Hygiene and public health / by B. Arthur Whitelegge.

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Whitelegge, Arthur, Sir, 1852-1933.
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Publication/Creation

London : Cassell, 1895.

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Hygiene and Public Health

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MANUALS

FOR

STUDENTS OF MEDICINE

HYGIENE

AND

PUBLIC HEALTH

BY

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WITH 25 ILLUSTRATIONS

FIFTH EDITION

CASSELL AND COMPANY, LIMITED

LONDON, PARIS & MELBOURNE

1895

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BELLE SAUVAGE

PREFACE.

In preparing a fourth edition for the press several corrections have been made in the text, and new matter has been added in the Appendix. The additions include a summary of the Local Government Act of 1894, and the Isolation Hospitals Act, both of which are new and important elements in the sanitary government of the country. In view of the increasing demand for hospitals for infectious diseases, outline plans are given which will serve to indicate the arrangements suggested by the Local Government Board as most suitable for small hospitals of this class. One or two new Statistical Tables have also been introduced, and, lastly, some data which it is hoped will serve to lessen the difficulty caused by the unavoidable use of many different systems of measurement in public health work.

B. A. W.

Wakefield,
July, 1894.

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HYGIENE
AND
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INTRODUCTION.

No satisfactory simple name has yet been found for that branch of medicine of which the Medical Officer of Health is the official representative. Those in current use, namely, Hygiene, Public Health, State Medicine, Preventive Medicine, Sanitary Science, are all open to the objection that their primary signification is too limited in certain respects, while some of them include much that is beyond the province of medicine. Nor can any well-defined limit be assigned to a science which touches upon such widely-divergent subjects as law, engineering, architecture, statistics, chemistry, meteorology, and geology, in addition to those which form part of the routine training for the profession of medicine. The aspect of medical science with which we are now concerned is very different from that of the physician or surgeon. We have to consider the causes of disease and the means of combating them, rather than its symptoms and treatment, and the incidence of disease and death upon multitudes rather than upon individuals. Infection, disinfection, bacteriology, and epidemiology, are studies

of far greater moment in preventive than in curative medicine.

Without attempting any strict sequence, it will be convenient to consider first the influence of air, water, food, and soil, upon the public health; secondly, buildings, drainage, and other structural works; thirdly, specific diseases and their prevention; fourthly, sanitary law and the duties of Medical Officers of Health; and lastly, vital statistics.

CHAPTER I.

AIR.

PURE air contains about 21 per cent. (by volume) of oxygen, and about 79 per cent. of nitrogen, but there are also traces of ammonia and carbonic acid, and a very variable amount of watery vapour. The suspended solid matter includes organic and mineral particles, and microbes.

Oxygen.—The purest sea or mountain air contains 20·999 volumes per cent. of oxygen, and the worst air found in a mine 18·27 per cent. (*Angus Smith*). In over-crowded halls the percentage may be as low as 20·65. Even in the open air of towns it varies widely, considering the narrow limits stated above, but 20·96 per cent. may be taken as an average. It is lessened by respiration, by combustion, by putrefactive processes, by organic effluvia, and by fog; but increased by vegetation and by rain.

Ozone is an irrespirable gas, regarded as a more active allotropic form of oxygen, with the molecular formula O^3 instead of O^2. It appears to be only an occasional component of air, and never present in more than minute traces. Although these do not admit of exact measurement, the proportion is greatest after thunderstorms, and greater on the coast than inland. The ozone reaction (page 17) is more often met with when the wind is S.W. than when it is N.E. Ozone is readily reduced by oxidisable matter, and its presence therefore implies absence of organic impurity in the air.

Carbonic acid is usually adopted as the measure of the impurity of air, to which it bears a fairly constant relation. It varies from 0·3 per thousand in the purest mountain or sea air to 1·0, 2·0,

or even 3·0 in over-crowded rooms. In open air it is as a rule about 0·4 per thousand. Anything over 0·6 is to be regarded as indicating concomitant and injurious organic impurity, of which the carbonic acid is the harmless index (page 20). Carbonic acid *per se*, apart from organic exhalations, does not begin to be injurious until a proportion of about 15 per thousand is reached. It is increased by respiration, by combustion, by putrefaction, and by fog, but diminished by vegetation, by rain, by high winds, and, of course, by ventilation. At great elevations also the proportion is increased, owing perhaps to the complete oxidation of organic matter (*Angus Smith*). Both carbonic acid and organic matter increase as we pass from rural districts to suburbs, and from suburbs to the centre of a town, but the former varies less than the latter. At night the proportion of carbonic acid in the open air is increased, but Carnelley found in night air only half of the organic matter and a tenth of the number of microbes present in similar samples taken during the day.

In town-air traces of sulphurous acid are found: least in clear breezy weather, most during fog and under anti-cyclonic conditions.

Ammonia salts in air, like carbonic acid, are due mainly to animal exhalations and putrefactive processes. Pure air contains from 0·03 to 0·1 mgr. of ammonia per cubic metre, but over middens or in crowded rooms there is often 0·50, or more. As a rule, the ammonia is in combination with carbonic, nitric, or other acid. Its variations are upon the whole parallel with those of carbonic acid, and are similarly influenced by meteorological conditions.

Sulphuretted hydrogen may be found in the air of marshes, excavations, sewers, and near gasworks and chemical works.

Marsh gas is met with in the air of coal mines and marshes. In the former case the proportion may

be sufficient to destroy life by exclusion of oxygen, but 300 parts per thousand can be breathed with comparative impunity.

Carbonic oxide is present in minute quantity in the air of towns. It is formed as a product of imperfect combustion, and cast-iron stoves give it off in considerable quantity. Air containing 0·05 per thousand causes poisonous symptoms.

Microbes in air vary enormously in number according to locality, and very considerably in relation to season, time of day, and meteorological conditions. Miquel gives the following among other examples :—

Place.	Microbes per cubic metre of Air.
High mountains	1
Mid-Atlantic *	6
Summit of Panthéon (Paris)	200
Hôtel de Dieu (Hospital, Paris)	79000

Month.	Microbes per cubic metre of Air : mean of six years' observations.	
	Park of Montsouris.	Rue de Rivoli.
January	225	1880
February	155	2480
March	495	3710
April	420	4905
May	575	5750
June	495	5535
July	740	5205
August	685	4405
September	605	4615
October	500	3825
November	335	2650
December	225	2015
Annual Mean	455	3910

* Fischer found no microbes beyond 120 miles from land.

The seasonal maximum occurs about midsummer, the minimum about Christmas. Exactly the reverse of this was found in examining the air of hospital wards in Paris. The microbes were most numerous in winter, and fewest in hot weather, owing, beyond doubt, to the difference in ventilation.

Miquel found also two daily maxima, from 2 to 3 a.m., and from 2 to 3 p.m.; and corresponding minima between 7 and 8 a.m., and between 7 and 8 p.m. The numbers diminish rapidly with elevation above the ground level, and after rain. There are practically none in the air of deserts, and very few in that of high mountains.

Unlike the organic matter and carbonic acid, the number of microbes in the air of crowded rooms is dependent rather upon the habitual ventilation and cleanliness than upon the conditions at the time of observation. The microbes are not due to respiration, or to want of cleanliness of persons or clothing, but come from the walls, ceiling, and floor of the room itself, especially if these are porous and absorbent. Microbes adhere to moist surfaces, and hence the air of well-constructed sewers is remarkably free from them, except in the vicinity of fresh-air inlets, or at junctions where splashing occurs. Neither microbes nor any other solid particles are given off from quiescent liquid surfaces, but the bursting of bubbles upon the surface of stagnant and putrefying sewage continuously re-charges the air with them. As to the nature of the microbes, little that is definite can be said. Their variety is enormous, and for the most part they are probably harmless to man, but they include putrefactive organisms, and under certain conditions the specific germs of disease. Spores of moulds, though more bulky than most other air-borne organisms, are less readily deposited. Other low organisms and pollen may also be met with.

Dust consists chiefly of mineral particles, but in part of formed or unformed organic matter, of animal or vegetable origin; for example, epithelial scales, and fragments of cotton, or wool, or other animal or vegetable tissues. Aitken found the number of dust particles per cubic inch of air to range from a minimum of about 2,000 in the open country, up to 3,000,000 in towns and 30,000,000 in inhabited rooms.

Respiration. — Respiration abstracts oxygen from air and adds carbonic acid, water, organic matter, and a little ammonia. An average adult gives off about ·6 cubic foot* of carbonic acid per hour, or 17 litres, of which perhaps about one-fiftieth part is yielded by the skin (*Regnault*). The amount is less in women, children, and aged persons.

