.

In some boats engaged in the cattle trade, the animals occupy the whole fore part of the vessel, while the crew are berthed below in the after part with the officers placed amidships in a deck-house.

The legitimate contents of crew spaces are hammocks or bunks, bedding, lockers, chests, a table, stove and lamp. Unfortunately, many crew quarters too frequently contain other articles, which, to say the least, are improper. These articles embrace all the different materials and implements on board which it is possible to stow away, notably, sails, cordage, spare blocks, cans, buckets, brushes, paint, tar, oil, paraffin, wet clothes, boots, and even provisions. These various articles not only pollute the air, but materially occupy space, and that illegally. The principal defects of sailors' quarters may be summed up as insufficient height, light, ventilation, and means of heating; to these may be added effluvia from cargo or bilge-water, improper storage, and overcrowding.

The Merchant Shipping Act, 1894, section 210, requires that every seaman shall have 72 cubic feet of air space and 12 square feet of floor area, and that such space shall be entirely free from stores, &c. This, the legal minimum limit, is certainly too small. Fortunately, in the larger vessels, there is a tendency rather to underman than to overcrowd; hence it is not unusual to find fewer men occupying a given crew space than could be allotted to it. On the other hand, there are a certain number of vessels on which the minimum only is provided, and the opinion prevails that this allowance should be increased to not less than 100 cubic feet per head. If the height of the forecastle were 6 feet, this would allow 16 square feet per man, or a fairly reasonable allowance.

It is noticeable that the Act of 1894 does not specify that a crew space shall be of any particular height, but merely provides that every such place shall be such as to make the space "available for the proper accommodation of the men who are to occupy it"; it also provides for a minimum amount of cubic capacity, as well as a minimum amount of floor space per man.

In iron ships, moisture frequently condenses from the air of the crew's quarters on to the metal plates and beams overhead, rendering the apartment damp generally, and also dropping into the bunks and wetting the seamen's bedding. This evil can be remedied by sheathing the metal with wood, or covering it with thick varnish and dusting thereon finely granulated cork. Where wood sheathing or sweat-boards are used, this lining often serves as a resting-place for filth and vermin. The surveyors of the Board of Trade are instructed not to sanction wood lining unless fitted quite close to deck and sides.

Seamen's bunks should be arranged so as to leave a clear space between them and the ship's side. This space should be wide enough for a man to pass round for cleaning and painting purposes. In no case should a crew space be certified for a greater number of seamen than there are bunks fitted for. The bunks themselves should be made of iron covered with a non-conducting composition. They should be not less than 6 feet long by 2 feet wide, and arranged in two tiers only; the distance between each tier and between the upper tier and the deck should be not less than 2 feet 6 inches. The bottom of the lower bunk should be at least 12 inches above the floor level, so as to permit of thorough cleansing underneath. Hammocks are preferable to bunks as sleeping accommodation for seamen, on account of their being more cleanly and occupying less space.

In all forecastles and crew spaces the decks or floors must be of wood, not less than 2½ inches thick, properly laid and caulked. Planks laid on quartering over an iron deck, or loose boards on an iron deck, are inadmissible. The floor or deck should slope to a well-constructed water-way, which should be efficiently drained by trapped scuppers so placed that they can be readily seen and cleaned.

In the Royal Navy the crews of battleships and first class cruisers are commonly berthed between decks; but in some of the smaller cruisers there is accommodation in the top-gallant forecastle. As in the merchant vessels, these forecastles are apt to be damp and unhealthy, owing to water gaining access through the hawse pipes when the ship is under way. There appears to be no exact scale of berthing accommodation for seamen and marines laid down by the Admiralty. The number berthed in any given space is mainly determined by the so-called hammock space; the usual interval between the hammock hooks as seen projecting downwards from the beams or girders being 18 inches. The cubic space actually available in the crew spaces varies in different classes of ship and often in different parts of the same ship; it may be roughly stated to vary from 100 to 200 cubic feet per man. In the naval transports or troopships, the ship's company are berthed separately in the forecastle, while the troops are placed in the main deck and in the fore part of the lower deck. In these ships the actual cubic space available for both sailors and soldiers is little in excess of 80 cubic feet per man.

Accommodation for Passengers.—As regards accommodation for passengers and emigrants there are special provisions in the Board of Trade's Regulations and in the tenth and eleventh schedules of the Merchant Shipping Act, 1894, which direct "that the height between decks must not be less than 6 feet, that there must not be more than two tiers of berths on any one deck, and that the height between the tiers and between the upper tier and the deck overhead must not be less than 2½ feet. In respect of floor area, it is laid down that on the upper passenger deck there must be at least 15 square feet, and on the lower passenger deck 18 square feet for each adult; but if the height between decks on the lower passenger deck be less than 7 feet, and if the apertures (exclusive of side scuttles) through which light and air are admitted together are less in size than in the proportion of 3 square feet to every 100 superficial feet of that deck, then the floor area of each adult must be at least 25 square feet."

The Board of Trade's *Instructions as to Survey*, 1895, enact that the number of passengers to be carried in the after-cabins, saloons, or fore-cabins must be determined by the number of berths or sofas, properly constructed for sleeping-berths, and so much of the floor area of the saloons or principal cabins as is not covered by tables or permanent fittings may be measured at the rate of 9 square feet for each passenger. The floor of state rooms is not to be counted for passengers, but the berths may be counted, provided there are 72 cubic feet of space in the state room for each passenger.

The aggregate number of passengers other than saloon or first class passengers, as certified on the passenger certificate of any vessel or ship, is limited to six times the number for which there is a clear sheltered space for the voyage; such sheltered space may be, either space in a house on deck, or in a cabin below deck, or under a waterproof turtle-back open only at the after end, or in two or more of such spaces.

Clear space on the spar or weather-deck must be left for the use and exercise of passengers, at the rate of at least 10 superficial feet for each adult. No greater number of passengers may be carried than in the proportion of fifteen for every 100 tons of a ship's registered tonnage.

Accommodation for Sick Persons.—In respect of hospital accommodation on ordinary merchant ships there appears to be no definite regulation, although it is clear that on every vessel of any size some special arrangement should be made for the berthing of sick members of the crew. The position of such accommodation will necessarily vary according to circumstances, but all that is essential is a well-ventilated isolated structure, fitted with an iron cot, washstand, and seat. This much at least should be available in case of accident or illness where a patient requires to be kept quiet, or in the event of infectious disease. In this latter circumstance, provision of such means of isolation are obvious and cannot be too strongly insisted upon.

In vessels carrying passengers or emigrants, the Merchant Shipping Act and Regulations of the Board of Trade demand the provision of hospital accommodation in the proportion of not less than 18 square feet of floor area for every fifty passengers. The lighting and ventilation must be such "as the circumstances of the case may, in the judgment of the emigration officer at the port of clearance, require."

In the Royal Navy the hospital accommodation or *sick bay* is usually constructed in definite relation to the number of the crew on any given vessel. The usual proportion in battleships is a sleeping accommodation for 3 per cent. of the total ship's complement, the floor area allowed being from 20 to 30 square feet per man. The location of the sick bay varies in different classes of ship. In the more modern large battleships it occupies the midship part of the main deck, where it is lighted and ventilated from above, and also by means of louvres and gratings in the bulkheads. In some few other large ships it is on the upper deck inside the superstructure, where it receives natural ventilation, and is lighted from above. In the smaller ships the sick bay is situated on the fore part of the main or lower deck. In these cases, natural ventilation is the exception, and provision is made for special means of lighting and supply of fresh air.

Prisoners in the Royal Navy receive special accommodation on board battleships and cruisers. This accommodation consists of special cells, usually placed on the main or lower decks. In size they average 200 cubic feet per man; if not ventilated by natural means, they are always specially connected with the system of artificial ventilation provided for the ship.

Ventilation on Shipboard.—This is one of the most important points to be considered, and often one of the most difficult to satisfactorily arrange. The ventilation of ships has been aptly compared to that of an uncorked bottle, and the larger the vessel the more complex does the question become.

Although the *air* of ships is sweet and fresh above deck, it is notoriously foul below. The chief causes of this are (1) excessive humidity, arising not only from respiration, but from washing of decks, and the wetting of the various parts by sea-water gaining access in rough weather; (2) excess of carbon dioxide associated with organic effluvia, attributable to respiratory vitiation and the products of combustion from oil lamps or candles; (3) sulphides of ammonium and hydrogen emanating from the bilges, and the product of chemical interaction between sea-water, wood or metal work, oil, cotton waste from engines, soap, paint, decomposing organic matter, dead rats, coal dust, and cargo material of various kinds; (4) effluvia from cargoes, more particularly from cattle, sugar, grain, lime, guano, compressed fuel, bones, fish, onions, tar, and petroleum; (5) gases from coal bunkers, the products of heat and moisture.

In respect of the evil effects of cargoes on the air of ships the following legislative enactments are of importance. The Board of Trade *Instructions as to Survey*, 1895, provide "that every place occupied by seamen shall, as far as practicable, be shut off and protected from effluvium which may be caused by cargo or bilge-water; the surveyor must, therefore, see that the bulkheads, sides, and decks of the crew spaces are so fitted, laid, and caulked, and are of such thickness that this provision is complied with, &c. The bulkheads, if made of wood, should be constructed of well-seasoned material, and, besides being tongued and grooved, should be doubled with felt between, or battened over the seams with felt under the battens."

In passenger or emigrant ships, under the Merchant Shipping Act, 1894, schedule 13, it is provided that "animals shall not be carried on any deck below that on which passengers are berthed, nor in any compartment in which passengers are berthed, nor in any adjoining compartment, except in a ship built of iron, and of which the compartments are divided off by watertight bulkheads extending to the upper deck."

Passenger ships of less than 500 tons register may not carry more than two head of cattle, nor, in larger vessels, more than one additional head for every additional 200 tons, nor more in all than ten head of large cattle. The expression "large cattle" includes both sexes of horned cattle, deer, horses, and asses; and four sheep of either sex, or four female goats, are deemed equivalent to, and, subject to the same conditions, may be carried in lieu of one head of large cattle. Not more than six dogs, and no pigs or male goats, may be conveyed as cargo in any passenger or emigrant ship.

Speaking generally, the ventilation of ordinary merchant or trading vessels is not well attended to. The means and appliances are not always there, and when provided, their use is often neglected. It is otherwise in the mail or passenger ships and in the ships of the Royal Navy, where the efficiency of the crews and the furnaces or engines is fully appreciated; but even in these vessels it is evident from the mere number and variety of appliances in use that the ventilation is not perfect.

As regards methods of ventilation on ships, their principles and application do not differ materially from those of ventilation on shore, as already enunciated in Chapter III. of this book. Where possible, natural ventilation is aimed at, but in the larger vessels and in men-of-war, owing to peculiarities of structure, natural methods are impossible; in them ventilation can only be secured by artificial means, and even then often but imperfectly. The special appliances used for effecting natural ventilation in ships are, hatchways and sky-lights, ports and scuttles, windsails and trysails, fixed tubular ventilators, hollow iron masts, and the funnel casing. For artificial ventilation the chief appliances employed are, the funnel and funnel casing, rotary fans, steam ejectors, compressed air, Perkin's ventilator and punkahs.

In lower forecastles on small vessels the hatchway is practically the only inlet and outlet for air, and in stormy weather is usually closed. Sometimes this hatch has a scuttle with side openings, but quite insufficient for the object desired. A few lower forecastles have a hole of six inches diameter through the roof, fitted with a cowl or mushroom ventilator, but this is often closed.

The top-gallant forecastles of the larger sailing-vessels and steamers have side ports or scuttles opening to the outer air in addition to other means of ventilation. In cattle steamers or other cargo boats, where a large amount of fresh air is needed, the ventilation of the decks and holds is commonly effected by ordinary circular cowled tubes and by large flat-sided shafts, the tops of which are provided with hinged flaps to direct the air downwards. Holds are almost invariably ventilated by windsails, trysails, or fixed tubular ventilators surmounted by a cowl. The height of these is regulated by the height of the structure in front of them, but in no case should there be less than 6 feet from deck to bottom of cowl or mouth.

The windsail or trysail is practically a canvas cowl, consisting of a tube or shaft, the upper end of which is fitted with wings or valves to direct the wind down the tube. It is most commonly met with in the naval service. The principle upon which it acts is like that of ordinary tubular fixed ventilators having an adjustable cowl, or the propulsion of fresh air into the parts to be ventilated by means of the ship's motion. All these contrivances are inoperative unless the inlet be directed to the wind. In calm weather they are more or less useless unless the vessel be moving swiftly.

In modern ships the employment of hollow iron masts constitutes an important means of ventilating holds and spaces between decks; in a similar way the bitts are often made hollow in iron ships and can be made to act as ventilators. The funnel casings, also, of steamers can be perforated with gratings or louvres, and, independently of its artificial action by virtue of an updraught produced in it by heat radiated from boilers, funnel and steam-pipes, is naturally and directly available as an outlet for the removal of vitiated air from the decks.

As to whether any given crew space is properly ventilated on a merchant vessel, the decision rests with the surveyor of the Board of Trade. His "Instructions" on this point are as follows:—"The simplest method is to have an iron pipe with a revolving cowl, which in lower forecastles must be as high as the bulwarks, fitted at each end or side of the crew space, so that while impure air escapes at one, pure and fresh air will enter at the other, and a constant circulation be kept up. Where such means for ventilation are adopted, one of the ventilators should pass through the deck to at least the lower side of the beams." Mushroom ventilators should be discouraged, as the screws are liable to rust and become jammed, while the opening is usually much less than the sectional area of the tube. The Board of Trade do not permit these ventilators unless they are at least 30 inches high for top-gallant forecastles and as high as the bulwarks for lower forecastles. Scuttles, companions, and doors are not to be considered as efficient means of ventilating crew spaces. There must always be two ventilators. Among other provisions for top-gallant forecastles is one for openings in the top and bottom of the bulkheads, covered with perforated zinc, and fitted with doors for closure.

Under the Merchant Shipping Act, 1894, it is enacted that "no passenger ship shall clear out or proceed to sea without such provision for affording light and air to the passenger decks as the circumstances of the case may, in the judgment of the emigration officer at the port of clearance, require; nor, if there are as many as one hundred passengers on board, without having an adequate and proper ventilating apparatus, to be approved by such officer, and fitted to his satisfaction; the passengers shall, moreover, have the free and unimpeded use of such hatchway, situated over the space appropriated to their use, &c."

The various means of securing ventilation on ships, as yet mentioned, include only those more or less available through the ordinary openings of the different parts of the vessel. These, though useful in their way and under appropriate circumstances, are only of limited value. Some are only available during fine weather, while others are only of use in certain ships or parts of ships. It is, therefore, necessary to secure ventilation by some other means, such as can be used at all times, in all weathers or climates, and on all parts of vessels, independently of whether they are cargo, passenger or war ships. All artificial systems of ventilation, whether on shore or on ships, act either by (*a*) extraction, (*b*) propulsion, or (*c*) by a combination of both.

Experience shows that, on ships, the most satisfactory system of artificial ventilation is one by propulsion. The interior of a ship, especially a large ship, is so complicated that ventilation by extraction or exhaust, unless maintained for a long period, will produce no appreciable improvement in the state of the air in the more remote parts. Under similar conditions, if the system of air-trunks, shaft and delivery tubes be well planned, artificial ventilation by propulsion is readily efficient throughout the largest vessels. The comparative value of artificial ventilation methods has been discussed already on page 214, *et seq.*, and the general arguments there expressed are fully applicable to the conditions met with on board ships. Just as in mines, tunnels and buildings on shore, so in ships the resistance to the movement of the air due to friction from the air-trunks, abrupt turns, angles, bends, expansions and contractions of ducts, and from eddies is enormous, so much so that a large part of the power employed to produce air-currents is needed to overcome this resistance; and, moreover, ventilating engines on board ship as elsewhere are usually constructed so as to provide a large reserve of power for overcoming such resistances.

In respect of the general conformation of air-trunks and ducts in ships, although the circular or cylindrical form is more economical as regards friction, owing to exigencies of ship construction, it is the practice generally to adopt rectangular ducts in all large vessels. These various air-trunks are usually provided with valves, in order to prevent the passage of water through watertight bulkheads by means of these air-channels, in case of accident. In men-of-war these valves are further necessitated in order to enable communication by the ventilating tubes between the magazines and the rest of the ship to be shut off in case of fire. The actual air-valves are either automatic or hand-worked. In some cases the occlusion of the lumen of the air-trunk is secured by the rising of a float on the incoming water; in others a hollow metal float releases a catch which permits a weighted sluice valve to close the air-tube. In men-of-war all air-tubes passing through watertight bulkheads and protective decks are automatic; those in the magazine air-tubes are hand sluices.

The following is a summary of the many forms of apparatus for artificial ventilation that have been or are now used in ships.

1. Pipes from the hold, &c., opening beneath or over fires. The draught induced by the heat removes the foul air from the lower parts of the ship to the fire, where it is consumed.
2. Placing special exhaust or foul-air pipes inside the funnel casing of steamships.
3. Steam or gas jets discharging into exhaust pipes. Edmund's steam jet is in use in the Navy.
4. Air-pumps fitted to special outlet tubes.
5. Cowls of various kinds fixed to exhaust pipes. In Boyle's system by this method, fresh air is introduced by special downcast ventilators.
6. Jets of compressed air discharging into a main air-trunk. This is D. C. Green's system in use on some merchant ships. The air is under a pressure of from 3 to 4 ℔ per square inch, and the discharge of a cubic foot of this compressed air is said to induce the discharge of 25 cubic feet of ordinary air. This system can be used for either propulsion or extraction.
7. *Perkin's automatic ventilator* is an exhaust arrangement which in various forms has been tried with indifferent success in the Navy, and

depends for its action upon the rolling or pitching motions of the ship. It consists of two cylindrical tanks placed one on either side of the deck, and connected below by a horizontal tube. From the upper part of each vessel pass two tubes; one leads upwards to the outer air, the other downwards to the space to be ventilated. Each of these tubes is fitted with valves. Each cylinder is filled half full with water. As the ship rolls, water gravitates from one tank to the other, and by so doing sucks foul air into one vessel and expels it from the other. It is practically an automatic air-pump, but only capable of action when the ship is rolling or pitching. It is placed diagonally in the ship, but owing to the small volume of air operated upon does not give results commensurate with the space which the apparatus occupies. The same principle has been adopted in the ventilating pumps of Thiers of New Orleans and of Roddy of New York; neither of these arrangements have been altogether satisfactory.

8. Rotary fans of various kinds. The general principle and power of these appliances has already been considered at page 211. Their use is very general in the Royal Navy, especially in the form of centrifugal fans varying from 3 to 6 feet in diameter. Blackman's fans, which are not centrifugal, are not much used in H.M. ships, except for moving air in comparatively small spaces, such as cabins.

The following list shows the relative number of supply and exhaust fans fitted in some of H.M. ships; it clearly shows that, while the principle of extraction is not altogether ignored in the Navy, the preference is given to supply methods of ventilation.

Name of Ship.	Exhaust Fans.		Supply Fans.	
	Number.	Diameter.	Number.	Diameter.
Devastation,	4	4′ 6″	4	5′ 6″
Thunderer,	4	4′ 6″	4	5′ 6″
Trafalgar,	3	two 6′ 0″ one 4′ 0″	4	4′ 0″
Nile, .	3	4′ 6″	4	4′ 6″
Imperieuse,	2	3′ 6″	4	4′ 6″
Edinburgh,	2	3′ 0″	6	4′ 1″
Colossus,	2	3′ 0″	6	4′ 6″
Inflexible,	1	3′ 3″	8	4′ 0″
Vulcan,	2	4′ 0″	2	4′ 0″
Polyphemus,	1	3′ 6″	2	one 4′ 0″ ,, 3′ 0″
Howe,	1	3′ 0″	5	4′ 0″
Anson,	1	3′ 0″	4	4′ 0″
Camperdown,	1	3′ 0″	4	4′ 0″
Royal Sovereign,	...	...	12	six 6′ 0″ ,, 5′ 6″
Royal Arthur,	...	...	5	four 5′ 0″ one 3′ 0″
Dreadnought,	...	...	6	4′ 0″
Neptune, .	...	...	4	4′ 0″
Collingwood,	...	...	4	4′ 0″
Severn,	...	...	2	4′ 0″
Galatea,	...	...	2	3′ 0″
Barossa,	...	...	2	3′ 0″
Barham,	...	...	2	3′ 0″
Bellona,	...	...	2	3′ 0″
Calliope,	...	...	1	3′ 0″

Heating and Lighting.—Apart from considerations of climate, the temperature or warmth of a ship depends upon the material of which she is constructed, whether she is propelled by steam or not, and upon the condition and nature of her cargo. Sailing-ships are as a rule colder than steamers; this is mainly due to the large amount of coal used on these latter vessels. This extra heat is naturally greatest near the furnaces, and not unfrequently is conveyed to distant parts of the vessel by steam-pipes, from which, if not suitably covered by some non-conducting material, an enormous waste of heat takes place.

Allusion has previously been made to the excessive temperatures which often prevail in engine-rooms and stokeholds. In many cases this condition arises from insufficient ventilation, and, unless suitable provision for the admission of fresh air to the stokeholds is made, the fires will not burn properly. If adequately ventilated, in tropical climates, the stokeholds of large vessels are often the coolest part of a ship. The holds of ships, especially sailing-ships, are frequently warmer than other parts. This is partly due to its depth from the external air, but more commonly depends on heating of the cargo. Certain cargoes, such as coal, grain, lime, sugar and many others, are apt to undergo various chemical changes attended with the evolution of much heat; this is particularly the case if the cargoes be stowed when damp, or if the holds in which they are placed be insufficiently ventilated. In steamships, a common source of increased temperature in the holds is the blowing out of hot water from the boilers into the bilges.

Iron ships are peculiarly liable to extremes of temperature, owing to the readiness with which the metal conducts heat.

As regarding the efficient heating of crew spaces on ships, there appears to be no official ruling. The various parts of ships are usually warmed artificially by fireplaces, stoves, or by steam-pipes or radiators. In the forecastles of merchant vessels there is usually a "bogey" or small square stove, constructed of thin cast-iron with a movable cover. It has many disadvantages: it requires constant attention, when heated allows the products of combustion to pass freely through its substance, readily cracks, is dangerous as a constant source of accident, is dirty, and from its shape clumsy and inconvenient. One of the rarest sights on board ships is a bogey stove in perfect condition. Much improvement might be made in crew spaces were a more rational stove made compulsory in these parts of ships. Probably the best and most economical stove would be a well-constructed circular wrought-iron slow-combustion one, lined with fire-clay. The flue should be of iron, connected to the stove by means of a curved pipe. The funnel should pass through the deck by a properly constructed flange and terminate in a cowl. When not in regular use, the stove might be disconnected and the cowl remain as a ventilator. Or the funnel of the stove might be made to pass up through the centre of an ordinary ventilator, allowing the smoke to escape at a higher level; the general effect of this arrangement would be to heat the air in the ventilator and so cause a considerably increased discharge by the outlet shaft.

While the *lighting* of the cabins of ships' officers and saloon passengers may be said to be fairly good, the reverse is too often the case in respect of emigrants and seamen. These deficiencies are commonly more apparent to occupants during the day than at night, as during this latter period illumination is effected by means of oil, candles, or electricity.

The following are the official instructions to surveyors of the Board of Trade upon this important point. "Every space appropriated to crew space should be properly lighted. To ensure that such will be the case under the ordinary conditions of a vessel's employment, it will generally be necessary to have so much provision for light when the ship is new and the paint clean, that if one-third of it be closed it will be possible to read the print of an ordinary newspaper in any part of the space."

Although the necessity at times of supplying light to forecastles by means of glass prisms or bull's-eyes in the deck is recognised, the Board of Trade discourage their use, except in cases where it is impracticable to obtain the requisite amount of light by other means, or in small vessels where side scuttles would be too near the water. The maximum diameter for side scuttles is fixed at 10 inches, as a larger size may weaken the structural strength of the side plating of a vessel.

Cleansing and Disinfection of Ships.—The unclean condition of ships, more particularly small ships, cattle-boats and fishing-vessels, is very common, not only in parts which are out of sight, but on their decks, forecastles, cabins, and holds. In the Royal Navy and on the better vessels of the mercantile marine, daily inspections are made by the ship's officers of the various parts in order to ensure their being kept thoroughly clean, and this routine needs to be strictly carried out. Merchant ships, as a rule, are not kept so clean as warships, which, in the Royal Navy, by Article 529 of the Queen's Regulations, it is the duty of the captain to strictly supervise and also to cause the holds to be whitewashed every six months or oftener if necessary.

In the Royal Navy the decks are cleaned by holy-stoning (wet or dry), and in the berthing parts by scraping and scrubbing with hot water, wetting only small portions at a time and drying thoroughly. The two former methods are open to objection in the inhabited parts of the ship, one from filling the air with dust, the other from loading it with vapour.

The commonest fault committed in cleansing ships is to employ water too frequently and in unnecessarily large quantities. Thorough scrubbing and cleansing can be effectively carried out without the use of large quantities of water, which very often, by accumulation charged with organic matter in out of the way corners, are productive of more trouble than the original dirt. There is much reason to believe that the unhealthiness of many ships in tropical parts is due to this cause; the more ships wash their decks in these places, the more sickly they are; the organic matter in suspense in the water is left upon the decks as they dry, with disastrous results. Great care should be taken to see that all superfluous water is removed, and that the forecastle is dried as quickly as possible; in wet or damp weather dry scrubbing should always be resorted to. It cannot be too clearly understood that "a damp ship is an unhealthy ship." Flushing with water or wet scrubbing should not be carried on when there is less than three degrees difference between the readings of the dry and wet bulb thermometers placed under a screen in the open air. It should also be a rule that, whenever the weather will permit, all bedding should be removed from the forecastle or crew berth spaces and exposed to the sun and wind for a certain time every day.

As regards the details necessary for the proper drainage and cleansing of merchant ships, their provision and supervision rests with the surveyor of the Board of Trade. His instructions upon this matter practically amount to this:—That he will see that there are holes, sufficient in number and size, through the cant or coaming of upper forecastles and deck-houses, to admit of a ready escape of water, and that there are plugs, with lanyards or chains attached, fitted to each hole. Where such drainage passes through a privy or other compartment, it is necessary to have a pipe for the drainage to pass through such privy or compartment, with the pipe made perfectly tight through the cant or coaming.

The most difficult parts of a ship to keep sweet or fairly clean are the bilges; that this is the case is readily understood from the nature of the material and refuse which they constantly receive. Bilges should not be flushed out with sea-water, neither should reliance be placed upon the use of deodorants or antiseptics; the only efficient means of keeping the bilges sweet is to pump them dry periodically and completely remove overboard the bilge-water itself. After being pumped dry, they may be flushed with fresh sea-water or with water mixed with a disinfectant or antiseptic.

The question of the disinfection of ships need not be reconsidered in this place, as it has already been discussed on page 695.

Water-supply of Ships.—Except in small sailing-vessels, the question of supply is no longer a difficult one, inasmuch as condensation and subsequent aëration can always be resorted to; however, difficulties often exist in regard to source and storage.

In ports, ships are usually furnished with water by "water-boats" fitted with tanks, from which the supply is pumped to the vessel requiring it; or direct from companies' mains. The former method has grave objections, owing often to the water-boats being dirty or having leaking decks, also owing to the difficulty, in cases of enteric fever, &c., of ascertaining the source from which the water-boat derived its supply. Where water-boats are the means of supply, a responsible ship's officer (the surgeon, if one is carried) should always inspect the barge and examine the water before allowing it to be delivered on board, and should further insist upon the hose being washed by the first pumpings before the end is put into the ship's tank. Under no circumstances should water be taken from a wooden water-barge. In the Royal Navy the rule is that no water is to be taken or used on board ship until it has been examined and passed by the surgeon.

In foreign ports the water is often of doubtful and in some cases of absolutely harmful quality. In many such ports in place of methods of supply, as above detailed, recourse has to be made to fetching the water from shore, either in casks and barrels, or by clearing the ship's boats of all removable gear and then filling them with water; finally towing them back to the vessel, where the water is pumped on board. Sometimes this latter method is improved upon by fitting each boat with a collapsible canvas bag. These methods are obviously objectionable, since the water may be and often is fouled by leakage of sea-water through the boat's sides, or by washing in over the gunwale.

As an alternative to the foregoing sources of water-supply, all large steamships and vessels of the Royal Navy rely upon the distillation of water from sea-water. There are a large number of distilling apparatus which have been approved by the Board of Trade; those of the first class will distil as much as 800 gallons in ten hours. Well-known kinds are those of Normandy, Kircaldy, and Caird & Rayner, all of which are employed in various ships of the naval service and mercantile marine. The Board of Trade's regulations as to the survey of steamships carrying passengers state that the distilling apparatus should, with certain exceptions, be taken to pieces every voyage and tested. "The water should be cold, pure, and fit to drink immediately after it is drawn off from the filter. No distilling apparatus should be passed unless fitted with a suitable sized filter, charged with animal charcoal."

The storage of water on ships is a difficult and unsatisfactory matter. In small vessels, casks are still in common use; they should be abolished altogether except in cases of emergency. The alternate wetting and drying rapidly sets up decomposition of the wood, and this being favoured by want of ventilation pollutes the water, rendering it unfit for dietetic purposes. If wooden casks are used, they should be properly charred inside, and not capable of containing more than 300 gallons; the staves should not be made of fir, pine, or soft wood. In large ships water is stored in galvanised iron tanks, holding often 600 gallons or more each. These, painted outside and cement washed within, form the most economical, and at the same time fairly sanitary receptacles. They need to be furnished with large manholes for the purpose of cleansing, which should be carried out as a matter of routine after every voyage. If possible, the manhole should be placed in such a position that natural light finds its way into every part of the tank when the cover is removed. Unfortunately, too often these water tanks are placed in most awkward and inaccessible parts of the ship, with the result that their supervision and cleansing are frequently neglected.

On ordinary merchant ships the supply carried must be equal to a daily allowance of 3 quarts per statute adult, exclusive of the quantity necessary for cooking, which latter must be shipped at the rate of at least 10 gallons for every day of the prescribed length of the voyage for every 100 statute adults on board (section 295, Merchant Shipping Act, 1894, read in conjunction with the twelfth schedule of same Act). Passenger ships provided with proper distilling apparatus, however, are required to store only half the above amount of water.

In the Royal Navy, the *Queen's Regulations and Admiralty Instructions*, Appendix XXI., state that for troops or third-class passengers water "is to be issued on the most liberal scale possible; and the minimum daily allowance of water is to be for each individual embarked, 6 pints when out of the tropics, and 1 gallon when within the tropics, which quantities are to suffice for all purposes." For the crews and complement of warships there is no definite enactment in the Admiralty Instructions as to the amount of water to be issued daily. General precautions are taken to prevent waste, but practically the sailor receives an unlimited supply. The daily average consumption of water on ships of the Royal Navy is 4 gallons per man, and of this some 2½ gallons are used for personal and clothes washing.

For the purification of water in the mercantile marine, various filters charged with animal charcoal are in use. For the same purpose, in the Navy, Morris' filter containing manganous carbon, Crease's filter charged with carbalite, and a special form of filter charged also with carbalite, and usually fitted in the bottom of a water tank, appear to be chiefly employed. The general conditions and principles of water purification on board ship do not differ from those explained on page 45, *et seq.;* it is probably merely a question of time and the dissemination of a better knowledge concerning the fallacies and dangers attaching to the use of imperfect filters, for the use of those of the Pasteur-Chamberland type to be officially required not only on vessels of the Royal Navy but in the greater number of those belonging to the mercantile marine.

Food on Shipboard.—The true economy and importance of providing the sailor with good and adequate food is sufficiently self-evident to need no special arguments in this place. Yet notwithstanding a practically unanimous opinion on this point, it is astonishing how little attention is really given to the feeding of seamen by those who employ them.

For the merchant service there is no official dietary scale; what food a seaman shall receive in any given ship or for any given voyage is entirely a matter of contract between the master and the man, and the Board of Trade merely see that the scale is inserted in the articles of agreement. The Merchant Shipping Act simply requires that *a* diet scale shall form part of the agreement, but in no way (except so far as lime-juice and sugar are concerned) indicates what such diet scale should be. The following tabular statement practically represents the diet scale signed for by the crew in the majority of British ships.

	Bread.	Flour.	Beef.	Pork.	Peas.	Sugar.	Coffee.	Tea.	Water.
	℔.	℔.	℔.	℔.	pts.	oz.	oz.	oz.	qts.
Sunday,	1	½	1½	...	...	2	½	⅛	3
Monday,	1	...	...	1¼	⅓	2	½	⅛	3
Tuesday,	1	½	1½	...	...	2	½	⅛	3
Wednesday,	1	...	...	1¼	⅓	2	½	⅛	3
Thursday,	1	½	1½	...	...	2	½	⅛	3
Friday,	1	...	...	1¼	⅓	2	½	⅛	3
Saturday,	1	...	1½	...	...	2	½	⅛	3

This dietary has a mean daily nutritive value of: proteids, 5·2 oz.; fats, 0·9 oz.; carbo-hydrates, 13·2 oz.; and salts, 3 oz. On some ships extras are allowed; thus, very often a fresh mess, composed chiefly of soup-bouilli, is given on Sundays in addition; occasionally preserved meat is substituted once a week for salt; sometimes a certain quantity of butter is served out instead of a portion of meat, while a few owners issue marmalade and pickles. In some coasting vessels, in which the labour is hard, the dietary is practically unlimited.

In addition to the foregoing or other articles of ordinary diet, the Merchant Shipping Act, 1894, section 200, demands the issue of lime or lemon juice with sugar (the sugar to be in addition to any sugar acquired by agreement with the crew). This lime or lemon juice must be served out daily at the rate of an ounce per day to each member of the crew, so soon as they have been at sea ten days, and during the remainder of the voyage, except during such time as they are in harbour and are there supplied with fresh provisions. Before being served out, the lime or lemon juice must be mixed with a due proportion of water; further, no lime or lemon juice may be taken on board ship for issue to the crew unless it has been obtained from a bonded warehouse for and to be shipped as stores; moreover, it may not be so obtained or delivered unless it contain 15 per cent. of proper and palatable proof spirit, to be approved by the Board of Trade inspector, or by the proper officer of customs.

Whilst fully admitting the grave difficulties in the way of securing satisfactory food on board ships, there appears much necessity for having the rations of coasting as well as ocean-going ships fixed by law. The chief defects apparent in the customary diet are: (1) monotony, (2) excess of salt meat, (3) deficiency of vegetable food, and (4) improper proportion of the different ingredients, more particularly an excess of proteids with a deficiency of fats and carbo-hydrates.

The regulations of the Board of Trade for the inspection of the provisions and water of ships are sufficiently comprehensive. They relate to notice being given to the inspector for the inspection of stores, and for supplying him with a list of all stores; they also provide for the inspection of all surplus stores left over after a previous voyage, and for turning out the contents of all casks of wet provisions among such surplus stores. The requisite condition of beef, pork, preserved meats and vegetables, vegetables in tins, flour and biscuits is defined. Briefly stated, "animal food is to be sweet and properly packed and pickled in pickle of full strength; vegetables are to be sound and fresh, properly preserved, and in strong and suitable tins. Flour is to be of fine grade, milled from fully-matured, good sound wheat, containing a proper proportion of nutritious matter, and packed in suitable casks or tanks. Biscuits are to be thoroughly baked and dried, and made of fully-matured wheat-flour. When stored in tanks, these are to be thoroughly cleansed, lined with fresh lime and dried before being refilled. The water left in the ship's tanks from a former voyage must all be completely emptied, and the tanks thoroughly cleansed and refilled with good fresh water."

A noticeable defect on board many merchant vessels is the want of proper places in which to store provisions; the result being that they are often exposed to unwholesome exhalations. It is not at all unusual to find on some vessels that the bread store opens into the crew's quarters, or that portions of the crew's food are kept in the forecastle. Such arrangements are obviously in violation of all sanitary teaching, and need not only official condemnation but legislative prohibition.

	Weekly Allowance per Statute Adult.			
	Scale A. For Voyages not Exceeding 84 Days in Sailing-Ships or 50 Days in Steamers.		Scale B. For Voyages Exceeding 84 Days in Sailing-Ships or 50 Days in Steamers.	
	℔	oz.	℔	oz.
Bread or biscuit,	3	8	3	8
Wheaten flour,	1	0	2	0
Oatmeal,	1	8	1	0
Rice,	1	8	0	8
Peas,	1	8	1	8
Potatoes,	2	0	2	0
Beef,	1	4	1	4
Pork,	1	0	1	0
Tea,	0	2	0	2
Sugar, .	1	0	1	0
Mustard, . .	0	0½	0	0½
Black or white pepper, ground,	0	0¼	0	0¼
Vinegar,	One gill.		One gill.	
Lime juice,	...		0	6
Preserved meat,	...		1	0
Suet,	...		0	6
Raisins,	...		0	8
Butter,	...		0	4
Salt,	0	2	0	2

Scale of Substitutes.

1 ℔ preserved meat = 1 ℔ salt beef or pork.
1 ℔ flour, bread, or biscuit or ½ ℔ beef or pork = 1¼ ℔ oatmeal or 1 ℔ rice or 1 ℔ peas.
1 ℔ rice = 1¼ ℔ oatmeal.
¼ ℔ preserved potatoes = 1 ℔ potatoes.
10 oz. currants = 8 oz. raisins.
3½ oz. cocoa or coffee = 2 oz. tea.
¾ ℔ treacle = ½ ℔ sugar.
1 gill mixed pickles = 1 gill vinegar.

In some small ships, particularly coasters, a system prevails of giving pay in lieu of food; this is bad, inasmuch as the men have neither proper storage for their provisions nor often enough money to provide themselves with sufficient food or of adequate quality.

In cases where the food or water supplied on board a merchant ship is deemed to be either bad or insufficient, any three or more of the crew may complain to any officer in command of any of Her Majesty's ships, or to any British consular officer, or to a superintendent or a chief officer of customs, who, after examining the food or water and finding it defective, must signify the same in writing to the master of the ship; in case of failure to provide proper provisions, &c., in place thereof, the master is liable to a penalty of twenty pounds.