Expired air contains about 4·5 per cent. of carbonic acid, and only about 16 per cent. of oxygen. As a rough average it may be stated that 10 oz. of watery vapour are given off by the lungs in 24 hours, and 20 oz. by the skin. In health, expired air contains few, if any, microbes, but much organic matter, the nature of which is very imperfectly known. It is nitrogenous, oxidisable, molecular, and probably exists in combination with water, since it is readily absorbed by hygroscopic objects. It is precipitated from solution by argentic nitrate, blackens on ignition, reduces potassic permanganate, yields ammonia on distillation with alkaline permanganate, and has a fœtid smell. Unlike carbonic acid, it diffuses sluggishly through the air of a room, and is slowly destroyed by fresh air. It promotes the growth of organisms; and milk, meat, or other food in contact with it readily becomes tainted. Both carbonic acid and organic matter are increased after exercise.

Combustion. — Coal when burnt gives off — (1) Carbonic acid, together with carbonic oxide unless

* 0·56 during sleep; 0·78 when awake. (Pettenkofer.)

the combustion is perfect; (2) Sulphurous and sulphuric acids; carbon bisulphide, ammonic sulphide, and sometimes sulphuretted hydrogen; (3) Water; (4) Fine particles of carbon and tarry matter.

Coal gas yields similar products, but there is little free carbon or organic matter. The sulphur in gas should not exceed 20 grains per 100 cubic feet.

Wood differs from coal in yielding comparatively little of the sulphur compounds. Oil and candles give scarcely any, but increase the organic matter in the air.

The gaseous products, especially carbonic acid, are rapidly diffused by air-currents; but the suspended particles of carbon and tar diffuse slowly, and are not as a rule found at a greater elevation than 600 feet.

Pollution by sewage emanations.—Oxygen is lessened, carbonic acid increased, and there is much fœtid organic matter, together with variable quantities of marsh gas, sulphuretted hydrogen, and ammonic sulphide. The composition of the organic matter is unknown, but its properties are similar to those of the organic matter in respired air.

Sewer gas has no constant composition, and if the sewer is well ventilated the air in it may differ little from that outside. Much depends upon the sewage being removed quickly, or, on the other hand, being allowed to stagnate and undergo decomposition.

Air polluted by sewage emanations, whether from cesspools, sewers, or drains, is undoubtedly capable of giving rise to diarrhœa and gastro-intestinal disturbance, and to certain forms of sore throat which often closely simulate diphtheria. Anæmia, depression, and general ill-health are caused by protracted exposure to such an atmosphere. It is also certain that cholera, enteric fever, pneumonia, erysipelas, puerperal fever, and diphtheria have a much

heavier incidence, both in numbers and severity, upon persons exposed to these conditions ; and, according to some authorities, scarlet fever should be added to the list. It is not necessary to assume an origin *de novo* in such cases, the evidence being consistent with the supposition either that the specific poison is sometimes carried by such emanations, or that their effect is merely to predispose to the disease. There is at present no clear evidence of any specific relation between sewer gas and small-pox, measles, or whooping-cough.

Men working in well-ventilated sewers are not found to suffer any ill effects, but if ventilation is wanting they are liable to ophthalmia and to syncopal or apoplectic attacks. It is said that venereal disease is greatly aggravated by this employment. Meat, milk, and other food substances readily decompose if exposed to sewage emanations.

Recent observations show that the air in sewers contains comparatively few organisms capable of cultivation upon ordinary media. The reasons for this have already been explained. Haldane examined the air of an unventilated sewer in Bristol, and found 2 volumes of carbonic acid per 1,000, but only two microbes per litre, half of which were moulds. The sewer had a good fall, and the air in it was scarcely offensive.

The air of marshes contains excess of carbonic acid and watery vapour, and often marsh gas, hydrogen, sulphuretted hydrogen, and phosphoretted hydrogen. It is said not to be deficient in ozone. There is much organic matter, and micro-organisms abound. The relation of marsh air to malaria will be considered later.

The air of graveyards contains excess of carbonic acid. In vaults, and over graves with an insufficient covering of earth, there are also found fœtid

organic matter, ammonia, ammonic sulphide, and sulphuretted hydrogen.

We have no direct proof of injury to health caused by the air of burial-grounds conducted under modern regulations. There is, however, considerable evidence of increased sickness and mortality among persons residing close to over-crowded graveyards. It has been noticed that such persons are especially liable to cholera, and it is said that in such localities other diseases assume a more deadly type.

Persons taking part in exhumations have in many instances suffered from febrile attacks of varying character and intensity; but as a rule nothing more than diarrhœa, and occasionally vomiting, results from such exposure, and that only in a minority of cases. Much depends upon the completeness of the putrefactive changes. Grave-diggers do not appear to be an unhealthy or short-lived class.

Putrefying carcases of horses killed in battle, and left unburied in camp, have given rise to diarrhœa and dysentery among the troops. Other diseases were increased in severity.

Contamination of air by trade processes and manufactures.—It is not always practicable to distinguish ill effects due to air-borne impurities from those caused in other ways. In some of the metal industries the injurious matters are doubtless accidentally conveyed to the mouth by hand and swallowed, besides being inhaled as dust or fumes.

Atmospheric impurities of trade origin may be roughly classified as follows:—(1) Mechanical impurities, *i.e.* dust; (2) Metallic and other impurities which are poisonous; (3) Organic effluvia; (4) Excessive or deficient humidity. This last is, however, intimately associated with respiratory impurity, already considered.

1. *Mechanical impurities.*—Sheffield grinders (page

537) suffer a heavy mortality from lung diseases, and especially from phthisis, due beyond doubt to the constant inhalation of stone dust and metallic dust. The evil is to some extent mitigated by the use of fans, and by wet grinding. Potters and Cornish miners are also subject to a high death-rate from phthisis, from a similar cause. Coal dust, however, seems to be less injurious, the death-rate among colliers being comparatively low. Phthisis and other respiratory diseases are common among workers in wool, cotton, flax, and shoddy; in cotton mills the dust contains china-clay from the "sizing," as well as cotton fibre. The mortality among millers and bakers is not high. Tailors, drapers, and hairdressers are subject to lung diseases; and this is probably due in part to the inhalation of dust. In most of these trades the air is liable to be vitiated in other ways. It would seem that sharp angular mineral particles are more injurious than other kinds of dust.

2. *Metallic and other impurities which are directly poisonous.*—Zinc fumes (oxide of zinc) are given off in brass foundries, and cause a disease which is known as "brass-founder's ague," the attacks of which present a cold stage with rigors, a stage of febrile reaction, and a stage of profuse sweating. They differ from true ague in not being periodic.

Copper works are liable to produce arsenical fumes.

Mercurial fumes, or dust, are partially responsible for the symptoms of mercurial poisoning to which "water-gilders" and other workers in the metal are liable. Apart from the ordinary symptoms—namely, salivation, alimentary disturbances, and cachexia—there are peculiar fine tremors of the hands and arms, with occasional pains in the joints; in aggravated cases the movements become more violent and more general; as a rule, they cease when the patient is recumbent and making no effort.

Brickfields, cement-works, and lime-kilns emit carbonic acid, carbonic oxide, and sulphuretted hydrogen; iron and copper furnaces give off much carbonic oxide. Copper works send out also sulphurous and sulphuric acids. Alkali works formerly poured considerable quantities of hydrochloric acid into the air, but this has been to a great extent remedied. The fumes of phosphorus frequently cause necrosis of the lower jaw among makers of lucifer-matches. Bisulphide of carbon is used in india-rubber works, and is volatilised. From chemical works fumes of various kinds, notably sulphuretted hydrogen and ammonic sulphide, may be given off.

Some of these emanations are, as already stated, definitely injurious to health. Others, such as alkali works and copper-smelting, are destructive to vegetation for a considerable distance around, but no clear injury to health of surrounding residents has been made out. Brickfields and chemical works, though often most offensive, can scarcely be proved to act as direct causes of disease.

3. *Organic effluvia.*—Most of the multifarious trades concerned with animal products are liable to cause effluvia. Among them may be specially mentioned manure works of all kinds; slaughterhouses and knackers' yards; tanyards, fellmongers' works, and hide markets; bone-boiling or burning, glue and size works; soap, oil, and tallow works; gut-scraping, or preparation of intestines for use as sausage-skins; fish-curing. To this list may be added "marine stores" and the keeping of pigs, horses, cows, fowls, and other animals.

Effluvia from such sources frequently constitute grave nuisances, but it is difficult to define their relation to disease. Persons actually employed in these trades do not appear to suffer in health, but residents in the vicinity of the works frequently complain of

loss of appetite, nausea, vomiting, diarrhœa, headache, giddiness, faintness, and general illness and depression. It is fair to assume that the general health of the community is lowered by such conditions, and that diseases tend to run a more unfavourable course. The public are not slow to credit such effluvia with the power of generating "fevers" and all manner of infectious diseases; and it is at least conceivable that trade effluvia, like sewer gas, may predispose to those zymotic diseases which have a relation to septic conditions—*e.g.* enteric fever, diphtheria, erysipelas, and puerperal fever.

4. *Excessive humidity*, associated with a high temperature, is found in Lancashire weaving sheds, and also in the woollen and certain branches of the silk trade. Dryness of the air causes considerable loss in the weight and quality of the work, and the air is therefore often steamed. Respiratory impurities also accumulate, as the ventilation is usually kept to a minimum for similar reasons. Such conditions, together with the sudden changes from the hot, moist, impure air of the workrooms to the external air, co-operate with the inhalation of dust particles to cause a high mortality from lung diseases. Hatmakers, as a rule, suffer from similar conditions.

Bakers, confectioners, and glass-workers are exposed to hot dry air, and their mortality is rather high, especially from lung diseases.

Examination of air.—1. *Solid particles* suspended in the air may be collected for microscopic examination by aspirating the air through water; or by allowing a jet of air to pass into an exhausted receiver through a fine aperture, so as to impinge upon a piece of glass smeared with glycerine, which arrests the particles (Pouchet's aëroscope). Another plan is to aspirate air through a filter of powdered sugar, and then dissolve away the sugar in water, leaving the

intercepted particles available for examination. By measuring the volume of air aspirated, and counting the particles in an aliquot part of the intercepting material, these methods can be made quantitative.

Micro-organisms will, for the most part, escape detection by this method, and, indeed, no means exist of determining their number with accuracy. A rough approximation may be obtained by making a plate-cultivation from the whole (or an aliquot part) of the material obtained in the manner described above, and counting the colonies; but for obvious reasons the result gives only the number of organisms which happen to be able to thrive upon the particular pabulum used, and under the particular thermometric and other conditions of the experiment. Hesse aspirates air slowly through a wide horizontal glass tube smeared on the inside with nutrient gelatine, the air entering through a pin-hole at such a speed as to allow all suspended particles to fall upon the gelatine before reaching the other end.

2. *Organic matter* in air may be measured by determining the volume of air required to decolorise a known volume of a standard solution of permanganate of potash, such as that mentioned on page 98. The air may be aspirated through the solution, or successive volumes washed with the permanganate, by shaking in a bottle, until the solution is no longer pink.

Another plan is to aspirate a known large volume of air through distilled water, and then examine the latter by the albuminoid ammonia process, to be described presently.

Carbonic acid.—1. *Pettenkofer's method.*—The solutions required are: (*a*) Pure lime-water, saturated or nearly so; (*b*) Standard solution of crystallised oxalic acid of such strength (2·25 grammes per litre) that 1 c.c. exactly neutralises 1 mgr. of lime, CaO. From the equation $CaO + CO^2 = CaCO^3$ it is evident

56 mgr. 44 mgr. 100 mgr.

that 1 mgr. of CaO takes $\frac{44}{56}$ mgr. of CO^2. The volume of 44 mgr. of CO^2 is 22·4 c.c., so that $\frac{44}{56}$ mgr. = 0·4 c.c. Hence each c.c. of oxalic solution corresponds to 0·4 c.c. of carbonic acid, either being capable of neutralising exactly 1 mgr. of lime.

A wide-mouthed glass bottle, provided with a tight-fitting glass or rubber stopper, is also necessary. Its capacity should be about five litres, and must be determined accurately.

The bottle having been cleaned and dried, is filled with sample air, either by means of a bellows, or by pumping out air from it, or by filling with water and then emptying. Sixty c.c. of lime-water are put into the bottle, the stopper is inserted, and the air thoroughly washed with lime-water by means of vigorous shaking. The carbonic acid combines with lime and forms a milky precipitate of carbonate of lime; the loss of strength of the lime-water therefore measures the amount of carbonic acid present. After the bottle has stood at rest for a few hours, 30 c.c. of the lime-water are removed for analysis. It is not possible to collect the whole of the 60 c.c., nor would there be any advantage in doing so.

It only remains to determine by means of the oxalic solution the amount of lime present in the lime-water before and after the process, and from the loss to calculate the proportion of carbonic acid in the known volume of sample air. The determination of the "causticity" of the lime-water (that is, the amount of caustic lime it contains) is made by a simple process of alkalimetry. Oxalic solution is dropped from a graduated burette into a measured quantity (30 c.c.) of lime-water, until the exact point of neutralisation is reached. Several "indicators" are available for the recognition of this point. If a drop of the lime-water

is removed from time to time and put upon turmeric paper, it will give a brown stain as long as any caustic lime remains unneutralised, but none when the neutralisation is complete. A still simpler indication is obtained by adding to the lime-water a few drops of a solution of "phenol-phthalein," which is decolorised as soon as all the lime is neutralised.

Example.—The capacity of the bottle is 4,840 c.c., and 30 c.c. of lime-water take respectively 38 and 31 c.c. of oxalic solution before and after the process.

The volume of air is 4,840 c.c. — 60 c.c. = 4,780 c.c. Since 30 c.c. lost 7 mgr. of lime, the 60 c.c. employed lost 14 mgr., and from data already given this corresponds to $14 \times 0{\cdot}4 = 5{\cdot}6$ c.c. of carbonic acid. Hence, the sample air contained (by volume) 5·6 parts of carbonic acid in 4,780 of air, or 1·17 per thousand.

Corrections must be made if the temperature deviates materially from 32° Fahr., or the barometric pressure from 30 inches of mercury. One per cent. should be added to the result for every 5° above 32° Fahr. If the barometric reading is B, the result must be multiplied by $\frac{30}{B}$. Thus, if in the above example the temperature were 72° Fahr., and the pressure 29·2 inches, the corrections would be as follows :—

$$1{\cdot}17 \times \frac{108}{100} \times \frac{30}{29{\cdot}2} = 1{\cdot}3 \text{ part of carbonic acid}$$

per thousand.

2. *Angus Smith's Minimetric method and "Household" test.*—It is found that a certain amount of carbonic acid is needed in order to produce a cloud in a given volume of lime-water. The volume of lime-water being constant, the volume of air necessary to give a visible precipitate affords a simple inverse measure of the carbonic acid it contains. Half an ounce of clear lime-water is placed in each of a series of stoppered bottles of different sizes

and well-shaken. The *smallest* bottle which shows any cloudiness indicates the proportion of carbonic acid present in the sample air, according to the following empirical scale :—

A ppt. in a bottle of	443	c.c. capacity indicates the presence of at least		0·4	parts CO_2 per 1,000.
,,	356	,,	,,	0·5	,,
,,	299	,,	,,	0·6	,,
,,	259	,,	,,	0·7	,,
,,	228	,,	,,	0·8	,,
,,	204	,,	,,	0·9	,,
,,	185	,,	,,	1·0	,,
,,	157	,,	,,	1·2	,,
,,	128	,,	,,	1·5	,,
,,	100	,,	,,	2·0	,,

Adopting 0·6 per 1,000 as the permissible limit of carbonic acid, there should be no precipitate when half an ounce of lime-water is shaken in a bottle of 300 c.c. or 10½ oz. capacity.

Carbonic oxide, CO, may be determined quantitatively by exposing a measured volume of air to a solution of cuprous chloride, which absorbs this gas. The loss in volume shows the amount of carbonic oxide present.

Oxygen is determined quantitatively by exposing a measured volume of air to a solution of potassic pyrogallate, which absorbs the oxygen. The analysis may be conveniently made in a graduated glass tube inverted over a mercurial trough; the tube having been filled with air, the pyrogallate solution is passed up into it through the mercury. All the readings must be taken at the same pressure.

Ozone is detected by its action upon potassic iodide. Strips of porous paper are steeped in a solution containing starch and potassic iodide, and then dried. These are exposed for a definite period to the air, care being taken to exclude sun and rain. Ozone causes a blue tint, the intensity of which is taken as

indicating the amount of ozone according to a standard scale of tints;* the ozone liberates iodine from the potassic iodide, and the iodine strikes a blue colour with the starch.

Ammonia may be collected by aspirating a known volume of air through distilled water, and then determined quantitatively as well as qualitatively by Nesslerising (page 92).

Nitrogen is determined with sufficient accuracy as the residue left when oxygen is removed by pyrogallate solution. The proportions of other gases are so small that their retention does not materially affect the determination of nitrogen.

Water, or rather aqueous vapour in air, may be measured by the hygrometer, or by the spectroscope, or volumetrically by its absorption by sulphuric acid, etc.

It may occasionally be necessary to test for sulphuretted hydrogen, or for mineral acids due to chemical manufacturing processes. The former is detected by exposing strips of porous paper moistened with a solution of plumbic acetate, and noting the black colour due to formation of plumbic sulphide. Free mineral acids will redden moist blue litmus paper; and may be obtained for chemical analysis by aspirating the air through distilled water or solution of caustic potash.