The provisions for the crews of passenger ships are not to be inferior to those of the passengers. The table on page 1001 illustrates the scales of dietary authorised by the Board of Trade for passengers; these scales, it will be observed, vary according to the length of the voyage.

In the case of failure to supply issues of good and wholesome provisions in accordance with the above scales, the master is liable to a penalty of fifty pounds.

In the Royal Navy the seaman's dietary is in accordance with the following scale as laid down in Appendix XXI. of the *Queen's Regulations and Admiralty Instructions*, 1893.

	When to be Issued.	Articles.		Seamen.	
				Officers, Crew, and others, at a Seaman's Full Allowance.	Supernumeraries at two-thirds of a Seaman's Allowance.
1	Daily,	Biscuit, or	lb.	1¼	⅚
2		Soft bread,	,,	1½	1
3		Spirit,	pint.	⅛	1/12
4		Sugar,	oz.	2	1⅓
5		Chocolate—Ordinary,		1	⅔
		,, Soluble,		1·2	...
6		Tea,		¼	⅙
7	Weekly,	Oatmeal,	,,	3	2
8		Mustard,	,,	½	⅓
9		Pepper,	,,	¼	⅙
10		Vinegar,	pint.	¼	⅙
11	Daily, when procurable,	Fresh meat,	lb.	1	⅔
12		Vegetables,		½	⅓
When fresh provisions cannot be secured:—					
13	Every other day,	Salt pork,	,,	1	⅔
14		Split peas,	,,	⅓	2/9
15		Celery seed,	½ oz. to every 8 lb of split peas put into the coppers.		
16	On one alternate day,	Salt beef,	lb.	1	⅔
17		Flour,	oz.	9	6
18		Suet,	,,	¾	½
19		Raisins,	,,	1½	1
20	On the other alternate day,	Preserved meat, with either	lb.	¾	½
21		(1) Preserved potato, or	oz.	4	2
22		(2) Rice, or	,,	4	2
21		(3) Preserved potato, and	,,	2	1⅓
22		Rice, or	,,	2	1
17		(4) Flour,	,,	9	6
18		Suet,	,,	¾	½
19		Raisins,		1½	1

Scale of Substitutes.

In case it should be necessary to issue substitutes for any of the articles in this scale of victualling, the following proportion is to be adopted, viz. :—

Biscuit,	1 pound	are to be considered equal to each other.
Flour,	1 pound	
Rice,	1 pound	
Wine, .	½ pint	do. do.
Spirit,	½ gill	
Porter,	1 pint	
Coffee,	1 ounce	do. do.
Cocoa, . .	1 ounce	
Chocolate, ordinary,	1 ounce	
,, soluble, .	1·2 ounce	
Tea,	¼ ounce	

The following, when issued with meat rations, are to be considered equal to each other :—

1	Split peas,	⅓ pound.
	Peas (whole),	½ pint.
	Flour, .	¾ pound.
	Calavances,	½ pint.
	Dholl,	½ pint.
	Rice, .	¾ pound.
2	Vegetables, . .	½ pound.
	Compressed mixed vegetables,	1 ounce.
	Preserved potato,	2 ounces.
3	Oatmeal, .	⅙ pint or 2 ounces.
	Split peas,	⅖ pound.

When the men desire it, ¼ ℔ of flour may be issued in lieu of ¼ ℔ of biscuit; *and ships proceeding to sea are to fill up on this basis.*

Article 1726 of the Admiralty Instructions directs that, whenever practicable, whether at home or abroad, sea-going ships are to be supplied with fresh meat and vegetables. Fresh beef is to be received in quarters, and mutton in carcasses. Salt meat is not to be issued on board H.M. ships in harbour, or when fresh meat and vegetables can be obtained, except abroad, when an issue may take place once a week (Article 1727). No person is to receive a spirit ration in kind unless he is twenty years of age (Article 1729). Those not receiving or declining the rum ration are allowed by Article 1732 either the savings price of the rum or one of the following substituted rations :—

(1)	Tea, .	¼ oz.
	Soluble chocolate,	½ ,,
	Sugar,	1¼ ,,
(2)	Tea,	¼ oz.
	Sugar,	2¾ ,,
(3)	Soluble chocolate,	¾ oz.
	Sugar,	2 ,,

When required by the medical officer half an ounce each of lime-juice and sugar are to be issued daily to each individual (Article 1735).

Oatmeal or a ration of lime-juice and sugar is allowed to men working in the engine-rooms or stokeholds (Article 1736).

Prisoners receive no spirit ration or allowance in lieu, either in kind or money. Those sentenced to cell punishment receive either low diet, consisting of 1 ℔ of biscuit daily, or full diet, consisting of half the ordinary ration, omitting meat and rum. Low diet is limited to the first three days of punishment, and, in the case of an award of fourteen days cells, to the last three days (Article 742).

The nutritive value of the sailor's daily ration in the Royal Navy is, practically, proteids, 4·8 oz.; fats, 1·3 oz.; carbo-hydrates, 18 oz.; salts, 2·5 oz. As in the case of the soldier's ration, considerable and variable additions are made by the men themselves, by private purchase from the canteen, to the regulation allowance; these being entirely a matter of personal selection, are difficult to express in terms of food-principles, but their nature is such as to considerably increase the nutritive value of the daily food-supply.

In the training-ships of the Royal Navy a special dietary is provided for the boys. It permits of more variety than that of the ordinary seaman. It is given in detail in the following table :—

		Sunday and Thursday.	Monday and Friday.	Tuesday and Saturday.	Wednesday.	Total for 7 Days.
		Quantity Issued Daily.				
Soft Bread,	lb.	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$11\frac{1}{4}$
Sugar,	oz.	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$12\frac{1}{4}$
Chocolate,	,,	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$5\frac{1}{4}$
Tea, .	,,	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{7}{8}$
Fresh beef,	lb.	...	$\frac{3}{4}$	$\frac{3}{4}$	...	3
,, mutton,	,,	$\frac{3}{4}$	...	...	...	$1\frac{1}{2}$
Corned pork, .	,,	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	1	$2\frac{1}{2}$
Mixed vegetables, .	,,	...	...	$\frac{1}{2}$	...	1
Potatoes, or other vegetables according to season,	,,	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$5\frac{1}{4}$
Flour, .	,,	$\frac{1}{2}$	...	$\frac{1}{4}$	...	$1\frac{1}{2}$
Suet, fresh,	oz.	1	...	$\frac{1}{2}$	...	3
Raisins,	,,	2	...	...	...	4
Split peas,	,,	...	...	...	4	4
Celery seed,	,,	...	...	...	$\frac{1}{64}$	$\frac{1}{64}$
Mustard,	,,	$\frac{1}{4}$	Every	four days		
Pepper,	,,	$\frac{1}{8}$				
Vinegar,	pt.	$\frac{1}{16}$				
Salt,	oz.	1				

The nutritive value of this ration may be taken to be, proteids, 5 oz.; fats, 2·1 oz.; carbo-hydrates, 20 oz.; and salts, 2 oz.

On board H.M. troopships special dietary scales are authorised by the Admiralty Instructions. These are given in detail for men, women and children respectively on pages 1005 and 1006. The mean nutritive daily value of those for adults may be taken to be, proteids, 3·5 oz.; fats, 1·5 oz.; carbo-hydrates, 13 oz.; salts, 1·5 oz. Boys of 10 years and under 14 years of age receive the woman's ration; boys of 14 years of age or upwards receive the man's ration; girls of 10 years of age or upwards receive the woman's ration.

Disease, Accident, and Death at Sea.—The statistical facts at our disposal in respect of these matters are not very satisfactory. While those having reference to the Royal Navy may be deemed fairly complete, those relating to the mercantile marine are far from reliable; this arises from the fact that many merchant vessels do not carry a surgeon, and that in many cases the information respecting both sickness and death is derived from unprofessional sources.

In accordance with the Births and Deaths Registration Act, 1874, commanding officers of ships trading to or from British ports are required, under penalty, to transmit returns of all births and deaths occurring on board their ships to the Registrar-General of Shipping and Seamen, who furnishes certified copies of such returns to the Registrars-General of England, Scotland, and Ireland. Similar returns are furnished by persons having charge of Her Majesty's ships directly to the Registrars-General of Births and Deaths.

Mercantile Marine.—That even this service has shared in the general reduction of death-rates which so peculiarly characterises this generation, is shown in the summary on page 1007 of the number and mortality of seamen employed in vessels registered in the United Kingdom, under the Merchant Shipping Acts.

Transport or Troopship Dietaries.

Scales of Rations for Her Majesty's Troopships.

Troops or Third-Class Passengers.

Days of the Week.	Daily.														Weekly.				
	Salt Beef.	Flour.	Suet.	Raisins.	Salt Pork.	Split Peas.	Preserved Meat.	Compressed Mixed Vegetables.	With Fresh Meat an additional 4 oz. of Bread, or 3 oz. of Biscuit, is to be issued to each Man. Biscuit.	Fresh Bread.	Rice.	Preserved Potatoes (uncooked).	Sugar (unrefined).	Tea.	Vinegar.	Mustard.	Pickles (of various descriptions).	Pepper (ground).	Salt.
SCALE OF RATIONS per Man.	oz.	oz.	oz.	oz.	oz.	pint.	oz.	oz.	oz.	lb.	oz.	oz.	oz.	oz.	pint.	oz.	oz.	oz.	oz.
Sunday,	12	6	1	2	...	...	...	...	12	...	...	2	4	$\frac{1}{2}$	$\frac{1}{6}$	$\frac{1}{2}$	6	$\frac{1}{6}$	2
Monday, .	...	...	...	...	...	...	12	...	...	1	4	...	2	$\frac{1}{2}$					
Tuesday,	...	...	...	...	12	$\frac{2}{9}$	...	1	12	...	...	...	2	$\frac{1}{2}$					
Wednesday,	12	6	1	2	...	...	...	...	...	1	...	2	4	$\frac{1}{2}$					
Thursday,	...	...	...	...	...	...	12	...	12	...	...	2	2	$\frac{1}{2}$					
Friday,	...	...	...	...	12	$\frac{2}{9}$	...	1	...	1	...	...	2	$\frac{1}{2}$					
Saturday,	...	...	...	...	...	...	12	...	...	1	...	2	2	$\frac{1}{2}$					
SCALE OF RATIONS per Woman.																			
Sunday,	8	6	1	2	...	...	...	...	With Fresh Meat each Woman is to receive an additional 4 oz. of Bread.	$\frac{3}{4}$	...	2	4	$\frac{1}{2}$	$\frac{1}{6}$	$\frac{1}{2}$	6	$\frac{1}{6}$	2
Monday,	...	...	...	...	...	...	8	...		$\frac{3}{4}$	4	...	2	$\frac{1}{2}$					
Tuesday,	...	...	...	...	8	$\frac{2}{9}$	...	1		$\frac{3}{4}$	...	...	2	$\frac{1}{2}$					
Wednesday,	8	6	1	2	...	...	...	...		$\frac{3}{4}$	...	2	4	$\frac{1}{2}$					
Thursday,	...	...	...	...	...	...	8	...		$\frac{3}{4}$	...	2	2	$\frac{1}{2}$					
Friday,	...	...	...	...	8	$\frac{2}{9}$	...	1		$\frac{3}{4}$	...	...	2	$\frac{1}{2}$					
Saturday,	...	...	...	...	...	...	8	...		$\frac{3}{4}$	...	2	2	$\frac{1}{2}$					

TRANSPORT OR TROOPSHIP DIETARIES—*continued.*

Days of the Week.	SCALE OF RATIONS per Child of 5 Years and under 10 Years of Age.													SCALE OF RATIONS per Child of 1 and under 5 Years of Age.					
	DAILY.												WEEKLY.	DAILY.					
	Salt Pork or Salt Beef.	Flour.	Suet.	Raisins.	Soup and Bouilli.	Rice.	Preserved Meat.	Fresh Bread.	Preserved Potatoes (uncooked).	Sugar.	Tea.	Fresh Milk.	Salt.	Biscuits or Rusks.	Sugar.	Fresh Milk.	Soup, Bouilli, or Essence of Beef.	Rice or Oatmeal.	Fresh Bread.
	oz.	oz.	oz.	oz.	oz.	oz.	oz.	lb.	oz.	oz.	oz.	pint.	oz.	oz.	oz.	pint.	pint.	oz.	lb.
Sunday,	6	3	½	2	...	2	...	½	...	3	¼	½	1	½	2	2	Sufficient to make ½	4	¼
Monday,	...	...	...	...	...	...	4	½	2	2	¼	½		½	2	2	½	4	¼
Tuesday,	...	...	...	...	10	2	...	½	...	2	¼	½		½	2	2	½	4	¼
Wednesday,	6	3	½	2	...	...	...	½	1	2	¼	½		½	2	2	½	4	¼
Thursday,	...	...	...	...	...	...	4	½	2	2	¼	½		½	2	2	½	4	¼
Friday,	...	...	...	...	10	2	...	½	...	2	¼	½		½	2	2	½	4	¼
Saturday,	...	...	...	...	...	...	4	½	2	2	¼	½		½	2	2	½	4	¼

Note.—Each infant under 1 year of age to be provided with milk, corn-flour, sago or arrowroot and sugar at discretion of Medical Officer.

If condensed milk be used, sufficient to make half a pint for children over five years of age, and sufficient to make 2 pints for children over one but under five years of age.

In using soup and bouilli, it is reckoned that 5½ ounces may be cooked with ¼ pint of water, or 10 ounces with ½ pint.

In using essence of beef half of a quarter pint canister should be cooked with half a pint of water.

Year.	Persons Employed.	Deaths Reported.	Death-rate per 1000.	Year.	Persons Employed.	Deaths Reported.	Death-rate per 1000.
1873	202,239	5,393	26·6	1884	199,654	3,757	18·8
1874	203,606	4,602	22·6	1885	198,781	3,286	16·5
1875	199,667	4,076	20·4	1886	204,470	3,546	17·3
1876	198,638	4,151	20·9	1887	220,266	3,384	15·4
1877	196,562	4,181	21·3	1888	223,673	3,114	13·9
1878	195,585	3,870	19·8	1889	230,263	3,018	13·1
1879	193,548	3,692	19·0	1890	236,108	3,305	14·0
1880	192,972	4,100	21·2	1891	240,480	3,263	13·6
1881	192,903	4,464	23·1	1892	241,735	3,452	14·3
1882	195,937	4,659	23·8	1893	240,974	3,172	13·1
1883	200,727	4,451	22·2				

The improvement in the rate of mortality shown in the foregoing table is mainly due to reductions of deaths on steam-vessels—that on board sailing-vessels in the year 1893 having been 18·8 per 1000, and in steamships 7·4 per 1000. No returns are issued by the Board of Trade relative to non-fatal forms of sickness among seamen. The chief source of loss of life at sea is due to wreck, drowning, or accident. The exact proportions of these losses in the mercantile marine are shown in the following table issued as Parliamentary Paper No. 430 of Session 2, 1895, and having reference to the year 1894.

	Masters and Seamen Employed.	Lives Lost.					Percentages and Proportions.		Total Number of Lives Lost in Merchant Ships Registered in the United Kingdom.		
		Drowned.			Masters and Seamen Lost by Accident other than Drowning.	Total Number Lost by Drowning and other Accident.	Lives Lost by Drowning of Persons employed.	Lives Lost by Drowning and other Accident of Persons employed.	Crew.	Passengers (lost by Wreck only).	Total.
		Masters and Seamen Lost by Wrecks and Casualties.	Masters and Seamen Lost when Vessel was not Damaged.	Total.							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Sailing,	58,537	622	261	883	91	974	1·51 or 1 in 66	1·66 or 1 in 60	974	7	981
Steam,	159,257	444	300	744	141	885	·47 or 1 in 214	·56 or 1 in 180	885	*1,183	*2,068
Total,	217,794	1,066	561	1,627	232	1,859	·75 or 1 in 134	·85 or 1 in 117	1,859	*1,190	*3,049

* These figures include about 1,150 persons lost from the ss. "Kowshing," which was sunk by a Japanese man-of-war.

Royal Navy.—The latest returns in connection with this force, at present available, are those for 1893; in that year, the average daily sick-rate was 41·32 per 1000; the number finally invalided out of the service was 1626, or in the ratio of 27·04 per 1000 of strength; the total number of deaths was 679, or a ratio of 11·29 per 1000; this mortality rate exhibits an increase of 5·71 per 1000 in comparison with 1892, and of 4·69 on the average of the last six years. This high death-rate, however, was due mainly to the sinking of H.M.S. "Victoria," in which no less than 358 persons were drowned. If the deaths consequent on the loss of the "Victoria" are excluded, the total number would be 317, equal to a death-rate of 5·27 per 1000, or 0·31 below that of the preceding year. The death-rate from disease alone was 4·07 per 1000, and from injury and accident 7·22 per 1000.

A summary of the mortality in the Navy during the past twenty years is given below:—

Year.	Death-rates per 1000.			Year.	Death-rates per 1000.		
	All Causes.	Disease.	Violence.		All Causes.	Disease.	Violence.
1874	9·4	6·7	2·7	1884	9·0	5·8	3·2
1875	8·8	6·9	1·9	1885	7·0	4·7	2·3
1876	9·2	6·0	3·2	1886	6·9	5·1	1·8
1877	7·1	5·0	2·1	1887	8·3	4·9	3·4
1878	14·4	5·3	9·1	1888	5·7	3·9	1·8
1879	8·6	6·2	2·4	1889	5·3	3·8	1·5
1880	12·6	4·6	8·0	1890	8·5	4·1	4·4
1881	10·9	5·3	5·6	1891	6·2	4·7	1·5
1882	7·5	6·9	2·6	1892	5·6	4·4	1·2
1883	5·9	4·1	1·8	1893	11·3	4·1	7·2

The Navy, like the Army, must be regarded as a force of specially selected, and presumably healthy, men in the prime of life; a comparison, therefore, of the death-rates of this picked body of males at varying age-periods with the rates for males in civil life for the same ages is of interest. The facts are as follow:—

	Death-rates per 1000, at the following Age-periods.			
	15 to 25.	25 to 35.	35 to 45.	45 to 55.
Royal Navy (1892),	4·14	6·03	9·56	19·23
Males in civil life,	4·7	7·4	12·8	20·8

In the above table the year 1892 has been taken for the Royal Navy, as the year 1893 yielded an exceptional mortality owing to special accidental causes. The civil death-rates are those for England and Wales. The comparative statement clearly shows that the conditions of life in the Navy are distinctly favourable to health.

Special Causes of Sickness among Sailors.—When we come to analyse the statistics of sickness and mortality of seafaring people, we find that sea life is apt to give rise to certain ailments which are more or less characteristic of, or peculiar to, the sailor's surroundings. Thus, sea-sickness is an ailment of marine life only, while formerly scurvy was especially associated with life on board ship. Cholera and yellow fever are diseases closely connected with ships; the contagion of both being not infrequently carried by them from one country to another.

The chief ailments to which sailors as a class are subject are, constipation, boils, erysipelas, lymphangitis, ennui, diarrhœa, sea-sickness, nostalgia, melancholia, hypochondriasis, colic, scurvy, the contagious fevers, itch, the effects of vicissitudes of climate, catarrhs, rheumatism, dysentery, and venereal affections.