Ventilation.—Taking the average frequency of respiration as 16 per minute, and the average volume of each breath as 30 cubic inches, the volume of air expired is about 17 cubic feet per hour, and if it were

* For several reasons this test is held to be inexact. The chief are (1) that nitrous acid and peroxide of hydrogen, as well as ozone, give the reaction; (2) that the conditions of exposure are not uniform—light, wind, humidity, and temperature all vary, and all affect the reaction; (3) some of the liberated iodine is volatilised, and some reacts again upon the potash to form inert iodide and iodate.

possible to carry this immediately away a fresh-air supply of 17 cubic feet per hour would suffice. In practice, the expired air cannot be prevented from mixing with the rest, and we have to determine how much fresh air is needed to dilute down the respiratory impurities to a permissible point, assuming that the whole of the air in the room is equally contaminated.

When the carbonic acid in the air of a room exceeds 0·6 volume per 1,000, the air begins to be perceptibly "close" *to a person entering from the open air*, and it is usual to adopt this as a standard of purity, and to aim at introducing a sufficient supply of fresh air to keep the carbonic acid at or below this point.

A thousand cubic feet of fresh air contain 0·4 cubic foot of carbonic acid, and can, therefore, take up 0·2 cubic foot more without exceeding the limit of 0·6. As already stated, an average man gives off 0·6 cubic foot of carbonic acid per hour, so that $\frac{0·6}{0·2} \times 1{,}000$, or 3,000 cubic feet of fresh air per hour are needed to maintain the standard of purity. If we adopt other values for any of the preliminary data, the volume of fresh air needed will be proportionately modified. In general terms, if

A = the number of cubic feet of carbonic acid in 1,000 cubic feet of fresh air = 0·4,
C = the proposed maximum limit of carbonic acid in the air of the room,
R = the number of cubic feet of carbonic acid given off per head per hour = 0·6,
F = volume of fresh air required per head per hour to maintain the standard C,

Then $F = \frac{R}{C - A} \times 1{,}000$, and for n persons the required volume becomes $\frac{R \times n}{C - A} \times 1{,}000$, or $\frac{600 \times n}{C - 0·4}$.

Example I.—What hourly supply of fresh air is needed for a hall containing 100 persons, in order that the air of the

hall may not contain more than 0·7 part of carbonic acid per 1,000 volumes of air?

Answer: $F = \frac{0{\cdot}6 \times 100}{0{\cdot}7 - 0{\cdot}4} \times 1{,}000 = 200{,}000$ cubic feet.

Example II.—If 12,000 cubic feet of fresh air per hour are supplied to a room containing 10 persons, what proportion of carbonic acid will be found in the air of the room?

The formula $F = \frac{R \times n}{C - A} \times 1{,}000$ becomes

$$12{,}000 = \frac{0{\cdot}6 \times 10}{C - 0{\cdot}4} \times 1{,}000.$$

Hence C = 0·9 per 1,000 cubic feet.

It is of course assumed that an equal volume of impure air is removed to make way for the fresh air.

Carnelley, Haldane, and Anderson find that the determination of carbonic acid alone is not a satisfactory measure of the impurity of the air in other respects. There is no definite connection between the number of microbes and the amount of CO^2, but in general a high proportion of CO^2 is accompanied by a high proportion of organic matter. The standards suggested are as follows:—

Microbes . . not exceeding 20 per litre. Not more than 30 bacteria to 1 mould.

Organic Matter . not exceeding 2 volumes oxygen required for oxidation, per million volumes of air (page 14).

Carbonic Acid . not exceeding 1·0 (dwellings) or 1·3 (schools) per 1,000.

The poisonous qualities of respiratory impurities are mainly, if not entirely, due to the organic matter.* In air so impure that the carbonic acid reaches 1·5 per 1,000 the majority of persons suffer from headache

* Important experiments by Haldane and Lorrain Smith, published in October, 1892, are in direct contradiction to the view stated here, and hitherto generally accepted. They find that disturbance of respiration begins when CO^2 rises to 30, or oxygen falls to 120, per 1,000; and becomes excessive at 100 and 60 per 1,000 respectively. They attribute to these two factors all immediate danger in breathing highly vitiated air.

and depression. Persons habitually breathing impure air become anæmic, languid, weak, and suffer in nutrition; such persons are prone to suffer from bronchitis and pneumonia. If the impurity is extreme, as in the Black Hole at Calcutta, the consequences may be rapidly fatal, partly from deprivation of oxygen, partly from poisoning by organic exhalations; those who survive are apt to suffer from boils and febrile symptoms. Among the more specific diseases, typhus and phthisis have a close relation to impurity of air, but all diseases in which the breath is infectious must necessarily be more readily transmissible when the infected air is breathed in a concentrated form. The aggregation of acute cases of small-pox has been shown to contribute to its aërial spread, though perhaps the expired air is not wholly responsible for this; the same may be suspected of measles and whooping cough. Overcrowding of surgical cases with imperfect ventilation is conducive to erysipelas and hospital gangrene.

Air space. — It is found experimentally that with ordinary appliances, and under the average atmospheric conditions of the climate of England, the air of a room cannot be changed more than about three times per hour without causing an inconvenient amount of draught. Hence, in order to supply 3,000 cubic feet of fresh air per hour, we should have an air-space for each person of at least 1,000 cubic feet. In calculating the cubic space, only the available air-space should be taken into account, deduction being made for furniture and other solid objects. It must be remembered, too, that air stagnates in nooks and corners, and the useful part of the air-space is that in which the air moves freely. For these and other reasons it is more difficult to provide for the efficient ventilation of a small room than of a large one, the air-space per head being the same in each case.

Average Results of Analyses of Air in Sleeping Rooms between 12.30 and 4.30 a.m. (*Carnelley, Haldane, and Anderson.*)

Cubic Feet per Head.	Temperature (Fahrenheit.)	Carbonic Acid per 1,000 vols.	Organic Matter (vols. of Oxygen required per million vols. of air).	Microbes per litre.
100–180 . .	55°	1·15	15·1	80
180–260 . .	54°	1·07	15·1	49
260–340 . .	53°	1·03	11·8	32
340–500 . .	57°	0·92	8·4	42
500–1,000 . .	54°	0·86	5·6	6
1,000–2,500 . .	53°	0·67	3·9	9
2,500–4,000 . .	57°	0·79	5·0	13

The experiments summarised above were made in Dundee. They tend to show that about 1,000 cubic feet per head are sufficient, and, indeed, the impurities were somewhat greater when very large space was provided, owing probably to imperfect ventilation.

The same observers compared houses of one, two, three, and four rooms, in regard to impurity of air and mortality from different causes among the inmates. They found that the smaller the tenement the greater was the impurity of the air, as shown by increase of carbonic acid, microbes, and organic matter. The death-rate increased in like manner, and especially among children. Comparing one-roomed with four-roomed houses, the general death-rate was doubled, and the death-rate at ages below five years quadrupled. The increase was most marked in diarrhœa, measles, whooping cough, bronchitis, and pneumonia.

The actual air-space obtained in practice frequently falls very far short of 1,000 cubic feet per head, even in large private houses. In registered common

lodging-houses the minimum is usually 300 cubic feet per head, but varies according to the regulations of the different local authorities, and in working-class dwellings it is frequently much less still. The Education Department require 80 cubic feet per head as a minimum in Board schools. (*See* page 169.) The lowest standard expressly sanctioned by law is that for canal-boats, namely 60 cubic feet per head for adults, and 40 for children (page 445). It is important to bear in mind that cubic space is chiefly valuable as making ventilation possible without "draught," and not as a store of fresh air. The foul air of an average English bedroom in the morning is a proof that proper ventilation has not been provided, whatever the magnitude of the cubic space. No bedroom, however large, ever contains a sufficient supply of fresh air for the night, but the larger the room the more readily can efficient ventilation be contrived. A thousand cubic feet of space per person is ample, if the air is changed three times per hour, but in itself a thousand cubic feet of air is a sufficient supply for one person for twenty minutes only.

The objection to draught is largely dependent upon its chilling effect, so that in hot weather, or when the fresh air is warmed artificially, the air of a room may be changed more rapidly than three times an hour, and in that case a somewhat smaller cubic space may be sufficient.

Although the carbonic acid of expired air diffuses pretty readily, the organic matter is less volatile, and hangs about in invisible clouds unless dissipated by local currents. Hence the composition of air in an occupied room is not uniform, even at the same level, though for practical purposes it may usually be assumed to be so. In a large room occupied by many persons both the local currents and the foci of pollution are numerous, so that the composition of the

air is much more uniform than in a small room occupied by one person. If from any cause the air passing out of the room is not the most impure, the remaining air will be found to exceed the theoretical degree of impurity. The outlet should be at or near the highest point, since expired air, being warm and moist,* is lighter than ordinary air, and ascends at first to the upper part of the room.