Many of these are of exceptional prevalence, while one or two, notably scurvy and dysentery, are so much the effect of faulty dietaries, that attention to the food-supply of sea-going ships has practically removed these causes of death from the sea-casualty returns.

Some of the disorders prevalent among seamen appear to be closely associated with their duties. Thus, men engaged in the interior of ships, such as cargo-men, cooks, bakers, and storekeepers, are commonly anæmic and debilitated; so too are painters, who, like their fellow-workers on shore, are apt to suffer from colic and other symptoms of lead-poisoning. Look-out-men are said to suffer from weak sight, amblyopia, circumorbital pains, and loss of visual accommodation. Steersmen are liable to accidents from the wheel, and often suffer from auditory troubles, presumably effects of exposure, and prolonged efforts to keep on the alert for signals and words of command. Men engaged aloft generally suffer from traumatic lesions of the hands, feet, and inner parts of the thighs and legs; also from cardiac hypertrophy and hernia, the results of violent exertion. Boatmen and fishermen suffer much from rheumatism and other effects of frequent wettings and long exposure to weather. Boiler-cleaners are liable to asphyxia, while firemen, stokers, and engine-room artificers, who constantly work under conditions of high temperature, are usually anæmic, debilitated, and subject to vertigo, stupor, or convulsions. Phthisis is also common among these men. Firemen and stokers, as a class, are often morbid and prone to suicide.

Statistics showing the general prevalence of these and other forms of illness in the mercantile marine are unfortunately non-existent. How far these diseases and injuries prevail in the Royal Navy are shown in the following table, prepared from the *Statistical Reports on the Health of the Navy*, and based on the average ratios for the six years, 1887–92.

Disease or Injury.	Average Ratio per 1000, for Six Years, 1887–1892.			
	Cases.	Daily Sick.	Invalided.	Deaths.
Small-pox,	0·18	0·01	...	0·01
Other eruptive fevers,	5·64	0·34	...	0·04
Enteric fever,	2·85	0·4	0·35	0·67
Other continued fevers,	33·97	0·8	0·32	...
Yellow fever,	0·02	...	...	0·01
Cholera,	0·18	...	...	0·1
Dysentery,	1·28	0·08	0·17	0·05
Influenza,	41·93	0·78	...	0·04
Malarial fevers,	25·77	1·53	2·68	0·24
Septic diseases,	0·88	0·06	0·02	0·05
Syphilis—primary,	57·16	5·1	...	...
,, secondary,	23·97	2·48	1·97	0·05
Gonorrhœa,	76·21	5·09	0·69	0·02
Alcoholism,	1·27	0·02	0·01	0·02
Rheumatism,	44·64	1·97	1·54	0·07
Tubercular diseases,	0·65	0·06	0·22	0·17
Diseases of the nervous system,	12·75	0·66	2·75	0·24
,, circulatory system,	5·22	0·41	2·82	0·41
,, respiratory system,	89·13	3·22	4·03	1·34
,, digestive system,	120·4	2·51	2·8	0·29
,, urinary and generative system,	9·8	0·56	0·82	0·19
,, eye,	9·43	0·42	0·75	...
,, ear,	4·33	0·18	0·69	...
Poisoning,	0·85	0·02	0·02	0·04
Wounds and injuries, general,	3·87	0·06	0·16	1·83
,, local,	197·51	6·57	1·92	0·28
Suicides,	0·1	...	...	0·1

BIBLIOGRAPHY AND REFERENCES.

Armstrong, Article on "Marine Hygiene" in Stevenson and Murphy's *Treatise on Hygiene*, vol. ii. p. 513. This article gives a copious bibliography on this subject.

Cane, "The Hearing of Seamen," *Lancet*, April 13th, 1889.

Collingridge, *Annual Reports as Medical Officer of Health of the Port of London;* also "Practical Points on the Hygiene of Ships," *Proc. Shipmasters' Soc.*, Lond., 1894; also "On Port Sanitary Administration," *Journ. Sans. Instit.*, vol. xvi. p. 40.

Fonssagrives, *Traité d'Hygiène Navale*, Paris, 1877.

Froud, "Heating of Ships and Cargoes," *Proc. Shipmasters' Soc.*, Lond., 1891.

Gihon, *Practical Suggestions on Naval Hygiene*, Washington, 1871.

Holt, *Review of the Principles of Maritime Sanitation*, New Orleans, 1892.

Leach, *Hygienic Condition of the Mercantile Marine in the Port of London*, 1871.

Lewes, *Service Chemistry*, Lond., 1892.

MacDonald, *Naval Hygiene*, Lond., 1881; also "On Ship Ventilation," *Journ. Royal United Service Instit.*, July 1895. Mahé, *Manual Pratique d'Hygiene Navale*, Paris, 1874.

Paasch, *From Keel to Truck*, Antwerp, 1885.

Spooner, "Dietary Scales in connection with the Health of Seamen," *Trans. VIIth Internat. Congress of Hyg. and Demog.*, Lond., 1891, vol. viii. p. 41.

Taylor, "The Medical Supervision of the Mercantile Marine," *Trans. VIIth Internat. Congress of Hyg. and Demog.*, Lond., 1891, vol. viii. p. 18.

Turner, Article on "Marine Hygiene" in *Buck's Hygiene*, New York, 1878.

Wilson, *A Manual of Naval Hygiene*, Philadelphia, 1879.

APPENDIX I.

MEASURES OF LENGTH.

The **Standard Metre** is $\frac{443{\cdot}296}{864{,}000}$ of the distance, at the temperature of 16°·3 C., between the ends of a certain bar, called the "Toise of Peru," kept in the French Archives, and is approximately the ten-millionth part of the distance from one of the earth's poles to the Equator, at the meridian of Paris. This measure, and those founded on it, is lawful in this country, and a copy of the standard metre is kept in the Exchequer Office at Westminster.

The English **Standard Yard** is the distance, at the temperature of 62° F., between two marks on a certain bar which is kept in the Office of the Exchequer.

The relative values of the Metric and English measures of length can be gathered from the following table:—

	Metres.	Inches.	Feet.	Yards.	Miles.
Kilometre,	1000	...	...	...	0·6214
Hectometre,	100	...	...	...	...
Decametre,	10	...	...	...	...
Metre,	**1**	**39·37**	**3·28**	**1·0936**	...
Decimetre,	0·1	...	...	...	...
Centimetre,	0·01	...	...	...	...
Millimetre,	0·001	0·03937	...	...	...

APPENDIX II.

MEASURES OF AREA.

	Square Metres.	British Measures of Area.	
Square Kilometre,	1,000,000	0·3861	sq. mile.
„ Hectometre, or Hectare,	10,000	2·4711	acres.
„ Decametre, or Are,	100	119·6	sq. yards.
„ **Metre,**	**1**	**10·764**	sq. feet.
„ Decimetre,	0·01	15·5	sq. inches.
„ Centimetre,	0·0001	0·155	„
„ Millimetre,	0·000001	0·00155	„

APPENDIX III.

SOLID MEASURES.

1 Cubic Decametre, or Kilostere,	equals	35,316·5	cubic feet.
„ **Metre**, or **Stere**,	„	35·316	„
„ Decimetre, or Millistere,	„	61·025	cubic inches.
„ Centimetre	„	0·061	„
„ Millimetre	,	0·000061	„

APPENDIX IV

MEASURES OF WEIGHT.

The metric **Standard Kilogramme** is the weight, at the temperature of the maximum density of water (4° C.), and under the atmospheric pressure of 760 millimetres of mercury, in the latitude of Paris, of a certain piece of platinum which is kept in the French Archives. A copy of this standard kilogramme is kept in our Exchequer Office. The kilogramme was at first intended to be the weight of one cubic decimetre of pure water at its maximum density, but it is in actual fact slightly greater.

The English **Standard Pound Avoirdupois** is the weight, at the temperature of 62° F., and under the atmospheric pressure of 30 inches of mercury, in the latitude of London, and at or near the level of the sea, of a certain piece of platinum which is kept in the Exchequer Office at Westminster.

The relative values of the Metric and English weights is shown in the following table :—

	Grammes.	Grains.	Avoir. ozs.	Avoir. ℔.
Kilogramme,	**1000**	**15,432**	**35·3**	**2·204**
Hectogramme,	100	...	...	...
Decagramme,	10	...	...	...
Gramme,	1	15·432	0·0353	0·0022
Decigramme,	0·1	...	...	...
Centigramme,	0·01	...	...	...
Milligramme,	0·001	0·0154	...	...

APPENDIX V.

MEASURES OF CAPACITY.

The metric **Standard Litre** is the volume of a kilogramme of pure water at its temperature of maximum density (4° C.), and under the atmospheric pressure of 760 millimetres of mercury. It was originally intended to be a cubic decimetre, but is actually a little greater. Under the above mentioned conditions, a litre of pure water weighs one kilogramme.

The English **Standard Gallon** is the volume of 10 ℔ avoirdupois of pure water, at the temperature of 62° F., and under the atmospheric pressure of 30 inches of mercury.

The relative values of the Metric and English measures of capacity is shown in the following table :—

	Cubic centimetres.	Fluid ozs.	Pints.	Gallons.	Cubic ins.
Kilolitre,	1,000,000	...	...	...	...
Hectolitre,	100,000	...	...	...	...
Decalitre,	10,000	...	...	...	...
Litre,	**1000**	**35·3**	**1·76**	**0·22**	**61·027**
Decilitre,	100	...	...	...	...
Centilitre,	10	...	...	...	...
Millilitre,	1	...	...	...	...

APPENDIX VI.

TABLE OF FACTORS FOR CALCULATING EQUIVALENTS OF WEIGHT, VOLUME, LENGTH, &c.

To convert	grammes	to pounds,	multiply by	0·0022
„	„	to grains,	„	15·432
„	„	to ounces,	„	0·0353
„	grains	to grammes,	„	0·0648
„	ounces	to „	„	28·349
„	pounds	to „	„	453·592
„	kilogrammes	to pounds,	„	2·204
„	„	to ounces,	„	35·3
„	litres	to gallons,	„	0·22
„	„	to fluid ounces,	„	35·3
„	„	to pints,	„	1·76
„	„	to cubic feet,	„	0·354
„	„	to cubic inches,	„	61·027
„	gallons	to cubic feet,	„	0·1605
„	„	to litres,	„	4·5434
„	pints	to „	„	0·5679
„	„	to cubic centimetres,	„	568·1818
„	„	to cubic inches,	„	34·6592
„	cubic metres	to gallons,	„	0·0036
„	„	to pints,	„	0·0288
„	„	to fluid ounces,	„	0·5813
„	„	to cubic centimetres,	„	16·4
„	cubic feet	to cubic metres,	„	0·0283
„	„	to litres,	„	28·2153
„	„	to gallons,	„	6·2322
„	fluid ounces	to cubic inches,	„	1·72
„	„	to cubic centimetres,	„	28·35
„	square feet	to square metres,	„	0·0924
„	„	to square yards,	„	0·111
„	square metres	to square feet,	„	10·7641
„	inches	to metres,	„	0·0254
„	„	to millimetres,	„	25·4
„	metres	to inches,	„	39·37
„	„	to feet,	„	0·30479
„	feet	to miles,	„	0·000187
„	yards	to „	„	0·00057
„	„	to centimetres,	„	2·54
„	centimetres	to inches,	„	0·3937
„	millimetres	to „	„	0·03937
„	kilometres	to miles,	„	1·6
„	square kilometres	to square miles,	„	2·5899
„	hectares	to acres,	„	0·4046

APPENDIX VII.

Table showing the Daily Yield of Water from a Roof with varying Rainfalls.

Area of House, 10 feet by 20 feet, or 200 square feet.					
Mean Rainfall.	Loss from Evaporation.	Requisite capacity of Tank.	Mean daily yield of Water.	Mean daily yield of Water in wettest year.	Mean daily yield of Water in driest year.
inches.	per cent.	cubic feet.	gallons.	gallons.	gallons.
20	25	100	4·3	6·7	3·2
25	20	135	5·7	7·5	3·9
30	20	145	6·8	9·4	4·5
35	20	155	7·9	11·0	5·0
40	15	165	9·7	13·1	7·2
45	15	170	10·9	14·2	8·6

For any other size of Roof or amount of Rainfall, the numbers will be proportional.

One inch of rain = 101 tons per acre = 22,624 gallons.

APPENDIX VIII.

The Chemical Symbols and Atomic Weights of Elementary Bodies.

Names of Elements.	Chemical Symbols.	Atomic Weights.	Names of Elements.	Chemical Symbols.	Atomic Weights.
Aluminium, .	Al	27·5	Nitrogen,	N	14·0
Antimony,	Sb	120·0	Oxygen,	O	16·0
Arsenic,	As	75·0	Palladium,	Pd	105·7
Barium,	Ba	137·0	Phosphorus, .	P	31·0
Bromine,	Br	80·0	Platinum,	Pt	197·2
Cadmium,	Cd	112·0	Potassium,	K	39·0
Calcium,	Ca	40·0	Rubidium,	Rb	85·3
Carbon,	C	12·0	Selenium,	Se	78·8
Chlorine,	Cl	35·5	Silicon,	Si	28·0
Chromium,	Cr	52·5	Silver,	Ag	108·0
Cobalt,	Co	59·0	Sodium,	Na	23·0
Copper,	Cu	63·2	Strontium,	Sr	87·4
Fluorine,	F	19·0	Sulphur,	S	32·0
Gold,	Au	196·2	Tantalum,	Ta	182·0
Hydrogen,	H	1·0	Tellurium,	Te	125·0
Iodine, .	I	126·6	Thallium,	Tl	203·7
Iridium,	Ir	192·7	Thorium,	Th	231·5
Iron,	Fe	56·0	Tin,	Sn	118·0
Lead,	Pb	206·5	Titanium,	Ti	48·0
Lithium,	Li	7·0	Tungsten,	W	184·0
Magnesium,	Mg	24·0	Uranium,	U	240·0
Manganese,	Mn	55·0	Vanadium,	V	51·3
Mercury,	Hg	200·0	Yttrium,	Y	88·0
Molybdenum,	Mo	95·5	Zinc,	Zn	65·0
Nickel,	Ni	59·0	Zirconium,	Zr	89·4

APPENDIX IX.

Table showing the amount of Oxygen capable of being dissolved in Distilled Water, at varying temperatures, under standard pressure.

Temperature Centigrade.	Cubic centimetres of Oxygen per litre of distilled Water.	Temperature Centigrade.	Cubic centimetres of Oxygen per litre of distilled Water.
5·0	8·68	18·0	6·54
5·5	8·58	18·5	6·47
6·0	8·49	19·0	6·40
6·5	8·40	19·5	6·34
7·0	8·31	20·0	6·28
7·5	8·22	20·5	6·22
8·0	8·13	21·0	6·16
8·5	8·04	21·5	6·10
9·0	7·95	22·0	6·04
9·5	7·86	22·5	5·99
10·0	7·77	23·0	5·94
10·5	7·68	23·5	5·89
11·0	7·60	24·0	5·84
11·5	7·52	24·5	5·80
12·0	7·44	25·0	5·76
12·5	7·36	25·5	5·72
13·0	7·28	26·0	5·68
13·5	7·20	26·5	5·64
14·0	7·12	27·0	5·60
14·5	7·04	27·5	5·57
15·0	6·96	28·0	5·54
15·5	6·89	28·5	5·51
16·0	6·82	29·0	5·48
16·5	6·75	29·5	5·45
17·0	6·68	30·0	5·43
17·5	6·61		

APPENDIX X.

THE STAINING AND MICROSCOPIC EXAMINATION OF MICRO-ORGANISMS.

Staining constitutes an indispensable aid to the study of micro-organisms, and a knowledge of the composition and preparation of various stains is essential to those making bacteriological examinations of either water or animal tissues.

The various stains or dye-stuffs in common use in pathological work are practically divided into two great classes, namely, the *basic* and the *acid.* The former exhibit a strong affinity for the protoplasmic contents of bacterial cells as well as for the nuclei of animal tissues; the latter or acid coal-tar colours do not exhibit this special affinity for the nuclei and bacteria, but stain animal tissues more or less uniformly throughout their entire extent. These two classes of dye-stuffs, therefore, are sharply distinguished from each other, the basic dyes being alone available for the exact exhibition of micro-organisms, while the acid colours are best suited for the demonstration of other elements in the microscopic specimen.

The basic aniline dyes in most common use for the staining of bacteria are:—fuchsine, methylene blue, Bismarck brown, gentian violet, and methyl violet. The chief acid coal-tar colours are:—eosine, acid magenta, picric acid, safranine, &c. The natural acid stains, such as hæmatoxylin and cochineal, have a similar action.

For bacteriological work, it is most convenient to prepare saturated alcoholic solutions of the basic dyes, which can be kept in stock ; these stock solutions are then diluted with about ten times their volume of distilled water for actual use. Small quantities only of the diluted solutions should be made at a time as they keep badly, with the one exception of methylene blue, which keeps well. Owing to the fact that the staining powers of these aqueous alcoholic solutions may be greatly increased by the addition to them of certain substances, a large number of special stains have been devised ; the principal of these special stains are the following :—

Löffler's Methylene Blue.—To 100 c.c. of a solution of caustic potash (1 in 10,000) add 30 c.c. of a saturated alcoholic solution of methylene blue.

Kühne's Carbolic Methylene Blue.—In a mortar rub 1·5 gramme methylene blue with 10 c.c. of absolute alcohol, and add 100 c.c. of a 5 per cent. aqueous solution of carbolic acid.

Weigert's Gentian Violet.—To 90 c.c. of distilled water add 0·5 c.c. of liquor ammoniæ, 10 c.c. of absolute alcohol, and 2 grammes of gentian violet.

Ziehl's Fuchsine Solution.—Five grammes of carbolic acid and 1 gramme of fuchsine are added to 100 c.c. of distilled water to which 10 c.c. of absolute alcohol is gradually added.

Ehrlich's Solution.—The distinctive feature of this staining solution is that, in place of diluting the alcoholic solution of the basic dye with pure water, the concentrated stock solution is diluted with water which is saturated with aniline oil. Four to five c.c. of aniline oil are shaken up with 100 c.c. of distilled water. This oily mixture is passed through a damp filter, whereby the excess of undissolved oily aniline is retained by the filter, and to the clear filtrate, or "aniline water" as it is called, are added 11 c.c. of a concentrated alcoholic solution of either fuchsine, methyl violet, or gentian violet. The whole is then frequently shaken during twenty-four hours, at the end of which time the liquid becomes clear and ready for use. This solution will keep about three weeks.

Ehrlich-Löffler Solution.—This is a modification of the foregoing. Dissolve 5 grammes of solid fuchsine or any other basic colour in 100 c.c. of aniline water prepared as above. If kept in a stoppered bottle in the dark, this solution will keep for some six weeks. Its staining powers may be increased by adding a solution (1 in 1000) of caustic soda drop by drop, until the previously clear solution just begins to become cloudy, but not actually precipitated.