The fresh-air inlets should be arranged as far as possible so as to avoid draughts impinging upon the occupants, to secure diffusion of the current, and to counteract the tendency of the fresh air (if cool) to sink to the lowest level. This may be effected by giving it an upward direction on entering, so that before descending it mixes with the air of the room.

In measuring a room for the purpose of calculating the air-space, recesses and projections may be taken separately, and then added to or deducted from the total. A similar procedure will obviate any difficulty in cases where the ceiling is not horizontal throughout.†

The ventilation of a room or building may be "natural" or "artificial," the latter term being

* The vapour of water is lighter than air. The volumes occupied by 18 parts by weight of water vapour, 32 of oxygen, and 28 of nitrogen, are equal; these proportions being, of course, those of their respective molecular weights.

† Very often only right angles are met with, so that the floor area = length × breadth, and the cubic capacity = area × height. The following rules cover most of the other conditions likely to occur in practice.

Area of triangle = Base × Height × $\frac{1}{2}$. (Euclid I. 41.)

Area of an irregular four-sided figure. Divide into two triangles, by joining two opposite angles. Find area of each triangle, and add together.

Area of a circle = (Diameter)^2 × 0·7854.

Area of a semicircle = (Diameter)^2 × 0·3927.

Area of segment of circle = Chord × Height × $\frac{2}{3} + \frac{(\text{Height})^3}{2 \times \text{Chord}}$

Area of an ellipse = Long Diameter × Short Diameter × 0·7854.

Capacity of a dome = Area of base × Height × $\frac{2}{3}$.

Capacity of a cone or pyramid = Area of Base × Height × $\frac{1}{3}$.

applied to mechanical means for extraction or propulsion of air, and the former to all other forms of ventilation.

Natural ventilation is dependent upon wind, upon local currents due to differences between internal and external temperatures, and upon still more local currents determined by artificial heat, as in chimneys or ventilating gas-lights, although these last may perhaps more properly be considered as artificial means of ventilation.

Inlets.—Air finds its way into a room by the doors and windows, however close-fitting, and to a less extent through brick or stone walls, ceilings, and floors. These leakages are very small if a proper fresh-air inlet has been provided. Such inlets may be window openings, or ventilating fire-places or stoves, or special openings (ventilators). Windows should be made to open at top and bottom, but it is desirable to have in addition some means of admitting air at all seasons without draught. This may be done by having double windows, or one or more double panes, and providing an opening at the bottom of the outer and at the top of the inner one, so as to admit fresh air in an upward current. Louvred panes and several modifications of "hit-and-miss" ventilators are also available, or a board may be placed beneath the lower sash so as to prop it up and thus allow space for an upward indraught between the two sashes. Another plan is for the upper part of the window to be hinged below, so as to fall forward and admit air into the room as by a Sheringham valve.

Ventilating fire-places have an air-chamber at the back of the grate, heated by the fire. Fresh air brought by a pipe from the outside is warmed in the hot chamber, and then passed into the room. There are many varieties, among which Galton's is the earliest and one of the best. Ventilating stoves are

in use, the fresh air entering through a coiled pipe exposed to the heat of the stove.

Special ventilators (Fig. 1) are of varied types, from simple openings through the wall to the most complex arrangements. *Perforated bricks* cause little

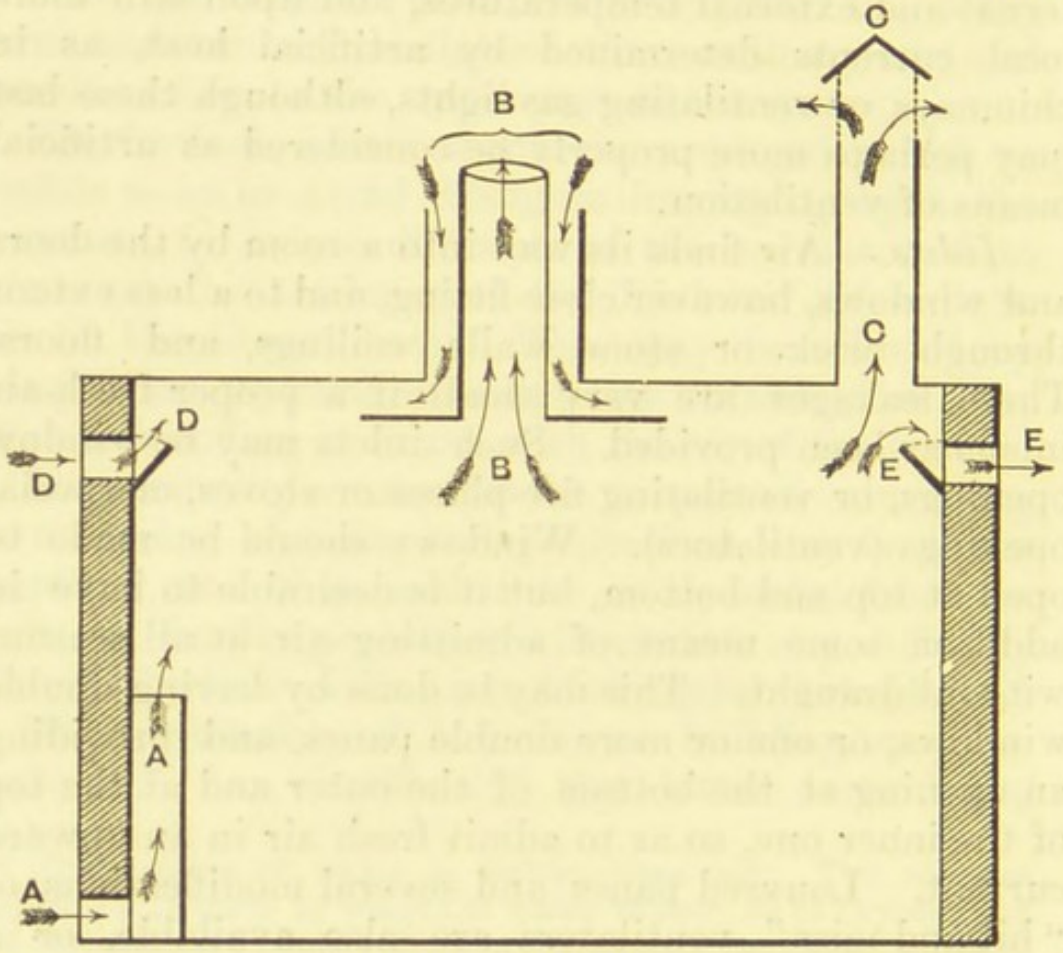

Fig. 1.—Ventilators.

A A, Tobin's; B B, McKinnell's; D D, Sheringham's (acting as inlet); E E, Sheringham's (acting as outlet); C C, Ventilating shaft.

draught, the holes being conical with the wider ends inside, so that the air stream slackens as it passes through the wall, and is diffused upon entering the room. *Sheringham's ventilator* is a small vertical flap door in the wall near the ceiling, balanced by a counterpoise and hinged below so as to fall forward towards the room; it is cased in at the sides and front so that the current can only pass upwards. *Tobin's ventilator* consists of a large upright tube

rising five feet or more from the floor; fresh air from outside passes up this tube and into the room. *Ventilating cornices* are made, consisting of a double channel of perforated metal, cold fresh air being brought into the room by the lower channel, and vitiated air being received into the upper channel and carried to the chimney or other outlet; another plan is to carry a perforated inlet tube along the cornice on three sides of the room, and a similarly perforated outlet tube along the fourth side. A hollow perforated metal beam, interrupted by a diaphragm at the centre, may be taken across the room, one half serving as an inlet and the other as an outlet, according to the direction of the wind. *McKinnell's ventilator* consists of a larger outer and a smaller inner tube, carried upwards through the ceiling; fresh air passes in between the tubes, and is dispersed on entering the room by a horizontal flange upon the inner tube; the inner tube, which is equal in sectional area to the inlet, and projects beyond the other both above and below, carries off impure air. It has also been proposed to ventilate by means of a vertical shaft divided longitudinally into two or four separate channels, along which currents in opposite directions will always establish themselves. Workrooms may be ventilated by means of a perforated ceiling of zinc or paper, over which is a chamber open to the outer air on every side.