Ehrlich-Weigert-Koch Solution.—To 100 c.c. of aniline water add 11 c.c. of a concentrated alcoholic solution of fuchsine or methyl violet, and 10 c.c. of absolute alcohol. This solution will only keep some ten days or so.

Simple Staining of Cover-glass Preparations of Micro-organisms.—All cover-glasses and slides must be scrupulously clean and free from grease. This cleansing is best secured by dipping them in pure sulphuric acid, then washing them with distilled water. The glasses and slides should be afterwards transferred to a mixture containing equal parts of alcohol and ammonia, and then dried with a perfectly clean soft rag.

A sample of the matter to be examined is conveyed on to a cover-glass with the point of a sterilised platinum needle, and diluted, if needful, with water, after which the organisms suspended in the water are spread out over the surface of the glass by means of the needle ; or, a better way is to press another cover-glass upon the prepared one, and then slide it off, so that the material appears equally distributed on both cover-glasses. Care must be taken that there is not too much material on the cover-glass, and that, in examining cultivations of micro-organisms, none of the culture medium is introduced along with the organisms, otherwise the preparation will be indistinct and dirty.

When the cover-glass, with its thin film of material, has become perfectly air-dried, it should be taken up with a pair of forceps by the edge and passed three times through a flame to *fix* the micro-organisms to its surface, after which the staining is effected by depositing a few drops of dye on the infected surface of the cover-glass, or by floating it with the prepared side downwards upon some of the staining solution in a watch-glass. After from one to five minutes it is freed from superfluous stain by washing in water, and then turned, prepared side downwards, on to a clean slide, gently pressed with blotting-paper, so that all moisture on the upper surface is removed, and examined with an oil immersion lens, a drop of cedar oil being first placed on the dried surface. If a permanent preparation is required, the cover-glass, after staining and washing, must be allowed to become quite dry, and be then pressed down on to a drop of canada balsam, previously placed on the slide.

Decoloration and Double-staining.—In order to obtain greater definition of bacteria, it is often necessary to stain in two colours. Decoloration is the essential principle of double-staining; whilst one part of the specimen remains coloured, the other portion is made to yield up its colour, after which it is treated with some other stain, the application of which does not affect in any way the already stained portion of the specimen. The strongest agents for decoloration are acids combined with alcohol. The following are the principal decolourising agents in use:—5 per cent. aqueous solution of acetic acid; 20 per cent. aqueous solution of nitric acid; 3 per cent. alcoholic solution of hydrochloric acid.

Spores in bacteria are very conveniently demonstrated by an application of these principles. A cover-glass preparation, having been simply stained with a heated Ehrlich's solution of fuchsine, is treated with a decolourising agent, and then thoroughly washed with water, and finally stained with the ordinary aqueous solution of methylene blue. The spores, which are not affected by the latter aqueous stain, will still remain red whilst the bacilli have assumed the blue colour.

Gram's method of staining consists in staining a cover-glass preparation or section in an aniline-water solution of gentian violet for about five minutes, after which it is placed in a solution of iodine and potassium iodide (1 iodine, 2 potassium iodide, 300 parts water) for two minutes, and then washed with alcohol until no more colour is removed; it is then placed in clove oil, by means of which some more colour is extracted. The bacteria come out stained with gentian violet.

Gram's method is useful as an aid to the diagnosis of some micro-organisms. Thus, the *Pneumococcus Friedländer* shows no staining after going through the process, and similarly the *spirilla of cholera and relapsing fever*, the *bacilli of enteric fever and glanders*, and *gonococci*, cannot retain the colouring matter, but give it up, as do the nuclei of cells.

It is important to bear in mind that fuchsine, methylene blue, and Bismarck brown cannot be used for Gram's method, but only the so-called *para-rosaniline* colours, to which belong methyl violet, gentian violet, and Victoria blue; all these latter have a strong affinity for iodine.

Staining of Flagella.—For the purpose of rendering visible the flagella of motile micro-organisms, Löffler recommends the use of a mixture of 10 c.c. of a 20 per cent. solution of tannin with 5 c.c. of a cold saturated solution of ferrous sulphate, and 1 c.c. of a concentrated aqueous or alcoholic solution of fuchsine. The above solution is called "the mordant." After the preparation has been stained or mordanted with the above solution, it is dyed with the Ehrlich-Löffler solution of fuchsine, above described, to which a 1 per 1000 solution of caustic potash has been added. After the dye has been washed off in water the preparation is ready, and may be examined in the usual way under the microscope.

For many organisms the treatment with the simple mordant is sufficient, but for bacteria, which form alkalies, the mordant must be rendered correspondingly acid; for those which form acids, alkaline. To render the mordant alkaline, Löffler recommends the use of a 1 per cent. aqueous solution of sodium hydrate, whilst for the acidification of the mordant he employs dilute sulphuric acid of such strength that a given volume is exactly neutralised by the same volume of the 1 per cent. solution of caustic soda.

The following are the additions of acid and alkali respectively made to the mordant, as recommended by Löffler, for particular micro-organisms:—

Spirillum choleræ Asiaticæ,	1	drop	of acid	to 16 c.c.	of mordant.
„ Metchnikovi,	4	drops	„	„	„
Bacillus pyocyaneus,	5	„	„	„	„
„ mesentericus vulgatus,	4	„	alkali	„	„
„ typhi abdominalis,	22	„	„	„	„
„ subtilis,	30	„	„	„	„
„ œdematis maligni,	36	„	„	„	„
„ anthracis,	35	„	„	„	„
Micrococcus agilis,	20	„	„	„	„

Löffler's method not only stains the flagella but the whole micro-organism.

Nicolle and Morax have recently and successfully modified the above details, whereby the addition of an acid or alkali is omitted; their method is simply to apply the mordant three or four times, instead of only once. This procedure takes a little longer to carry out, but is certainly simpler, and equally effective in demonstrating the flagella.

APPENDIX XI.

PREPARATION OF AMMONIA-FREE DISTILLED WATER.

This is a matter of very considerable importance in the preparation of standard solutions, particularly as ordinary distilled water is rarely free from ammonia. To overcome this difficulty, the Society of Public Analysts recommend that ordinary distilled water be boiled with 1 per 1000 of pure ignited sodium carbonate. A more preferable method is to fix all the ammonia present in the original water by the addition of pure phosphoric acid to the water before distillation, in the proportion of 1 c.c. of the acid to each gallon of water to be distilled. The distillate, as a rule, comes over quite free from ammonia, but it should be always tested with a little of Nessler's reagent.

APPENDIX XII.

STATISTICAL TABLES A AND B REQUIRED BY THE LOCAL GOVERNMENT BOARD TO BE APPENDED TO THE ANNUAL REPORTS OF MEDICAL OFFICERS OF HEALTH.

(A)—TABLE OF DEATHS *during the year* 18.........., *in the*....................*Sanitary District of*.................................;
classified according to Diseases, Ages, *and* Localities.

Names of Localities adopted for the purpose of these Statistics; public institutions being shown as separate localities. *See Note* 4.	Mortality from all Causes, at subjoined Ages.							Mortality from subjoined Causes, distinguishing Deaths of Children under Five years of Age.																						
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
													Fevers.																	
(*a*)	At all ages. (*b*)	Under 1 year. (*c*)	1 and under 5. (*d*)	5 and under 15. (*e*)	15 and under 25. (*f*)	25 and under 65. (*g*)	65 and upwards. (*h*)	(*i*)	Small-pox.	Scarlatina.	Diphtheria.	Membranous Croup.	Typhus.	Enteric or Typhoid.	Continued.	Relapsing.	Puerperal.	Cholera.	Erysipelas.	Measles.	Whooping Cough.	Diarrhœa and Dysentery.	Rheumatic Fever.	Ague.	Phthisis.	Bronchitis. Pneumonia. Pleurisy.	Heart Disease.	Injuries.	All other Diseases.	Total.
								Under 5																						
								5 upwards																						
								Under 5																						
								5 upwards																						
								Under 5																						
								5 upwards																						
								Under 5																						
								5 upwards																						
								Under 5																						
								5 upwards																						
								Under 5																						
								5 upwards																						
								Under 5																						
								5 upwards																						
								Under 5																						
								5 upwards																						
								Under 5																						
								5 upwards																						
								Under 5																						
								5 upwards																						
								Under 5																						
								5 upwards																						
Totals								Under 5																						
								5 upwards																						
The subjoined numbers have also to be taken into account in judging of the Mortality of this Division of the Sanitary District. *See Note* 5.																														
Add *								Under 5																						
								5 upwards																						
Deduct †								Under 5																						
								5 upwards																						

* Deaths occurring outside the Division or District among persons belonging thereto.

† Deaths occurring within the Division or District among persons not belonging thereto.

(B)—TABLE OF POPULATION, BIRTHS, AND OF NEW CASES OF INFECTIOUS SICKNESS *coming to the knowledge of the Medical Officer of Health, during the year* 18......, *in the*............*Sanitary District of*.................. ; *classified according to* DISEASES, AGES, *and* LOCALITIES.

NAMES OF LOCALITIES adopted for the purpose of these Statistics; public institutions being shown as separate localities. *See Note* 2. (*a*)	Population at all Ages.		Registered Births. (*d*)	Aged under 5 or over 5. (*e*)	New Cases of Sickness in each Locality coming to the knowledge of the Medical Officer of Health.													Number of such Cases removed from their Homes in the several Localities for Treatment in Isolation Hospital.												
	Census 1891. (*b*)	Estimated to middle of yr. 189... (*c*)			1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13
									Fevers.													Fevers.								
					Small-pox.	Scarlatina.	Diphtheria.	Membranous Croup.	Typhus.	Enteric or Typhoid.	Continued.	Relapsing.	Puerperal.	Cholera.	Erysipelas.			Small-pox.	Scarlatina.	Diphtheria.	Membranous Croup.	Typhus.	Enteric or Typhoid.	Continued.	Relapsing.	Puerperal.	Cholera.	Erysipelas.		
				Under 5																										
				5 upwards																										
				Under 5																										
				5 upwards																										
				Under 5																										
				5 upwards																										
				Under 5																										
				5 upwards																										
				Under 5																										
				5 upwards																										
				Under 5																										
				5 upwards																										
				Under 5																										
				5 upwards																										
				Under 5																										
				5 upwards																										
				Under 5																										
				5 upwards																										
				Under 5																										
				5 upwards																										
				Under 5																										
				5 upwards																										
TOTALS				Under 5																										
				5 upwards																										

State here whether "Notification of Infectious Disease" is compulsory in the District.......... Since when?........................ Besides the above-mentioned Diseases, insert in the columns with blank headings the names of any that are notifiable in the District, and fill the columns accordingly. State here the name of the Isolation Hospital used by the sick of the District. Mark (H) the Locality in which such Hospital is situated; and if not within the District, state where it is situated......................................

NOTES ON TABLES A AND B.

Note

1. Medical Officers of Health of "combined districts" must make a separate Return for the District of each Sanitary Authority.
2. Medical Officers of Health, acting for a portion only of the District of a Sanitary Authority, should write, in the heading of the Table, the designation of the Division for which they act.
3. The words "Urban," or "Rural," or "Metropolitan" must be inserted in the appropriate space in the heading, according as the Sanitary Authority for the District is Urban or Rural, or is within the Metropolitan area.
4. The "Localities" adopted for the purpose of these statistics should be areas of known population; such as parishes, groups of parishes, townships, or wards.

   As stated at the head of the first column in each Table, Public Institutions should be regarded as separate localities, and the deaths in them should be separately recorded. Workhouses, Hospitals, Infirmaries, Asylums, and other establishments into which numbers of people, and especially of sick people, are received, are Public Institutions for the purpose of these statistics.
5. The deaths that have to be classified in this Table, and summed up in the horizontal line of "Totals," are the whole of those *registered* as having actually occurred in the several localities comprised within the Division or District. But the registered number of deaths frequently requires correction before it can give an exact view of the mortality of a Division or District; and the two lowest horizontal lines are provided for the purpose of enabling Medical Officers of Health to indicate, to the best of their ability, what the extent of such corrections should be. Details concerning the corrective figures, *e.g.*, the Institutions that have been considered, or the particular localities to which corrections apply, may appear in the text of the report or in supplementary tables.

Area and Population of the District or Division to which this Return relates.

Area in Acres,..............................

Population (1891),........................

In recording the facts under the various headings of Tables A and B, attention has been given to the notes endorsed on the Tables.

....................................*Medical Officer of Health.*

(Date)................................

NOTES ON TABLE B. (See also Notes to Table A.)

Note

1. The present Table B is concerned with Population, Births, and Sickness (not with Mortality) in the Sanitary District or Division to which the Table relates.
2. As stated in the heading of column (*a*), Public Institutions should be regarded as separate localities, and the new cases of sickness in them should be separately recorded. Workhouses, Hospitals, Infirmaries, Asylums, and other establishments into which numbers of people, and especially of sick people, are received, are Public Institutions for the purpose of these statistics.
3. Comments on any unequal incidence of notifiable disease upon the several localities, and considerations as to the local incidence of consumption and other prevalent diseases, should be made in the text of the report.

INDEX.

NEILL AND COMPANY, PRINTERS, EDINBURGH.

Mental Physiology, especially in its Relation to Mental Disorders. By THEO. B. HYSLOP, M.D., Assistant Physician, Bethlem Royal Hospital; Lecturer on Mental Diseases, St. Mary's Hospital Medical School. 8vo, 18s.

The Insane and the Law: a Plain Guide for Medical Men, Solicitors, and Others as to the Detention and Treatment, Maintenance, Responsibility, and Capacity either to give evidence or make a will of Persons Mentally Afflicted. With Hints to Medical Witnesses and to Cross-Examining Counsel. By G. PITT-LEWIS, Q.C., R. PERCY SMITH, M.D., F.R.C.P., Resident Physician, Bethlem Hospital, and J. A. HAWKE, B.A., Barrister-at-Law. 8vo, 14s.

Illustrations of the Influence of the Mind upon the Body in Health and Disease: Designed to elucidate the Action of the Imagination. By D. HACK TUKE, M.D., F.R.C.P., LL.D. Second Edition. 2 vols. crown 8vo, 15s.

A Dictionary of Psychological Medicine, giving the Definition, Etymology, and Synonyms of the Terms used in Medical Psychology; with the Symptoms, Treatment, and Pathology of Insanity; and THE LAW OF LUNACY IN GREAT BRITAIN AND IRELAND. Edited by D. HACK TUKE, M.D., LL.D., assisted by nearly 130 Contributors, British, Continental and American. 2 vols., 1,500 pages, royal 8vo, Illustrated. 42s.

Lunacy Law for Medical Men. By CHARLES MERCIER, M.B., Lecturer on Neurology and Insanity to the Westminster Hospital Medical School, and to the Medical School for Women. Crown 8vo, 5s.

The Journal of Mental Science. Published Quarterly, by Authority of the Medico-Psychological Association. 8vo, 5s.

Mental Affections of Childhood and Youth (Lettsomian Lectures for 1887, &c.). By J. LANGDON-DOWN, M.D., F.R.C.P., Consulting Physician to the London Hospital. 8vo, 6s.

Manual of Midwifery: Including all that is likely to be required by Students and Practitioners. By ALFRED L. GALABIN, M.A., M.D., F.R.C.P., Obstetric Physician to, and Lecturer on, Midwifery, &c., at Guy's Hospital. Third Edition. Crown 8vo, with 261 Engravings, 15s.

Sterility. By ROBERT BELL, M.D., F.F.P. & S., Senior Physician to the Glasgow Hospital for Diseases peculiar to Women. 8vo, 5s.

The Student's Guide to the Practice of Midwifery. By D. LLOYD ROBERTS, M.D., F.R.C.P., Lecturer on Clinical Midwifery and Diseases of Women at the Owens College; Obstetric Physician to the Manchester Royal Infirmary. Fourth Edition. Fcap. 8vo, with Coloured Plates and Engravings. [*Preparing.*

Manual of the Diseases peculiar to Women. By JAMES OLIVER, M.D., F.R.S. Edin., M.R.C.P. Lond., Physician to the Hospital for Diseases of Women, London. Fcap. 8vo, 3s. 6d.

By the same Author.

Abdominal Tumours and Abdominal Dropsy in Women. Crown 8vo, 7s. 6d.

Obstetric Aphorisms: For the Use of Students commencing Midwifery Practice. By JOSEPH G. SWAYNE, M.D. Tenth Edition. Fcap. 8vo, with 20 Engravings, 3s. 6d.

Lectures on Obstetric Operations: Including the Treatment of Hæmorrhage, and forming a Guide to the Management of Difficult Labour. By ROBERT BARNES, M.D., F.R.C.P., Consulting Obstetric Physician to St. George's Hospital. Fourth Edition. 8vo, with 121 Engravings, 12s. 6d.

By the same Author.

A Clinical History of Medical and Surgical Diseases of Women. Second Edition. 8vo, with 181 Engravings, 28s.

Clinical Lectures on Diseases of Women: Delivered in St. Bartholomew's Hospital, by J. MATTHEWS DUNCAN, M.D., LL.D., F.R.C.P., F.R.Ss. L. & E., late Obstetric Physician to St. Bartholomew's Hospital. Fourth Edition. 8vo, 16s.

Gynæcological Operations: (Handbook of). By ALBAN H. G. DORAN, F.R.C.S., Surgeon to the Samaritan Hospital. 8vo, with 167 Engravings, 15s.

The Student's Guide to the Diseases of Women. By ALFRED L. GALABIN, M.A., M.D., F.R.C.P., Obstetric Physician to Guy's Hospital. Fifth Edition. Fcap. 8vo, with 142 Engravings, 8s. 6d.

A Practical Treatise on the Diseases of Women. By T. GAILLARD THOMAS, M.D. Sixth Edition, by PAUL F. MUNDÉ, M.D., Professor of Gynæcology at the New York Polyclinic and at Dartmouth College. Roy. 8vo, with 347 Engravings, 25s.

Notes on Diseases of Women: Specially designed to assist the Student in preparing for Examination. By JAMES J. REYNOLDS, L.R.C.P., M.R.C.S. Fourth Edition, Fcap. 8vo., 3s. 6d.

Abdominal Surgery. By J. GREIG SMITH, M.A., F.R.S.E., Surgeon to the Bristol Royal Infirmary, Professor of Surgery, University College, Bristol. Fifth Edition. Two Vols., 8vo, with 224 Engravings, 36s.

The Physiology of Death from Traumatic Fever: A Study in Abdominal Surgery. By JOHN D. MALCOLM, M.B., C.M., F.R.C.S.E., Surgeon to the Samaritan Free Hospital. 8vo, 3s. 6d.

Notes on Gynæcological Nursing. By JOHN BENJAMIN HELLIER, M.D., M.R.C.S., Lecturer on the Diseases of Women and Children in the Yorkshire College, and Surgeon to the Hospital for Women, &c., Leeds. Cr. 8vo, 1s. 6d.

A Manual for Hospital Nurses and others engaged in Attending on the Sick, with a Glossary. By EDWARD J. DOMVILLE, Surgeon to the Devon and Exeter Hospital. Eighth Edition. Crown 8vo, 2s. 6d.

A Manual of Nursing, Medical and Surgical. By CHARLES J. CULLINGWORTH, M.D., F.R.C.P., Obstetric Physician to St. Thomas's Hospital. Third Edition. Fcap. 8vo, with Engravings, 2s. 6d.

By the same Author.

A Short Manual for Monthly Nurses. Fourth Edition. Fcap. 8vo, 1s. 6d.

Diseases of Children. For Practitioners and Students. By W. H. DAY, M.D., Physician to the Samaritan Hospital. Second Edition. Crown 8vo, 12s. 6d.

The Diseases of Children. By JAS. F. GOODHART, M.D., F.R.C.P., Physician to Guy's Hospital. Fifth Edition. Fcap. 8vo, 10s. 6d.

A Practical Treatise on Disease in Children. By EUSTACE SMITH, M.D., F.R.C.P., Physician to the King of the Belgians, and to the East London Hospital for Children, &c. Second Edition. 8vo, 22s.

By the same Author.

Clinical Studies of Disease in Children. Second Edition. Post 8vo, 7s. 6d.

Also.

The Wasting Diseases of Infants and Children. Fifth Edition. Post 8vo, 8s. 6d.

A Practical Manual of the Diseases of Children. With a Formulary. By EDWARD ELLIS, M.D. Fifth Edition. Crown 8vo, 10s.

Materia Medica: A Manual for the use of Students. By ISAMBARD OWEN, M.D., F.R.C.P., Lecturer on Materia Medica, &c., to St. George's Hospital. Second Edition. Crown 8vo, 6s. 6d.

Materia Medica, Pharmacy, Pharmacology, and Therapeutics. By W. HALE WHITE, M.D., F.R.C.P., Physician to, and Lecturer on Materia Medica and Therapeutics at, Guy's Hospital; Examiner in Materia Medica on the Conjoint Board of the Royal Colleges of Physicians and Surgeons. Fcap. 8vo, 7s. 6d.

Materia Medica And Therapeutics. By CHARLES D. F. PHILLIPS, M.D., F.R.S. Edin.

Vegetable Kingdom — Organic Compounds—Animal Kingdom. 8vo, 25s.

Inorganic Substances. Second Edition. 8vo, 21s.

Recent Materia Medica. Notes on their Origin and Therapeutics. By F. HARWOOD LESCHER, F.C.S., Pereira Medallist. Fourth Edition. 8vo, 2s. 6d

Galenic Pharmacy: A Practical Handbook to the Processes of the British Pharmacopœia. By R. A. CRIPPS, M.P.S. 8vo, with 76 Engravings, 8s. 6d.

The Galenical Preparations of the British Pharmacopœia: A Handbook for Medical and Pharmaceutical Students. By CHARLES O. HAWTHORNE, M.B., C.M., Lecturer on Materia Medica and Therapeutics, Queen Margaret College, University of Glasgow. 8vo, 4s. 6d.

Practical Pharmacy. By BARNARD S. PROCTOR, formerly Lecturer on Pharmacy at the College of Medicine, Newcastle-on-Tyne. Third Edition. 8vo, with 44 Wood Engravings and 32 Lithograph Fac-Simile Prescriptions, 14s.

Selecta è Prescriptis: Containing Terms, Phrases, Contractions and Abbreviations used in Prescriptions, with Explanatory Notes, &c. Also, a Series of Abbreviated Prescriptions with Translations and Key. By J. PEREIRA, M.D., F.R.S. Eighteenth Edition, by JOSEPH INCE, F.C.S., F.L.S. 24mo, 5s.

A Companion to the British Pharmacopœia. By PETER SQUIRE, Revised by his Sons, P. W. and A. H. SQUIRE. Sixteenth Edition. 8vo, 12s. 6d.

By the same Authors.

The Pharmacopœias of the London Hospitals, arranged in Groups for Easy Reference and Comparison. Sixth Edition. 18mo. 6s.

Pocket Formulary
And Synopsis of the British and Foreign Pharmacopœias. By HENRY BEASLEY. Eleventh Edition. 18mo, 6s. 6d.

By the same Author.

Druggist's General Receipt-Book. Tenth Edition. 18mo, 6s. 6d.

Also.

Book of Prescriptions:
Containing upwards of 3,000 Prescriptions from the Practice of the most eminent Physicians and Surgeons, English and Foreign. Seventh Edition. 18mo, 6s. 6d.

The Prescriber's Pharmacopœia:
The Medicines arranged in Classes according to their Action, with their Composition and Doses. By NESTOR J. C. TIRARD, M.D., F.R.C.P., Professor of Materia Medica and Therapeutics in King's College, London. Sixth Edition. 32mo, bound in leather, 3s.

Year-Book of Pharmacy:
Containing the Transactions of the British Pharmaceutical Conference. Annually. 8vo, 10s.

Royle's Manual of Materia Medica and Therapeutics. Sixth Edition, including additions and alterations in the B.P. 1885. By JOHN HARLEY, M.D., Physician to St. Thomas's Hospital. Crown 8vo, with 139 Engravings, 15s.

Southall's Organic Materia Medica: a Handbook treating of some of the more important of the Animal and Vegetable Drugs made use of in Medicine, including the whole of those contained in the B.P. Fifth and Enlarged Edition. By JOHN BARCLAY, B.Sc.Lond., sometime Lecturer on Materia Medica and Pharmacy in Mason College, Birmingham. 8vo, 6s.

Manual of Botany.
By J. REYNOLDS GREEN, Sc.D., M.A., F.R.S., Professor of Botany to the Pharmaceutical Society. Two Vols. Cr. 8vo.
Vol. I.—Anatomy and Morphology. With 778 Engravings, 7s. 6d.
,, II.—Classification and Physiology. With 415 Engravings, 10s.

The Student's Guide to Systematic Botany, including the Classification of Plants and Descriptive Botany. By ROBERT BENTLEY, late Emeritus Professor of Botany in King's College and to the Pharmaceutical Society. Fcap. 8vo, with 350 Engravings, 3s. 6d.

Medicinal Plants:
Being descriptions, with original figures, of the Principal Plants employed in Medicine, and an account of their Properties and Uses. By Prof. BENTLEY and Dr. H. TRIMEN, F.R.S. In 4 vols., large 8vo, with 306 Coloured Plates, bound in Half Morocco, Gilt Edges, £11 11s.

Climate and Fevers of India, with a series of Cases (Croonian Lectures, 1882). By Sir JOSEPH FAYRER, K.C.S.I., M.D. 8vo, with 17 Temperature Charts, 12s.

By the same Author.

The Natural History and Epidemiology of Cholera: Being the Annual Oration of the Medical Society of London, 1888. 8vo, 3s. 6d.

A Manual of Family Medicine and Hygiene for India. Published under the Authority of the Government of India. By Sir WILLIAM J. MOORE, K.C.I.E., M.D., late Surgeon-General with the Government of Bombay. Sixth Edition. Post 8vo, with 71 Engravings, 12s.

By the same Author.

A Manual of the Diseases of India: With a Compendium of Diseases generally. Second Edition. Post 8vo, 10s.

Also,

The Constitutional Requirements for Tropical Climates, &c. Crown 8vo, 4s.

The Prevention of Disease in Tropical and Sub-Tropical Campaigns. (Parkes Memorial Prize for 1886.) By ANDREW DUNCAN, M.D., B.S. Lond., F.R.C.S., Surgeon-Major, Bengal Army. 8vo, 12s. 6d.

Practical Therapeutics:
A Manual. By EDWARD J. WARING, C.I.E., M.D., F.R.C.P., and DUDLEY W. BUXTON, M.D., B.S. Lond. Fourth Edition. Crown 8vo, 14s.

By the same Author.

Bazaar Medicines of India,
And Common Medical Plants: With Full Index of Diseases, indicating their Treatment by these and other Agents procurable throughout India, &c. Fourth Edition Fcap. 8vo, 5s.

A Commentary on the Diseases of India. By NORMAN CHEVERS, C.I.E., M.D., F.R.C.S., Deputy Surgeon-General H.M. Indian Army. 8vo, 24s.

Hooper's Physicians' Vade-Mecum. A Manual of the Principles and Practice of Physic. Tenth Edition. By W. A. GUY, F.R.C.P., F.R.S., and J. HARLEY, M.D., F.R.C.P. With 118 Engravings. Fcap. 8vo, 12s. 6d.

The Principles and Practice of Medicine. (Text-book.) By the late C. Hilton Fagge, M.D., and P. H. Pye-Smith, M.D., F.R.S., F.R.C.P., Physician to, and Lecturer on Medicine in, Guy's Hospital. Third Edition. 2 vols. 8vo, cloth, 40s.; Half Leather, 46s.

Manual of the Practice of Medicine. By Frederick Taylor, M.D., F.R.C.P., Physician to, and Lecturer on Medicine at, Guy's Hospital. Fourth Edition. Cr. 8vo, with Engravings, 15s.

The Practice of Medicine (Student's Guide Series). By M. Charteris, M.D., Professor of Therapeutics and Materia Medica in the University of Glasgow. Seventh Edition. Fcap. 8vo, with Engravings on Copper and Wood, 10s.

A Dictionary of Practical Medicine. By various writers. Edited by Jas. Kingston Fowler, M.A., M.D., F.R.C.P., Physician to Middlesex Hospital and the Hospital for Consumption. 8vo, cloth, 21s.; half calf, 25s.

A Text-Book of Bacteriology. By G. M. Sternberg, M.D., Surgeon-General, U.S. Army. With 9 Plates and 200 Figures in the Text. 8vo, 24s.

How to Examine the Chest: A Practical Guide for the use of Students. By Samuel West, M.D., F.R.C.P., Assistant Physician to St. Bartholomew's Hospital. Second Edition. With Engravings. Fcap. 8vo, 5s.

An Atlas of the Pathological Anatomy of the Lungs. By the late Wilson Fox, M.D., F.R.S., F.R.C.P., Physician to H.M. the Queen. With 45 Plates (mostly Coloured) and Engravings. 4to, half-bound in Calf, 70s.

By the same Author.

A Treatise on Diseases of the Lungs and Pleura. Edited by Sidney Coupland, M.D., F.R.C.P., Physician to Middlesex Hospital. Roy. 8vo, with Engravings; also Portrait and Memoir of the Author, 36s.

The Student's Guide to Diseases of the Chest. By Vincent D. Harris, M.D. Lond., F.R.C.P., Physician to the City of London Hospital for Diseases of the Chest, Victoria Park. Fcap. 8vo, with 55 Illustrations (some Coloured), 7s. 6d.

Uric Acid as a Factor in the Causation of Disease. By Alexander Haig, M.D., F.R.C.P., Physician to the Metropolitan Hospital and the Royal Hospital for Children and Women. Third Edition. With 54 Illustrations, 8vo, 12s. 6d.

Medical Diagnosis (Student's Guide Series). By Samuel Fenwick, M.D., F.R.C.P., Physician to the London Hospital. Seventh Edition. Fcap. 8vo, with 117 Engravings, 7s.

By the same Author.

Outlines of Medical Treatment. Fourth Edition. Crown 8vo, with 35 Engravings, 10s.

Also.

Clinical Lectures on Some Obscure Diseases of the Abdomen. Delivered at the London Hospital. 8vo, with Engravings, 7s. 6d.

Also.

The Saliva as a Test for Functional Diseases of the Liver. Crown 8vo, 2s.

The Microscope in Medicine. By Lionel S. Beale, M.B., F.R.S., Physician to King's College Hospital. Fourth Edition. 8vo, with 86 Plates, 21s.

By the same Author.

The Liver. With 24 Plates (85 Figures). 8vo, 5s.

Also.

On Slight Ailments: And on Treating Disease. Fourth Edition. 8vo, 5s.

Myxœdema and the Thyroid Gland. By John D. Gimlette, M.R.C.S., L.R.C.P. Crown 8vo, 5s.

The Physiology of the Carbohydrates; their Application as Food and Relation to Diabetes. By F. W. Pavy, M.D., LL.D., F.R.S., F.R.C.P., Consulting Physician to Guy's Hospital. Royal 8vo, with Plates and Engravings, 10s. 6d.

Medical Lectures and Essays. By Sir G. Johnson, M.D., F.R.C.P., F.R.S. 8vo, with 46 Engravings, 25s.

By the same Author.

An Essay on Asphyxia (Apnœa). 8vo, 3s.

Also.

History of the Cholera Controversy, with Directions for the Treatment of the Disease. 8vo, 3s.

Also.

The Pathology of the Contracted Granular Kidney and the Associated Cardio-Arterial Changes. With 29 Illustrations, 8vo, 4s.

Bronchial Asthma: Its Pathology and Treatment. By J. B. Berkart, M.D., late Physician to the City of London Hospital for Diseases of the Chest. Second Edition, with 7 Plates (35 Figures). 8vo, 10s. 6d.

Treatment of Some of the Forms of Valvular Disease of the Heart. By A. E. SANSOM, M.D., F.R.C.P., Physician to the London Hospital. Second Edition. Fcap. 8vo, with 26 Engravings, 4s. 6d.

The Schott Methods of the Treatment of Chronic Diseases of the Heart, with an account of the Nauheim Baths and of the Therapeutic Exercises. By W. BEZLY THORNE, M.D., M.R.C.P. Second Edition. 8vo, with Illustrations, 5s.

Guy's Hospital Reports. By the Medical and Surgical Staff. Vol. XXXVI. Third Series. 8vo, 10s. 6d.

St. Thomas's Hospital Reports. By the Medical and Surgical Staff. Vol. XXIII. New Series. 8vo, 8s. 6d.

Westminster Hospital Reports. By the Medical and Surgical Staff. Vol. X. 8vo, 6s.

Medical Ophthalmoscopy: A Manual and Atlas. By W. R. GOWERS, M.D., F.R.C.P., F.R.S. Third Edition. Edited with the assistance of MARCUS GUNN, M.B., F.R.C.S., Surgeon to the Royal London Ophthalmic Hospital. With Coloured Plates and Woodcuts. 8vo, 16s.

By the same Author.

A Manual of Diseases of the Nervous System.

Vol. I. Diseases of the Nerves and Spinal Cord. Second Edition. Roy. 8vo, with 179 Engravings, 15s.

Vol. II. Diseases of the Brain and Cranial Nerves: General and Functional Diseases of the Nervous System. Second Edition. Roy. 8vo, with 182 Engravings, 20s.

Also.

Clinical Lectures on Diseases of the Nervous System. 8vo, 7s. 6d.

Also.

Diagnosis of Diseases of the Brain. Second Edition. 8vo, with Engravings, 7s. 6d.

Also.

Syphilis and the Nervous System. Being a Revised Reprint of the Lettsomian Lectures for 1890. Delivered before the Medical Society of London. 8vo, 4s.

The Nervous System, Diseases of. By J. A. ORMEROD, M.D., F.R.C.P., Physician to the National Hospital for the Paralysed and Epileptic. With 66 Illustrations. Fcap. 8vo, 8s. 6d.

Handbook of the Diseases of the Nervous System. By JAMES ROSS, M.D., F.R.C.P., Professor of Medicine in the Victoria University, and Physician to the Royal Infirmary, Manchester. Roy. 8vo, with 184 Engravings, 18s.

Also.

Aphasia: Being a Contribution to the Subject of the Dissolution of Speech from Cerebral Disease. 8vo, with Engravings. 4s. 6d.

Diseases of the Nervous System. Lectures delivered at Guy's Hospital. By SAMUEL WILKS, M.D., F.R.S. Second Edition. 8vo, 18s.

Stammering: Its Causes, Treatment, and Cure. By A. G. BERNARD, M.R.C.S., L.R.C.P. Crown 8vo, 2s.

Secondary Degenerations of the Spinal Cord (Gulstonian Lectures, 1889). By HOWARD H. TOOTH, M.D., F.R.C.P., Assistant Physician to the National Hospital for the Paralysed and Epileptic. With Plates and Engravings. 8vo, 3s. 6d.

Diseases of the Nervous System. Clinical Lectures. By THOMAS BUZZARD, M.D., F.R.C.P., Physician to the National Hospital for the Paralysed and Epileptic. With Engravings, 8vo. 15s.

By the same Author.

Some Forms of Paralysis from Peripheral Neuritis: of Gouty, Alcoholic, Diphtheritic, and other origin. Crown 8vo, 5s.

Also.

On the Simulation of Hysteria by Organic Disease of the Nervous System. Crown 8vo, 4s. 6d.

Gout in its Clinical Aspects. By J. MORTIMER GRANVILLE, M.D. Crown 8vo, 6s.

Diseases of the Liver: With and without Jaundice. By GEORGE HARLEY, M.D., F.R.C.P., F.R.S. 8vo, with 2 Plates and 36 Engravings, 21s.

Rheumatic Diseases, (Differentiation in). By HUGH LANE, Surgeon to the Royal Mineral Water Hospital, Bath, and Hon. Medical Officer to the Royal United Hospital, Bath. Second Edition, much Enlarged, with 8 Plates. Crown 8vo, 3s. 6d.

Diseases of the Abdomen, Comprising those of the Stomach and other parts of the Alimentary Canal, Œsophagus, Cæcum, Intestines, and Peritoneum. By S. O. HABERSHON, M.D., F.R.C.P. Fourth Edition. 8vo, with 5 Plates, 21s.

On Gallstones, or Cholelithiasis. By E. M. BROCKBANK, M.D. Vict., M.R.C.P. Lond., late Resident Medical Officer at the Manchester Royal Infirmary and the Birmingham General Hospital. Crown 8vo, 7s.

Headaches: Their Nature, Causes, and Treatment. By W. H. DAY, M.D., Physician to the Samaritan Hospital. Fourth Edition. Crown 8vo, with Engravings, 7s. 6d.

Health Resorts at Home and Abroad. By M. CHARTERIS, M.D., Professor of Therapeutics and Materia Medica in Glasgow University. Second Edition. Crown 8vo, with Map, 5s. 6d.

The Mineral Waters of France And its Wintering Stations (Medical Guide to). With a Special Map. By A. VINTRAS, M.D., Physician to the French Embassy, and to the French Hospital, London. Second Edition. Crown 8vo, 8s.

Canary Islands Health Resorts, in their Climatological and Medical Aspects. By J. CLEASBY TAYLOR, M.D., M.R.C.S., Las Palmas. 8vo, with Maps, 3s. 6d.

Homburg Spa. An Introduction to its Waters and their use. By Dr. ARNOLD SCHETELIG. Crown 8vo, with Synoptical Table, 2s. 6d.

Illustrated Ambulance Lectures: To which is added a NURSING LECTURE. By JOHN M. H. MARTIN, M.D., F.R.C.S., Honorary Surgeon to the Blackburn Infirmary. Fourth Edition. Crown 8vo, with 60 Engravings, 2s.

Surgery: its Theory and Practice. By WILLIAM J. WALSHAM, F.R.C.S., Senior Assistant Surgeon to, and Lecturer on Anatomy at, St. Bartholomew's Hospital. Fifth Edition. Crown 8vo, with 380 Engravings, 12s. 6d.

Surgical Emergencies: Together with the Emergencies attendant on Parturition and the Treatment of Poisoning. By PAUL SWAIN, F.R.C.S., Surgeon to the South Devon and East Cornwall Hospital. Fifth Edition. Crown 8vo, with 149 Engravings, 6s.