Some of the preceding are intended to act as inlets, but all are liable to become outlets. Other kinds of ventilators are, like chimneys, designed as outlets only. An opening may be made from the room into the chimney near the ceiling, reflux of smoke being prevented by a number of little valves of mica (Boyle's valves) which, in the absence of up-current, close by their own weight, owing to the forward tilt of the latticed framework to which they are attached. Ventilating gas-lights are made, in which the

products of combustion are collected by means of a bell cover or glass globe, and conveyed away by a tube; this tube is surrounded by a larger one, and the space between the two acts as an extraction shaft for foul air from the room, being heated by the inner tube. A similar use may be made of chimneys, the smoke being contained in a central metal tube, leaving an air-space all round it which serves as an extraction shaft. Or outlet pipes from the higher part of the room may be carried upwards for some distance in or close to the chimney so as to utilise its heat in promoting an up-current. Extraction tubes may of course be carried from any part of the room, with or without taking advantage of these various convenient sources of heat, and they may be provided with Boyle's, Banner's, or other cowls.

The size of openings required for the efficient ventilation of an occupied room under average conditions is about 48 square inches *per head*, namely, 24 as inlet and 24 as outlet, but, according to Parkes, no single inlet should exceed 60 and no outlet 144 square inches.

The supplies of fresh air should be taken from suitable points free from risk of contamination, and, if necessary, the air may be screened through metal gratings or canvas. It may be washed by passing it through spray or a film of water, or by being made to impinge upon a tray containing water. Air may be warmed by means of ventilating fire-places or stoves, or by coils of hot-water tubes. If warmed, there is advantage in introducing fresh air at or near the floor level; but if cold, it is necessary to avoid draughts which might impinge upon any person in the room, and therefore the air is delivered at a higher level and with an upward direction.

Outlets should be as near the chimney as possible; the air in that part is the warmest, as well as the most

impure, so that the worst air is removed with the maximum velocity.

Any barometric pressure P may be regarded as produced by the weight of a column of air *of uniform density* and of height H. "Montgolfier's Rule" affirms that air under pressure will rush into a vacuum with a velocity equal to that acquired by a body falling from the corresponding height H, which velocity may be determined by the formula $V^2 = 2gH$, g being the acceleration due to gravity (32·18 feet per second), and V the velocity required. Thus under standard conditions of barometer and thermometer H is about 5 miles, or 26,400 feet, so that $V^2 = 2 \times 32{\cdot}18 \times 26{,}400$, and V = about 1,300 feet per second.

If, however, the air under pressure P passes not into a vacuum but into a space containing air under a low pressure p, the formula requires modification, the velocity being dependent upon the difference between P and p. It becomes necessary to calculate the height h of a uniform column of air (of the same standard of density as was adopted in determining H), which would give the pressure p.

The formula then becomes $V^2 = 2g\ (H\text{-}h)$, and in this form it is applicable to problems of ventilation.

For example, it may be required to determine the theoretical velocity of updraught in a vertical* flue x feet long, leading from a room containing air at a temperature $t°$ into the open air of temperature T°. An inlet for cold air is presupposed. The column of heated air in the flue may be regarded as opposed to (and overcome by) a similar column of cold air outside, and the (unequal) weights of these two columns correspond to P and p. The barometric pressure at the level of the top of the flue may be neglected, since it affects both columns alike. Then taking the density of the outside

* The *vertical* height only must be taken, even if the course of the flue is oblique or bent.

air as the standard, the height x may be put for H in the formula, and it only remains to determine h, the height of the heated column when reduced to the same standard density. Air expands with heat to the extent of ·002 of its volume for each degree Fahr.,* and hence 1 volume at T° becomes at $t°$ $1 + \cdot002(t\text{-T})$, so that the column of hot air of height x at $t°$ corresponds to a height $\frac{x}{1 + \cdot002\ (t - \mathrm{T})}$ at the standard temperature T. This, then, is the value of h, and

$$\mathrm{V}^2 = 2g\left(x - \frac{x}{1 + \cdot002\ (t - \mathrm{T})}\right).$$

Since $\sqrt{2g}$ is 8·02, or approximately 8·0, the formula may conveniently be written

$$\mathrm{V} = 8\sqrt{x - \frac{x}{1 + \cdot002\ (t - \mathrm{T})}}.$$

If, as an example, the external and internal temperatures are respectively 40° F. and 60° F., and the height of the flue 20 feet,

$$\mathrm{V} = 8\sqrt{20 - \frac{20}{1 + \cdot002\ (60 - 40)}},$$

and hence the theoretical velocity of the draught in the flue is rather more than 7·1 feet per second.

The linear velocity multiplied by the sectional area of the flue will give the number of cubic feet discharged per second.

The theoretical velocity is subject to correction for friction, which varies directly as the length of the tube L and the square of the velocity, and inversely as the diameter D, that is as $\frac{\mathrm{V}^2\mathrm{L}}{\mathrm{D}}$. In practice an allowance of $\frac{1}{4}$, or even $\frac{1}{2}$, has to be made for friction,

* Strictly speaking, this is accurate only when T = 32° F., but the error is immaterial for the present purpose.

which is also increased by angles in the course of the flue.

The following formula by De Chaumont is convenient for ascertaining the relation between the size of the opening and the hourly delivery of air :—

$$D = 200 \times \Phi \times \sqrt{\cdot 002 \times x \times (t - T)},$$

where D = delivery of air, in cubic feet per hour,
Φ = the sectional area of the tube, or of the inlet or outlet, in square inches,
x = height of heated column of air, in feet,
t and T = the internal and external temperatures respectively.

Thus, if the heated column be 20 feet in height, the internal and external temperatures 60° F. and 40° F., and the required delivery 6,000 feet per hour, the formula will give the sectional area necessary :—

$$6000 = 200\ \phi\ \sqrt{\cdot 002 \times 20 \times (60 - 40)},$$
$$\phi = 33 \cdot 56 \text{ square inches.}$$

The linear velocity with which air passes through an opening may also be determined experimentally by an *anemometer*, which should be placed, not at the centre, but about $\frac{2}{5}$ of the diameter from the side of the opening, so as to obtain the mean velocity. Very delicate instruments are now made, consisting of four light metal vanes mounted obliquely upon a common axis, the revolutions of which are indicated automatically upon dials. The registering apparatus can be thrown in or out of gear by a spring catch, while the vanes are revolving, so that the time can be determined accurately. The linear movement observed during one minute, or less, is readily converted into velocity per hour or second, and this, multiplied by the sectional area of the opening, gives the cubic discharge.

Artificial ventilation involves either propulsion or extraction of air, the establishment of a *plenum*

or *vacuum* in the room to be ventilated. Fresh air may be driven into a room or building by revolving fans or other motors; vitiated air may be extracted by means of fans, steam jets, or a heated outlet shaft. The fans used for the purpose have vanes set obliquely upon a rapidly revolving axis, and work in a closed box or tube so as to propel a constant current of air of any required volume and velocity, somewhat after the manner of an Archimedean screw. Steam allowed to escape in a powerful jet into a flue is capable of carrying with it 200 times its own volume of air. Gas may, by means of extraction shafts, be made to carry off a thousand times its own volume of air.

Heat is by far the most generally employed motive power. Ordinary fire-places, chimneys, and ventilating gas-lights act in this way. Special extraction shafts, with gas jets or furnaces at the bottom, are common. Mines are ventilated by means of a furnace at the foot of the upcast shaft, air being drawn down another shaft and made to traverse the whole of the workings on its way to the upcast. A similar plan is adopted in steamers, the upcast being a space around the funnel and boilers, a contrivance which has been applied also to house chimneys by confining the smoke, etc., to an iron tube passing up in the centre of the chimney shaft. Extraction is, upon the whole, the more convenient and satisfactory method, but is attended with some disadvantage from the difficulty of controlling the sources from which the supplies of fresh air are drawn, since it rushes in through all available openings. Provision may, however, be made at suitable points for admission of pure air, which may be warmed, cooled, moistened, washed, or screened, as it enters. When propulsion is adopted, the air is taken from one source only, and, being more under control, is more readily subjected to such heating or other treatment as may be needed.

The advantages of artificial ventilation are its constancy under all conditions and the facilities which it affords for regulating the source of fresh air, the volume delivered and the preparatory treatment as to temperature, moisture, and purification. Natural ventilation is, of course, less costly, but is inconveniently subject to atmospheric conditions, and is inadequate as regards theatres, schools, and other crowded buildings. Carnelley, Haldane, and Anderson have proved this experimentally.

A comparison was made between the results of natural and artificial ventilation of schools. The following averages, based in every case upon many observations (18 to 39), are conclusive evidence of the superiority of mechanical ventilation.

	Natural Ventilation.	Mechanical Ventilation.
Per cent. of windows open .	22	3
Cubic feet of air space, per head	168	164
Temperature (Fahrenheit) .	55·6°	62°
Carbonic acid (per 1,000 vols.). . . .	1·86	1·23
Organic matter (vols. of oxygen required per million vols. of air) . .	16·2	10·1
Microbes (per litre) . .	152	16 6

The difference is still more striking if only the excess over the impurities present in outside air is taken into consideration. It was found that mechanical ventilation kept the composition of the air fairly constant in all parts of the room, while natural ventilation often allowed of local stagnation.