Operations on the Brain (A Guide to). By ALEC FRASER, Professor of Anatomy, Royal College of Surgeons in Ireland. Illustrated by 42 life-size Plates in Autotype, and 2 Woodcuts in the text. Folio, 63s.

A Course of Operative Surgery. By CHRISTOPHER HEATH, Surgeon to University College Hospital. Second Edition. With 20 coloured Plates (180 figures) from Nature, by M. LÉVEILLÉ, and several Woodcuts. Large 8vo, 30s.

By the same Author.

The Student's Guide to Surgical Diagnosis. Second Edition. Fcap. 8vo, 6s. 6d.

Also.

Manual of Minor Surgery and Bandaging. For the use of House-Surgeons, Dressers, and Junior Practitioners. Tenth Edition. Fcap. 8vo, with 158 Engravings, 6s.

Also.

Injuries and Diseases of the Jaws. Fourth Edition. By HENRY PERCY DEAN, M.S., F.R.C.S., Assistant Surgeon to the London Hospital. 8vo, with 187 Wood Engravings, 14s.

Also.

Lectures on Certain Diseases of the Jaws. Delivered at the R.C.S., Eng., 1887. 8vo, with 64 Engravings, 2s. 6d.

Also.

Clinical Lectures on Surgical Subjects. Delivered in University College Hospital. Second Edition, Enlarged. Fcap. 8vo, with 27 Engravings, 6s.

Surgery. By C. W. MANSELL MOULLIN, M.A., M.D., Oxon., F.R.C.S., Surgeon and Lecturer on Physiology to the London Hospital. Large 8vo, with 497 Engravings, 34s.

The Practice of Surgery: A Manual. By THOMAS BRYANT, Consulting Surgeon to Guy's Hospital. Fourth Edition. 2 vols. crown 8vo, with 750 Engravings (many being coloured), and including 6 chromo plates, 32s.

By the same Author.

On Tension: Inflammation of Bone, and Head Injuries. Hunterian Lectures, 1888. 8vo, 6s.

The Surgeon's Vade-Mecum: A Manual of Modern Surgery. By R. DRUITT, F.R.C.S. Twelfth Edition. By STANLEY BOYD, M.B., F.R.C.S. Assistant Surgeon and Pathologist to Charing Cross Hospital. Crown 8vo, with 373 Engravings, 16s.

Diseases of Bones and Joints. By CHARLES MACNAMARA, F.R.C.S., Surgeon to, and Lecturer on Surgery at, the Westminster Hospital. 8vo, with Plates and Engravings, 12s.

The Operations of Surgery: Intended for Use on the Dead and Living Subject alike. By W. H. A. Jacobson, M.A., M.B., M.Ch. Oxon., F.R.C.S., Assistant Surgeon to, and Lecturer on Anatomy at, Guy's Hospital. Third Edition. 8vo, with many Illustrations. [*In the press.*

On Anchylosis. By Bernard E. Brodhurst, F.R.C.S., Surgeon to the Royal Orthopædic Hospital. Fourth Edition. 8vo, with Engravings, 5s.

By the same Author.

Curvatures and Disease of the Spine. Fourth Edition. 8vo, with Engravings, 7s. 6d.

Also.

Talipes Equino-Varus, or Clubfoot. 8vo, with Engravings, 3s. 6d.

Surgical Pathology and Morbid Anatomy. By Anthony A. Bowlby, F.R.C.S., Assistant Surgeon to St. Bartholomew's Hospital. Third Edition. Crown 8vo, with 183 Engravings, 10s. 6d.

By the same Author.

Injuries and Diseases of Nerves and their Surgical Treatment. 8vo, with 20 Plates, 14s.

Illustrations of Clinical Surgery. By Jonathan Hutchinson, F.R.S., Senior Surgeon to the London Hospital. In fasciculi. 6s. 6d. each. Fasc. I. to X. bound, with Appendix and Index, £3 10s. Fasc. XI. to XXIII. bound, with Index, £4 10s.

Clubfoot: Its Causes, Pathology, and Treatment. By Wm. Adams, F.R.C.S., Consulting Surgeon to the Great Northern and other Hospitals. Second Edition. 8vo, with 106 Engravings and 6 Lithographic Plates, 15s.

By the same Author.

Lateral and other Forms of Curvature of the Spine: Their Pathology and Treatment. Second Edition. 8vo, with 5 Lithographic Plates and 72 Wood Engravings, 10s. 6d.

Also.

Contraction of the Fingers: (Dupuytren's and Congenital Contractions), their Treatment by Subcutaneous Divisions of the Fascia, and Immediate Extension. Also on **Hammer Toe**; its Curability by Subcutaneous Division. And on **The Obliteration of Depressed Cicatrices** by a Subcutaneous Operation. 8vo, with 8 Plates and 31 Engravings, 6s. 6d.

Short Manual of Orthopædy. By Heather Bigg, F.R.C.S. Ed. Part I. Deformities and Deficiencies of the Head and Neck. 8vo. 2s. 6d.

Face and Foot Deformities. By Frederick Churchill, C.M. 8vo, with Plates and Illustrations, 10s. 6d.

The Human Foot: Its Form and Structure, Functions and Clothing. By Thomas S. Ellis, Consulting Surgeon to the Gloucester Infirmary. With 7 Plates and Engravings (50 Figures). 8vo, 7s. 6d.

Royal London Ophthalmic Hospital Reports. By the Medical and Surgical Staff. Vol. XIII., Part 4. 8vo, 5s.

Ophthalmological Society of the United Kingdom. Transactions, Vol. XV. 8vo, 12s. 6d.

The Diseases of the Eye (Student's Guide Series). By Edward Nettleship, F.R.C.S., Ophthalmic Surgeon to St. Thomas's Hospital. Fifth Edition. Fcap. 8vo, with 164 Engravings and a Coloured Plate illustrating Colour-Blindness, 7s. 6d.

Diseases and Refraction of the Eye. By N. C. Macnamara, F.R.C.S., Surgeon to Westminster Hospital, and Gustavus Hartridge, F.R.C.S., Surgeon to the Royal Westminster Ophthalmic Hospital. Fifth Edition. Crown 8vo, with Plate, 156 Engravings, also Test-types, 10s. 6d.

Diseases of the Eye: a Practical Handbook for General Practitioners and Students. By Cecil Edward Shaw, M.D., M.Ch., Ophthalmic Surgeon to the Ulster Hospital for Children and Women, Belfast. With a Test-Card for Colour-Blindness. Crown 8vo, 3s. 6d.

On Diseases and Injuries of the Eye: A Course of Systematic and Clinical Lectures to Students and Medical Practitioners. By J. R. Wolfe, M.D., F.R.C.S.E., Lecturer on Ophthalmic Medicine and Surgery in Anderson's College, Glasgow. With 10 Coloured Plates and 157 Wood Engravings. 8vo, £1 1s.

Normal and Pathological Histology of the Human Eye and Eyelids. By C. Fred. Pollock, M.D., F.R.C.S. and F.R.S.E., Surgeon for Diseases of the Eye to Anderson's College Dispensary, Glasgow. Crown 8vo, with 100 Plates (230 drawings), 15s.

Refraction of the Eye: A Manual for Students. By GUSTAVUS HARTRIDGE, F.R.C.S., Surgeon to the Royal Westminster Ophthalmic Hospital. Eighth Edition. Crown 8vo, with 100 Illustrations, also Test-types, &c., 6s.

By the same Author.

The Ophthalmoscope. A Manual for Students. Second Edition. Crown 8vo, with 67 Illustrations and 4 Plates. 4s. 6d.

Methods of Operating for Cataract and Secondary Impairments of Vision, with the results of 500 cases. By G. H. FINK, Surgeon-Captain in H.M. Indian Medical Service. Crown 8vo, with 15 Engravings, 5s.

Atlas of Ophthalmoscopy. Composed of 12 Chromo-lithographic Plates (59 Figures drawn from nature) and Explanatory Text. By RICHARD LIEBREICH, M.R.C.S. Translated by H. ROSBOROUGH SWANZY, M.B. Third Edition, 4to, 40s.

Glaucoma: Its Pathology and Treatment. By PRIESTLEY SMITH, Ophthalmic Surgeon to, and Clinical Lecturer on Ophthalmology at, the Queen's Hospital, Birmingham. 8vo, with 64 Engravings and 12 Zinco-photographs, 7s. 6d.

Eyestrain (commonly called Asthenopia). By ERNEST CLARKE, M.D., B.S. Lond., Surgeon to the Central London Ophthalmic Hospital, Surgeon and Ophthalmic Surgeon to the Miller Hospital. 8vo, with 22 Illustrations, 5s.

Diseases of the Eye: A Handbook of Ophthalmic Practice for Students and Practitioners. By G. E. DE SCHWEINITZ, M.D., Professor of Diseases of the Eye in the Philadelphia Polyclinic. With 216 Illustrations, and 2 Chromo-Lithographic Plates. 8vo, 18s.

Diseases and Injuries of the Ear. By Sir WILLIAM B. DALBY, F.R.C.S., M.B., Consulting Aural Surgeon to St. George's Hospital. Fourth Edition. Crown 8vo, with 8 Coloured Plates and 38 Wood Engravings. 10s. 6d.

By the same Author.

Short Contributions to Aural Surgery, between 1875 and 1896. Third Edition. 8vo, with Engravings, 5s.

Diseases of the Ear, Including the Anatomy and Physiology of the Organ, together with the Treatment of the Affections of the Nose and Pharynx which conduce to Aural Disease (a Treatise). By T. MARK HOVELL, F.R.C.S.E., M.R.C.S., Aural Surgeon to the London Hospital, and Lecturer on Diseases of the Throat in the College, &c. 8vo, with 122 Engravings, 18s.

Hints on Ophthalmic Out-Patient Practice. By CHARLES HIGGENS, Ophthalmic Surgeon to Guy's Hospital. Third Edition. Fcap. 8vo, 3s.

A System of Dental Surgery. By Sir JOHN TOMES, F.R.S., and C. S. TOMES, M.A., F.R.S. Third Edition. Crown 8vo, with 292 Engravings, 15s.

Dental Anatomy, Human and Comparative: A Manual. By CHARLES S. TOMES, M.A., F.R.S. Fourth Edition. Crown 8vo, with 235 Engravings, 12s. 6d.

A Manual of Nitrous Oxide Anæsthesia, for the use of Students and General Practitioners. By J. FREDERICK W. SILK, M.D. Lond., M.R.C.S., Anæsthetist to the Royal Free Hospital, Dental School of Guy's Hospital, and National Epileptic Hospital. 8vo, with 26 Engravings, 5s.

A Practical Treatise on Mechanical Dentistry. By JOSEPH RICHARDSON, M.D., D.D.S. Sixth Edition revised and Edited by GEORGE W. WARREN, D.D.S. Roy. 8vo, with 600 Engravings, 21s.

Notes on Dental Practice. By HENRY C. QUINBY, L.D.S.I., President-Elect of the British Dental Association. Second Edition. 8vo, with 92 Illustrations, 8s.

Papers on Dermatology. By E. D. MAPOTHER, M.D., Ex-Pres. R.C.S.I. 8vo, 3s. 6d.

Atlas of Skin Diseases. By TILBURY FOX, M.D., F.R.C.P. With 72 Coloured Plates. Royal 4to, half morocco, £6 6s.

Diseases of the Skin: A Practical Treatise for the Use of Students and Practitioners. By J. N. HYDE, A.M., M.D., Professor of Skin and Venereal Diseases, Rush Medical College, Chicago. Second Edition. 8vo, with 2 Coloured Plates and 96 Engravings, 20s.

A Handbook on Leprosy. By S. P. IMPEY, M.D., M.C., late Chief and Medical Superintendent, Robben Island Leper and Lunatic Asylums, Cape Colony. With 38 Plates and Map, 8vo, 12s.

Leprosy in British Guiana. By JOHN D. HILLIS, F.R.C.S., M.R.I.A., late Medical Superintendent of the Leper Asylum, British Guiana. Imp. 8vo, with 22 Lithographic Coloured Plates and Wood Engravings, £1 11s. 6d.

Diseases of the Skin (Introduction to the Study of). By P. H. PYE-SMITH, M.D., F.R.S., F.R.C.P., Physician to, and Lecturer on Medicine in, Guy's Hospital. Crown 8vo, with 26 Engravings. 7s. 6d.

Sarcoma and Carcinoma: Their Pathology, Diagnosis, and Treatment. By HENRY T. BUTLIN, F.R.C.S., Assistant Surgeon to St. Bartholomew's Hospital. 8vo, with 4 Plates, 8s.

By the same Author.

Malignant Disease of the Larynx (Sarcoma and Carcinoma). 8vo, with 5 Engravings, 5s.

Also.

Operative Surgery of Malignant Disease. 8vo, 14s.

On Cancer: Its Allies, and other Tumours; their Medical and Surgical Treatment. By F. A. PURCELL, M.D., M.C., Surgeon to the Cancer Hospital, Brompton. 8vo, with 21 Engravings, 10s. 6d.

Cancers and the Cancer Process: a Treatise, Practical and Theoretic. By HERBERT L. SNOW, M.D., Surgeon to the Cancer Hospital, Brompton. 8vo, with 15 Lithographic Plates. 15s.

By the same Author.

The Re-appearance (Recurrence) of Cancer after apparent Extirpation. 8vo, 5s. 6d.

Also,

The Palliative Treatment of Incurable Cancer. Crown 8vo, 2s. 6d.

Cancerous Affections of the Skin. (Epithelioma and Rodent Ulcer.) By GEORGE THIN, M.D. Post 8vo, with 8 Engravings, 5s.

By the same Author.

Pathology and Treatment of Ringworm. 8vo, with 21 Engravings, 5s.

Diagnosis and Treatment of Syphilis. By TOM ROBINSON, M.D., Physician to St. John's Hospital for Diseases of the Skin. Crown 8vo, 3s. 6d.

By the same Author.

Eczema: its Etiology, Pathology, and Treatment. Crown 8vo, 3s. 6d.

Also.

Illustrations of Diseases of the Skin and Syphilis, with Remarks. Fasc. I, with 3 Plates. Imp. 4to, 5s.

BY SIR HENRY THOMPSON, F.R.C.S.

Diseases of the Urinary Organs. Clinical Lectures. Eighth Edition. 8vo, with 121 Engravings, 10s. 6d.

Diseases of the Prostate: Their Pathology and Treatment. Sixth Edition. 8vo, with 39 Engravings, 6s.

Surgery of the Urinary Organs. Some Important Points connected therewith. Lectures delivered in the R.C.S. 8vo, with 44 Engravings. Student's Edition, 2s. 6d.

Practical Lithotomy and Lithotrity; or, An Inquiry into the Best Modes of Removing Stone from the Bladder. Third Edition. 8vo, with 87 Engravings, 10s.

The Preventive Treatment of Calculous Disease, and the Use of Solvent Remedies. Third Edition. Crown 8vo, 2s. 6d.

Tumours of the Bladder: Their Nature, Symptoms, and Surgical Treatment. 8vo, with numerous Illustrations, 5s.

Stricture of the Urethra, and Urinary Fistulæ: their Pathology and Treatment. Fourth Edition. 8vo, with 74 Engravings, 6s.

The Suprapubic Operation of Opening the Bladder for the Stone and for Tumours. 8vo, with 14 Engravings, 3s. 6d.

Electric Illumination of the Bladder and Urethra, as a Means of Diagnosis of Obscure Vesico-Urethral Diseases. By E. HURRY FENWICK, F.R.C.S., Surgeon to London Hospital and St. Peter's Hospital for Stone. Second Edition. 8vo, with 54 Engravings, 6s. 6d.

By the same Author.

The Cardinal Symptoms of Urinary Diseases: their Diagnostic Significance and Treatment. 8vo, with 36 Illustrations. 8s. 6d.

Atlas of Electric Cystoscopy. By Dr. EMIL BURCKHARDT, late of the Surgical Clinique of the University of Bâle, and E. HURRY FENWICK, F.R.C.S., Surgeon to the London Hospital and St. Peter's Hospital for Stone. Royal 8vo, with 34 Coloured Plates, embracing 83 Figures. 21s.

Lectures on the Surgical Disorders of the Urinary Organs. By REGINALD HARRISON, F.R.C.S., Surgeon to St. Peter's Hospital. Fourth Edition. 8vo, with 156 Engravings, 16s.

Chemistry of Urine; A Practical Guide to the Analytical Examination of Diabetic, Albuminous, and Gouty Urine. By ALFRED H. ALLEN, F.I.C., F.C.S. With Engravings, 8vo, 7s. 6d.

Clinical Chemistry of Urine (Outlines of the). By C. A. MAC MUNN, M.A., M.D. 8vo, with 64 Engravings and Plate of Spectra, 9s.

Urinary and Renal Derangements and Calculous Disorders. By LIONEL S. BEALE, F.R.C.P., F.R.S., Physician to King's College Hospital. 8vo, 5s.

Male Organs of Generation (Diseases of). By W. H. A. JACOBSON, M.Ch. Oxon., F.R.C.S., Assistant Surgeon to Guy's Hospital. 8vo, with 88 Engravings. 22s.

The Surgical Diseases of the Genito-Urinary Organs, including Syphilis. By E. L. KEYES, M.D., Professor in Bellevue Hospital Medical College, New York (a revision of VAN BUREN and KEYES' Text-book). Roy. 8vo, with 114 Engravings, 21s.

Diseases of the Rectum and Anus. By ALFRED COOPER, F.R.C.S., Senior Surgeon to the St. Mark's Hospital for Fistula; and F. SWINFORD EDWARDS, F.R.C.S., Senior Assistant Surgeon to St. Mark's Hospital. Second Edition, with Illustrations. 8vo, 12s.

Diseases of the Rectum and Anus. By HARRISON CRIPPS, F.R.C.S., Assistant Surgeon to St. Bartholomew's Hospital, &c. Second Edition. 8vo, with 13 Lithographic Plates and numerous Wood Engravings, 12s. 6d.

By the same Author.

Cancer of the Rectum. Especially considered with regard to its Surgical Treatment. Jacksonian Prize Essay. 8vo, with 13 Plates and several Wood Engravings, 6s.

Also.

The Passage of Air and Fæces from the Urethra. 8vo, 3s. 6d.

Syphilis. By ALFRED COOPER, F.R.C.S., Senior Surgeon to St. Mark's Hospital for Fistula. Second Edition. Edited by EDWARD COTTERELL, F.R.C.S., Surgeon (out-patients) to the London Lock Hospital. 8vo, with 24 Full-page Plates (12 coloured), 18s.

A Medical Vocabulary: An Explanation of all Terms and Phrases used in the various Departments of Medical Science and Practice, their Derivation, Meaning, Application, and Pronunciation. By R. G. MAYNE, M.D., LL.D. Sixth Edition by W. W. WAGSTAFFE, B.A., F.R.C.S. Crown 8vo, 10s. 6d.

A Short Dictionary of Medical Terms. Being an Abridgment of Mayne's Vocabulary. 64mo, 2s. 6d.

Dunglison's Dictionary of Medical Science: Containing a full Explanation of its various Subjects and Terms, with their Pronunciation, Accentuation, and Derivation. Twenty-first Edition. By RICHARD J. DUNGLISON, A.M., M.D. Royal 8vo, 30s.

Terminologia Medica Polyglotta: a Concise International Dictionary of Medical Terms (French, Latin, English, German, Italian, Spanish, and Russian). By THEODORE MAXWELL, M.D., B.Sc., F.R.C.S. Edin. Royal 8vo, 16s.

A German-English Dictionary of Medical Terms. By FREDERICK TREVES, F.R.C.S., Surgeon to the London Hospital; and HUGO LANG, B.A. Crown 8vo, half-Persian calf, 12s.

Chemistry, Inorganic and Organic. With Experiments. By CHARLES L. BLOXAM. Eighth Edition, by JOHN MILLAR THOMSON, Professor of Chemistry in King's College, London, and ARTHUR G. BLOXAM, Head of the Chemistry Department, The Goldsmiths' Institute, New Cross. 8vo, with nearly 300 Illustrations.

By the same Author.

Laboratory Teaching; Or, Progressive Exercises in Practical Chemistry. Sixth Edition. By ARTHUR G. BLOXAM. Crown 8vo, with 80 Engravings, 6s. 6d.

Watts' Manual of Chemistry, Theoretical and Practical. By WILLIAM A. TILDEN, D.Sc., F.R.S., Professor of Chemistry in the Normal School of Science, South Kensington.

PHYSICAL AND INORGANIC CHEMISTRY. Second Edition. Crown 8vo, with Coloured Plate of Spectra, and 122 Wood Engravings, 8s. 6d.

CHEMISTRY OF CARBON COMPOUNDS; or, ORGANIC CHEMISTRY. Second Edition. Crown 8vo, with Engravings, 10s.

Practical Chemistry
And Qualitative Analysis. By FRANK CLOWES, D.Sc. Lond., Professor of Chemistry in the University College, Nottingham. Sixth Edition. Post 8vo, with 84 Engravings and Frontispiece, 8s. 6d.

Quantitative Analysis.
By FRANK CLOWES, D.Sc. Lond., Professor of Chemistry in the University College, Nottingham, and J. BERNARD COLEMAN, Assoc. R. C. Sci. Dublin; Professor of Chemistry, South-West London Polytechnic. Third Edition. Post 8vo, with 106 Engravings, 9s.

By the same Authors.

Elementary Quantitative Analysis. Post 8vo, with 62 Engravings, 4s. 6d.

Also.

Elementary Practical Chemistry and Qualitative Analysis. Post 8vo, with 54 Engravings, 3s. 6d.

Also.

Elementary Qualitative Analysis. With 40 Engravings. Post 8vo, 2s. 6d.

Qualitative Analysis.
By R. FRESENIUS. Translated by CHARLES E. GROVES, F.R.S. Tenth Edition. 8vo, with Coloured Plate of Spectra and 46 Engravings, 15s.

By the same Author.

Quantitative Analysis.
Seventh Edition.

Vol. I., Translated by A. VACHER. 8vo, with 106 Engravings, 15s.

Vol. II., Parts 1 to 3, Translated by C. E. GROVES, F.R.S. 8vo, with Engravings, 2s. 6d. each.

Inorganic Chemistry.
By EDWARD FRANKLAND, Ph.D., D.C.L., LL.D., F.R.S., and FRANCIS R. JAPP, M.A., Ph.D., F.I.C., F.R.S., Professor of Chemistry in the University of Aberdeen. 8vo, with numerous Illustrations on Stone and Wood, 24s.

Inorganic Chemistry
(A System of). By WILLIAM RAMSAY, Ph.D., F.R.S., Professor of Chemistry in University College, London. 8vo, with Engravings, 15s.

By the same Author.

Elementary Systematic Chemistry for the Use of Schools and Colleges. With Engravings. Crown 8vo, 4s. 6d.; Interleaved, 5s. 6d.

Valentin's Qualitative Chemical Analysis. Eighth Edition. By W. R. HODGKINSON, Ph.D., F.R.S.E., Professor of Chemistry and Physics in the Royal Military Academy, and Artillery College, Woolwich. 8vo, with Engravings and Map of Spectra, 8s. 6d.

Analytical Chemistry.
Notes for Students in Medicine. By ALBERT J. BERNAYS, Ph.D., F.C.S., F.I.C. Third Edition. Cr. 8vo, 4s. 6d.

Volumetric Analysis:
(A Systematic Handbook of); or the Quantitative Estimation of Chemical Substances by Measure, applied to Liquids, Solids, and Gases. By FRANCIS SUTTON, F.C.S., F.I.C., Public Analyst for the County of Norfolk. Seventh Edition. 8vo, with 112 Engravings, 18s. 6d.

Commercial Organic Analysis:
A Treatise on the Properties, Modes of Assaying, Proximate Analytical Examination, &c., of the various Organic Chemicals and Products employed in the Arts, Manufactures, Medicine, &c. By ALFRED H. ALLEN, F.I.C., F.C.S., Public Analyst for the West Riding of Yorkshire, the Northern Division of Derbyshire, &c.

Vol. I.—Alcohols, Neutral Alcoholic Derivatives, Sugars, Starch and its Isomers, Vegetable Acids, &c. With Illustrations. Third Edition. 8vo. [*Preparing.*

Vol. II.—Fixed Oils and Fats, Hydrocarbons, Phenols, &c. With Illustrations. Third Edition. 8vo. [*Preparing.*

Vol. III.—Part I. Aromatic Acids, Tannins, Dyes, and Colouring Matters. Third Edition, 8vo. [*Preparing.*

Vol. III.—Part II. Amines and Ammonium Bases, Hydrazines, Bases from Tar, Vegetable Alkaloids. Second Edition. 8vo, 18s.

Vol. III.—Part III. Vegetable Alkaloids (concluded), Non-Basic Vegetable Bitter Principles, Animal Bases, Animal Acids, Cyanogen and its Derivatives.

Cooley's Cyclopædia
of Practical Receipts, and Collateral Information in the Arts, Manufactures, Professions, and Trades: Including Medicine, Pharmacy, Hygiene and Domestic Economy. Seventh Edition, by W. NORTH, M.A. Camb., F.C.S. 2 Vols., Roy. 8vo, with 371 Engravings, 42s.

Chemical Technology:
A Manual. By RUDOLF VON WAGNER. Translated and Edited by WILLIAM CROOKES, F.R.S., from the Thirteenth Enlarged German Edition as remodelled by Dr. FERDINAND FISCHER. 8vo, with 596 Engravings, 32s.

Chemical Technology ; Or, Chemistry in its Applications to Arts and Manufactures. Edited by CHARLES E. GROVES, F.R.S., and WILLIAM THORP, B.Sc.

Vol. I.—FUEL AND ITS APPLICATIONS. By E. J. MILLS, D.Sc., F.R.S., and F. J. ROWAN, C.E. Royal 8vo, with 606 Engravings, 30s.

Vol. II.—LIGHTING BY CANDLES AND OIL. By W. Y. DENT, J. McARTHUR, L. FIELD and F. A. FIELD, BOVERTON REDWOOD, and D. A. LOUIS. Royal 8vo, with 358 Engravings and Map, 20s.

Vol. III.—GAS AND ELECTRICITY. [*In the press.*

Technological Handbooks. EDITED BY JOHN GARDNER, F.I.C., F.C.S., and JAMES CAMERON, F.I.C.

BREWING, DISTILLING, AND WINE MANUFACTURE. Crown 8vo, with Engravings, 6s. 6d.

BLEACHING, DYEING, AND CALICO PRINTING. With Formulæ. Crown 8vo, with Engravings, 5s.

.OILS, RESINS, AND VARNISHES. Crown 8vo, with Engravings. 7s. 6d.

SOAPS AND CANDLES. Crown 8vo, with 54 Engravings, 7s.

The Microscope and its Revelations. By the late WILLIAM B. CARPENTER, C.B., M.D., LL.D., F.R.S. Seventh Edition, by the Rev. W. H. DALLINGER, LL.D., F.R.S. With 21 Plates and 800 Wood Engravings. 8vo, 26s. Half Calf, 30s.

The Quarterly Journal of Microscopical Science. Edited by E. RAY LANKESTER, M.A., LL.D., F.R.S.; with the co-operation of ADAM SEDGWICK, M.A., F.R.S., and W. F. R. WELDON, M.A., F.R.S. Each Number, 10s.

Methods and Formulæ Used in the Preparation of Animal and Vegetable Tissues for Microscopical Examination, including the Staining of Bacteria. By PETER WYATT SQUIRE, F.L.S. Crown 8vo, 3s. 6d.

The Microtomist's Vade-Mecum: A Handbook of the Methods of Microscopic Anatomy. By ARTHUR BOLLES LEE, Assistant in the Russian Laboratory of Zoology at Villefranche-sur-mer (Nice). Fourth Edition. 8vo, 15s.

Photo-Micrography (Guide to the Science of). By EDWARD C. BOUSFIELD, L.R.C.P. Lond. 8vo, with 34 Engravings and Frontispiece, 6s.

An Introduction to Physical Measurements, with Appendices on Absolute Electrical Measurements, &c. By Dr. F. KOHLRAUSCH, Professor at the University of Strassburg. Third Edition, translated from the Seventh German Edition, by THOMAS HUTCHINSON WALLER, B.A., B.Sc., and HENRY RICHARDSON PROCTER, F.I.C., F.C.S. 8vo, with 91 Illustrations, 12s. 6d.

Tuson's Veterinary Pharmacopœia, including the Outlines of Materia Medica and Therapeutics. Fifth Edition. Edited by JAMES BAYNE, F.C.S., Professor of Chemistry and Toxicology in the Royal Veterinary College. Crown 8vo, 7s. 6d.

The Principles and Practice of Veterinary Medicine. By WILLIAM WILLIAMS, F.R.C.V.S., F.R.S.E., Principal, and Professor of Veterinary Medicine and Surgery at the New Veterinary College, Edinburgh. Seventh Edition. 8vo, with several Coloured Plates and Woodcuts, 30s.

By the same Author.

The Principles and Practice of Veterinary Surgery. Eighth Edition. 8vo, with 9 Plates and 147 Woodcuts, 30s.

The Veterinarian's Pocket Remembrancer: being Concise Directions for the Treatment of Urgent or Rare Cases, embracing Semeiology, Diagnosis, Prognosis, Surgery, Therapeutics, Toxicology, Detection of Poisons by their Appropriate Tests, Hygiene, &c. By GEORGE ARMATAGE, M.R.C.V.S. Second Edition. Post 8vo, 3s.

Chauveau's Comparative Anatomy of the Domesticated Animals. Revised and Enlarged, with the Co-operation of S. ARLOING, Director of the Lyons Veterinary School, and Edited by GEORGE FLEMING, C.B., LL.D., F.R.C.V.S., late Principal Veterinary Surgeon of the British Army. Second English Edition. 8vo, with 585 Engravings, 31s. 6d.

INDEX TO J. & A. CHURCHILL'S LIST

Adams (W.) on Clubfoot, 9
——— on Contractions of the Fingers, &c., 9
——— on Curvature of the Spine, 9
Allen's Chemistry of Urine, 12
——— Commercial Organic Analysis, 13
Armatage's Veterinary Pocket Remembrancer, 14
Barnes (R.) on Obstetric Operations, 3
——— on Diseases of Women, 3
Beale (L. S.) on Liver, 6
——— Microscope in Medicine, 6
——— Slight Ailments, 6
——— Urinary and Renal Derangements, 12
Beale (P. T. B.) on Elementary Biology, 2
Beasley's Book of Prescriptions, 5
——— Druggists' General Receipt Book, 5
——— Pocket Formulary, 5
Bell on Sterility, 3
Bellamy's Surgical Anatomy, 1
Bentley and Trimen's Medicinal Plants, 5
Bentley's Systematic Botany, 5
Berkart's Bronchial Asthma, 6
Bernard on Stammering, 7
Bernay's Notes on Analytical Chemistry, 1
Bigg's Short Manual of Orthopædy, 9
Bloxam's Chemistry, 12
——— Laboratory Teaching, 12
Bousfield's Photo-Micrography, 14
Bowlby's Injuries and Diseases of Nerves, 9
——— Surgical Pathology and Morbid Anatomy, 9
Brockbank on Gallstones, 8
Brodhurst's Anchylosis, 9
——— Curvatures, &c., of the Spine, 9
——— Talipes Equino-Varus, 9
Bryant's Practice of Surgery, 8
——— Tension, Inflammation of Bone, Injuries, &c., 8
Burckhardt's (E.) and Fenwick's (E. H.) Atlas of Cystoscopy, 11
Burdett's Hospitals and Asylums of the World, 2
Butlin's Malignant Disease of the Larynx, 11
——— Operative Surgery of Malignant Disease, 11
——— Sarcoma and Carcinoma, 11
Buzzard's Diseases of the Nervous System, 7
——— Peripheral Neuritis, 7
——— Simulation of Hysteria, 7
Cameron's Oils, Resins, and Varnishes, 14
——— Soaps and Candles, 14
Carpenter and Dallinger on the Microscope, 14
Carpenter's Human Physiology, 2
Charteris on Health Resorts, 8
——— Practice of Medicine, 6
Chauveau's Comparative Anatomy, 14
Chevers' Diseases of India, 5
Churchill's Face and Foot Deformities, 9
Clarke's Eyestrain, 10
Clouston's Lectures on Mental Diseases, 2
Clowes and Coleman's Quantitative Analysis, 13
——— Elementary Analysis, 13
Clowes' Practical Chemistry, 13
Cooley's Cyclopædia of Practical Receipts, 13
Cooper on Syphilis, 12
Cooper and Edwards' Diseases of the Rectum, 12
Cripps' (H.) Cancer of the Rectum, 12
——— Diseases of the Rectum and Anus, 12
——— Air and Fæces in Urethra, 12
Cripps' (R. A.) Galenic Pharmacy, 4
Cullingworth's Manual of Nursing, 4
——— Short Manual for Monthly Nurses, 4
Dalby's Diseases and Injuries of the Ear, 10
——— Short Contributions, 10
Day on Diseases of Children, 4
——— on Headaches, 8
Domville's Manual for Nurses, 4
Doran's Gynæcological Operations, 3
Druitt's Surgeon's Vade-Mecum, 8
Duncan (A.), on Prevention of Disease in Tropics, 5
Duncan (J. M.), on Diseases of Women, 3
Dunglison's Dictionary of Medical Science, 12
Ellis's (E.) Diseases of Children, 4
Ellis's (T. S.) Human Foot, 9
Fagge's Principles and Practice of Medicine, 6
Fayrer's Climate and Fevers of India, 5
——— Natural History, &c., of Cholera, 5
Fenwick (E. H.), Electric Illumination of Bladder, 11
——— Symptoms of Urinary Diseases, 11
Fenwick's (S.) Medical Diagnosis, 6
——— Obscure Diseases of the Abdomen, 6
Fenwick's (S.) Outlines of Medical Treatment, 6
——— The Saliva as a Test, 6
Fink's Operating for Cataract, 10
Flower's Diagrams of the Nerves, 1
Fowler's Dictionary of Practical Medicine, 6
Fox's (T.) Atlas of Skin Diseases, 10
Fox (Wilson), Atlas of Pathological Anatomy of Lungs, 6
——— Treatise on Diseases of the Lungs, 6
Frankland and Japp's Inorganic Chemistry, 13
Fraser's Operations on the Brain, 8
Fresenius' Qualitative Analysis, 13
——— Quantitative Analysis, 13
Galabin's Diseases of Women, 3
——— Manual of Midwifery, 3
Gardner's Bleaching, Dyeing, and Calico Printing, 14
——— Brewing, Distilling, and Wine Manuf. 14
Gimlette on Myxœdema, 6
Godlee's Atlas of Human Anatomy, 1
Goodhart's Diseases of Children, 4
Gowers Diagnosis of Diseases of the Brain, 7
——— Manual of Diseases of Nervous System, 7
——— Clinical Lectures, 7
——— Medical Ophthalmoscopy, 7
——— Syphilis and the Nervous System, 7
Granville on Gout, 7
Green's Manual of Botany, 5
Groves' and Thorp's Chemical Technology, 14
Guy's Hospital Reports, 7
Habershon's Diseases of the Abdomen, 7
Haig's Uric Acid, 6
Harley on Diseases of the Liver, 7
Harris's (V. D.) Diseases of Chest, 6
Harrison's Urinary Organs, 11
Hartridge's Refraction of the Eye, 10
——— Ophthalmoscope, 10
Hawthorne's Galenical Preparations of B P, 4
Heath's Certain Diseases of the Jaws, 8
——— Clinical Lectures on Surgical Subjects, 8
——— Injuries and Diseases of the Jaws, 8
——— Minor Surgery and Bandaging, 8
——— Operative Surgery, 8
——— Practical Anatomy, 1
——— Surgical Diagnosis, 8
Hellier's Notes on Gynæcological Nursing, 4
Higgens' Ophthalmic Out-patient Practice, 10
Hill on Cerebral Circulation, 2
Hillis' Leprosy in British Guiana, 10
Hirschfeld's Atlas of Central Nervous System,
Holden's Human Osteology,
——— Landmarks, 1
Hooper's Physicians' Vade-Mecum, 5
Hovell's Diseases of the Ear, 10
Howden's Index Pathologicus, 2
Hutchinson's Clinical Surgery, 9
Hyde's Diseases of the Skin, 10
Hyslop's Mental Physiology, 3
Impey on Leprosy, 10
Jacobson's Male Organs of Generation, 12
——— Operations of Surgery, 9
Johnson's Asphyxia, 6
——— Medical Lectures and Essays, 6
——— Cholera Controversy, 6
——— Granular Kidney, 6
Journal of Mental Science, 3
Keyes' Genito-Urinary Organs and Syphilis, 12
Kohlrausch's Physical Measurements, 14
Lancereaux's Atlas of Pathological Anatomy, 2
Lane's Rheumatic Diseases, 7
Langdon-Down's Mental Affections of Childhood, 3
Lee's Microtomists' Vade Mecum, 14
Lescher's Recent Materia Medica, 4
Lewis (Bevan) on the Human Brain, 2
Liebreich's Atlas of Ophthalmoscopy, 10
MacMunn's Clinical Chemistry of Urine, 12
Macnamara's Diseases and Refraction of the Eye,
——— of Bones and Joints, 8
McNeill's Epidemics and Isolation Hospitals, 2
Malcolm's Physiology of Death, 4
Mapother's Papers on Dermatology, 10
Martin's Ambulance Lectures, 8
Maxwell's Terminologia Medica Polyglotta, 12
Mayne's Medical Vocabulary, 12
Mercier's Lunacy Law, 3
Microscopical Journal, 14
Mills and Rowan's Fuel and its Applications, 14
Moore's (N.) Pathological Anatomy of Diseases, 1

[*Continued on the next page.*

N.B.—J. & A. Churchill's larger Catalogue of about 600 *works on* ***Anatomy, Physiology, Hygiene, Midwifery, Materia Medica, Medicine, Surgery, Chemistry, Botany,*** *&c. &c., with a complete* ***Index*** *to their Subjects, for easy* ***reference,*** *will be forwarded post free on application.*

AMERICA.—*J. & A. Churchill being in constant communication with various publishing houses in America are able to conduct negotiations favourable to English Authors.*

LONDON: 7, GREAT MARLBOROUGH STREET.