In an ordinary room the chimney is the most important outlet when a fire is burning, air passing up with an average velocity of 4 or 5 feet per second.

In the absence of a fire the chimney still acts in some degree as an upcast, and ought on no account to be closed, unless a downward current establishes itself temporarily, and causes annoyance by its sooty smell.

Warming is closely connected with ventilation. The principal methods in use may be classed as open fires, closed fires and stoves, hot air, pipes containing hot water or steam.

Ordinary **open fires** are extravagant in regard to fuel, and it is estimated that only about one-eighth part of the potential heat is utilised in warming the room, the rest being lost in unconsumed smoke and cinder, and in the hot gases passing up the chimney. The heating effect is very unequal in different parts of the room, being chiefly confined to the vicinity of the grate, and cold currents pass along the floor. They are, however, most effective ventilators, and present a more cheerful appearance than stoves or hot pipes.

The principal practical points in regard to the construction of open fire grates are well summarised by Teale as follows :—(1) use as much firebrick and as little iron as possible ; (2) the back and sides should be made of firebrick ; (3) the back of the fire-place should lean over the fire ; the "throat" of the chimney should be contracted ; (4) the bottom of the fire should be deep from before back ; (5) the slits in the bottom grating should be narrow ; (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 last recommendation embodies an important improvement, the effect of which is to exclude cold air almost completely from the bottom of the fire, so that the fuel as it sinks is entirely burnt up, leaving only a fine ash, which drops into the space beneath. Another means of preventing waste of fuel is to make the bottom of the grate of solid fire-clay, as

in the various "slow combustion" grates; the same principle may be applied to ordinary grates by laying an iron plate upon the bars at the bottom of the grate.

Coke is the residue, consisting almost entirely of carbon and mineral matters (ash), left in the retorts when all the combustible gases have been driven off by heat in the process of gas-making. It is smokeless and less costly than coal, but it is difficult to light, and makes a dull fire. The prevention of smoke, and the complete utilisation of the gases and other products obtainable from coal by distillation, are important public advantages.

Gas-fires have much of the bright and attractive appearance of open fires. The gas is mingled with a considerable volume of air before ignition, as in a Bunsen burner, and the intensely hot but non-luminous flame impinges upon filaments or bars of asbestos or iron, which become red or white-hot, giving out both light and heat. Simpler forms are also made with ordinary luminous burners, the light and heat from which are thrown forward by metal reflectors; oil-stoves are made on the same principle. Sometimes the gas-fire consists of a number of small round blocks of asbestos, rendered incandescent by the flame from a series of Bunsen's burners beneath. In any case a chimney or flue to carry off the fumes is essential. A gas-fire burns from ten to twenty, or more, cubic feet per hour. It is economical and cleanly in use, creates no smoke, and can be lighted, extinguished, or regulated, in a moment. Ventilating gas-stoves are made, but the ordinary gas-fire, unless it be composed of incandescent fragments of asbestos in an open grate, is less effectual than an open fire in promoting ventilation. If the flue is too small, as is very often the case, the air becomes dry and oppressive, and there is risk of carbonic oxide escaping.

Stoves are commonly made of cast iron, the smoke and products of combustion being conducted by an iron flue to the chimney, or to the outside air. The fire may be more or less open, or hidden from sight, but in any case the waste of heat is less than in ordinary fire-places, the sides of the stove and also the flue contributing to the heating power. As a means of extraction of vitiated air a stove is inferior to the ordinary open fire, although there is no difficulty in utilising the hot flue for the purpose of producing an up-current in a chimney. Many forms of ventilating stoves are in use, fresh air being brought in through special pipes, which in their course are exposed to the heat of the stove; in the "Calorigen" a coil of the fresh air inlet pipe is placed inside the stove. Stoves make the air hot and dry, an objection which may be met by placing vessels of water upon them. A more serious difficulty is a burnt smell which is apt to result from their use, and the danger of ill effects among the occupants of the room from the presence of carbonic oxide in the air. The source of the carbonic oxide is a matter of some doubt. It has been attributed to oxidation of the organic matter in the air by contact with the heated iron, this being also assigned as the cause of the burnt smell. Oxidation of the carbon in the cast iron is another suggested explanation, and it has been found experimentally that red-hot cast iron is pervious to carbonic oxide, and even reduces carbonic acid to carbonic oxide, so that the gas found in the room may originate in the fire itself. Wrought iron offers far greater resistance. The joints, both of the stove and the flue, should be made strong and air-tight, and in order to minimise the risk of giving off carbonic oxide, it is desirable to line the stove with fire-clay, to coat it with silicate, or to use earthenware or wrought iron in place of cast iron.

Hot air is advocated by some authorities as the best mode of warming houses, as well as public buildings. This may be done upon the large scale by warming the fresh air in the basement, and conveying it thence to all parts of the house along the passages or by special channels. The same end is attained in some degree by placing a stove or fire-place in the hall. Warm air may be supplied to single rooms by the ventilating grates or stoves already referred to, or by allowing the fresh air to enter through a coil of hot pipes. The air should be moistened, and, if need be, purified by filtration or washing. Warming can also be effected by means of **hot water or steam** circulating in a system of closed pipes. The pipes may be carried round one or more sides of a room, near the floor, either open or concealed behind a skirting-board. Several turns or coils may be used at points where more heating power is required, and it is advisable to warm the fresh-air inlets by the same means.

Hot water is usually employed for heating purposes at a temperature below 212° Fahr. The circulation is dependent upon the water being hotter, and therefore lighter, in the tube through which it leaves the boiler than in that which brings it back. Hence the boiler is placed at the lowest point, and the centrifugal and centripetal pipes are respectively connected with the top and bottom of the boiler, so as to obtain the greatest possible vertical height of hot and cold columns respectively. A feeding cistern, and vents for the escape of air and steam, are provided at the highest points. About twelve feet of four-inch iron pipe are allowed for every thousand cubic feet of air-space to be warmed. The system should be so planned with valves and connecting pipes as to allow of "short-circuiting," so that the heat may be turned on or cut off from any part at will.

Hot water may also be used under pressure at temperatures considerably exceeding 212° Fahr., on Perkins' system. Strong half-inch iron pipes are used, and instead of a boiler part of the pipe is carried through the fire. Steam may be used at high or low pressure in like manner.

There is a material difference in the result of these various methods of heating, apart from their relation to ventilation. Hot air warms a room by convection only, ordinary open fires or gas-fires almost entirely by radiation; stoves and hot pipes act in both ways, but chiefly by convection. In the one case (radiation) the air remains comparatively cool, if the ventilation is efficient; in the other (convection) the air is hot, and therefore dry, and requires moisture. As will be explained in the next chapter, the "dryness" of air is merely a relative term; for example, the amount of moisture required at 52° is twice as great as at 32° F. (page 45).

CHAPTER II.

METEOROLOGY.

THE principal climatic phenomena requiring systematic record are: (1) Temperature of the air; (2) Pressure of the air; (3) Movement of the air; (4) Amount or degree of moisture in the air; (5) Presence and amount of ozone in the air; (6) Rainfall; (7) Sunshine; (8) Presence or absence of cloud, mist, fog, thunderstorms.

Temperature varies constantly, so that the reading at any one time has only a limited significance, and maximum and minimum registering thermometers are required. The *maximum thermometer* has a mercurial column, a detached portion of which serves as an index, being either permanently separated from the rest by a minute bubble of air (Phillips), or else detached afresh each time by means of a constriction near the bulb (Negretti), which allows the expanding mercury to pass, but renders the cohesion of the metal insufficient to draw it back upon cooling. The thermometer is kept horizontal, and the index is shaken back after each reading, ready for a new observation.

The *minimum thermometer* (Rutherford's) contains coloured alcohol. The index is a little metal rod included in the column, and is drawn back by capillary attraction as the column contracts, but allows the alcohol to flow past it when expanding. To set the instrument, it is only necessary to partially invert it, and let the index fall to the top of the spirit column. It is then replaced in the horizontal position.

If the instruments are read once daily, say at 9.0 a.m., they will indicate respectively the highest and lowest temperatures attained during the previous 24 hours, irrespective of the time of their occurrence.

Two sets of instruments are required, one for "shade" temperatures, *i.e.* the temperature of the air itself, the other for "radiation" temperatures with free exposure to the sun. The former are placed in a louvred wooden box, four feet above the ground. The "sun maximum" thermometer also is placed four feet above the ground; it has a blackened bulb, which is enclosed in a second glass bulb exhausted of air. The corresponding minimum instrument is supported upon a little wooden tripod, close to the ground.

Thus are obtained for each day—shade maximum, shade minimum, sun maximum, grass minimum; and from these the daily, weekly, monthly, or yearly ranges, both in shade and with free radiation.

The mean temperature of the day is calculated in several ways:—

(*a*) By taking the mean of the maximum and minimum recorded temperatures. This is correct only in winter; at midsummer it is often more than 2° too high.

(*b*) By taking the mean of two readings at twelve-hour intervals: *e.g.* 9.0 a.m. and 9.0 p.m.

(*c*) By taking a single reading at 9.0 p.m.

(*d*) By taking hourly readings, or a continuous record, by means of photography. The mean of these is the true mean temperature of the day.

The weekly, monthly, and annual means are the averages of the daily means.

Periodic conditions.—Taking the average of a number of years, the daily minimum occurs at about 4.0 a.m., the maximum at 2.0 p.m.; the annual extremes are in July and January respectively.

Non-periodic conditions.—Proximity to the sea lessens the range of temperature and moderates its extremes, water having (as compared with land) a high capacity for heat, but being slow to radiate or absorb it. Elevation lowers the temperature, by facilitating

radiation. The influence of latitude, of winds and ocean currents, and of aspect and exposure, is obvious. Some soils are hot—dry sands and hard rocks, for example,—while moist clayey soils are cold. A surface covered with vegetation radiates much more rapidly than bare earth ; at night a grass field is colder than a road.

The radiation thermometers are affected principally by the degree of sunshine and the humidity of the atmosphere.

The duration and intensity of **sunshine** are recorded by Campbell's or Jordan's apparatus. The former consists essentially of a glass sphere, which acts as a lens, and brings the rays to a focus at successive points upon a curved sheet of paper placed at the right distance. A burnt track is thus described for such time as bright sunshine continues. Jordan's sunshine recorder is a small flat circular box. The sunshine is admitted through a slit, and impinges upon sensitised paper, leaving a varying photographic record of its duration and intensity. In either apparatus the papers must be renewed daily, and in the latter the sensitised paper must be "fixed" by immersing it in water.

The humidity of the atmosphere is a question involving rather complex considerations. Water evaporates into dry air, as into a vacuum, but the volume of the resulting moist air is greater than that of the original dry air. For example, a cubic foot of dry air at 60° Fahr. weighs 536·3 grains, and is capable of taking up 5·77 grains of water ; the product, however, is not 1 cubic foot of moist air, weighing 542·1 grains, but 1·0176 cubic foot, and a cubic foot of the same moist air would weigh only 532·7 grains. At 32° Fahr. a cubic foot of dry air can take up only 2·13 grains of water ; at 80° Fahr. it can take up 10·98 grains. The proportion of moisture in air, therefore, varies greatly at different

temperatures, even if the air is always saturated. As a rule, the water present is only about 70 or 75 per cent. of the amount required for saturation, but if the air is cooled, the same quantity of aqueous vapour may suffice to saturate it; and if the cooling is carried further some of the water will be precipitated as mist or dew. It will be understood, therefore, that, however dry the air may be, it always contains a certain proportion of water, and if cooled to a certain temperature will be "saturated" by that moisture; this temperature is called the *dew-point*. "Super-saturated" air deposits its moisture only upon solid surfaces. No "mist" is formed in air, however much it may be cooled below its dew-point, if it contains no suspended particles.

Humidity is measured by **hygrometers** of various kinds.

Daniell's, now rarely used, consists of two dependent glass bulbs, connected by a tube bent twice at right angles. One bulb is of black glass, and contains a thermometer, the stem of which is visible in the tube above; the other bulb is covered with linen. Both bulbs contain ether. A little ether is dropped on the linen coating, and by its evaporation lowers the temperature of that bulb, so that ether distils over from the blackened bulb. This causes the temperature of the latter to fall; as soon as it sinks to the dew-point the black surface is dulled by deposit of atmospheric vapour, and this temperature is instantly read off by means of the contained thermometer.

Regnault's is somewhat similar, but the black bulb is replaced by a more sensitive bright silver cup, and the distillation is brought about more conveniently and rapidly by means of an aspirator.

Dines's consists of a plate of black glass, covering a small chamber containing the bulb of a thermometer. Cold water is passed through this chamber until the

dew-point is reached and the glass becomes dull; the current is then stopped, the temperature gradually rises, and the thermometer is read at the moment when the cloud disappears.

Saussure's, which has the advantage of giving the relative humidity directly, consists of a human hair, fixed at one end and stretched by a light weight attached to the other. It passes round a movable axis which carries a finger pointing to a graduated arc. The hair, which must be uninjured and free from oil, elongates with moisture and contracts as it becomes dry; and in so doing rotates the axis and the indicator. The instrument has to be graduated empirically by exposing it first to perfectly dry air, and then to air saturated with moisture, and making the respective positions of the index the 0 and 100 points upon the graduated scale.

The *Wet and dry bulb* hygrometer is usually employed. Two ordinary thermometers are fixed side by side, one of them having its bulb covered with muslin, kept wet with distilled water; a tail of the muslin dips into a vessel of water so as to make good the loss by evaporation. If the air is saturated with moisture, no evaporation takes place, and the two thermometers give the same reading. If it is not saturated, evaporation occurs and lowers the temperature of the wet bulb.

From the wet and dry bulb readings the *dew-point* can be calculated, and from the dew-point the weight of water present in the air. The dew-point is determined by calculation,* or, more conveniently,

* By the use of Apjohn's Formula, $f'' = f' - \frac{t - t'}{87}$, where t and t' are the dry and wet bulb readings respectively, f' the elastic tension of vapour corresponding to t' (as ascertained from a table of tensions), and f'' the tension of vapour at the dew-point. Having thus found the value of f'', the temperature corresponding to it in a table of tensions is the dew-point.

by reference to Glaisher's Tables,* in which the results are given for all ordinary values of both readings. The dew-point being known, it remains only to find the **relative humidity** of the air, which is always expressed as the percentage of total saturation. For this purpose reference is made once more to hygrometric tables, giving the weight of a cubic foot of vapour at each temperature; and the relative humidity =

$$\frac{\text{weight of cubic foot of vapour at the dew-point}}{\text{weight of cubic foot of vapour at dry-bulb temperature}} \times 100,$$

since the numerator is the weight actually present, and the denominator the weight which is required for complete saturation.

In practice none of these calculations are necessary, since Glaisher's Tables give the relative humidity corresponding to all ordinary readings of the wet and dry bulb thermometers. This is by far the most important hygrometric datum, the absolute weight or tension of vapour present, and even the dew-point, being of minor interest. The relative humidity is an inverse measure of the drying effect of air. The capacity for taking up moisture increases with the temperature, but far more rapidly, so that the mere difference between the dew-point and the air temperature is no criterion of the humidity.

Indeed, it may almost be said that, comparing temperatures which increase in arithmetic progression, the capacity of dry air for moisture at those temperatures increases in geometric progression. Taking 0·0° F. as a starting-point, the capacity for moisture (in other words, the weight of a cubic foot of aqueous vapour) doubles with successive increments

* Based upon the "Greenwich Factors," or "Glaisher's Factors," a different factor being employed for each temperature. If D is the factor corresponding to the dry bulb temperature, the dew-point is $t - D\,(t - t')$.

of temperature, not departing greatly from an arithmetic series.

Temperature (Fahrenheit).	Weight of a cubic foot of vapour.
0°	0·55 grains
16°	1·09 ,,
33°	2·21 ,,
52°	4·39 ,,
73°	8·82 ,,
96°	17·68 ,,

At 40° F. a cubic foot of vapour weighs 2·9 grains, at 50° 4·1, at 60° 5·8, at 70° 8·0, at 80° 11·0, at 90° 14·9, and at 100° 19·8.

Humidity has an important bearing upon radiation, and thus upon climate. Aqueous vapour intercepts some of the sun's luminous rays, and very greatly impedes the radiation of non-luminous rays from the surface of the earth into space. Hence the difference between the sun-maximum and grass-minimum temperatures is chiefly dependent upon the humidity. The intensity of radiation at high altitudes is largely due to the absence of aqueous vapour. In Arctic expeditions the intensity of the unimpeded solar radiation has been sufficient to boil the pitch in the seams of ships which were surrounded by ice.

Atmospheric pressure is measured by mercurial, glycerine, or aneroid barometers.

Mercurial barometers consist essentially of a glass tube some 36 inches long filled with mercury, and then inverted over a mercurial trough. The tube being vertical, the mercury sinks until the column is of just sufficient height to balance the atmospheric pressure acting upon the free surface of the mercury in the trough. The vertical distance between the two mercurial surfaces exactly measures the pressure of the atmosphere in terms of mercury. The level of the top of the column is read off against a fixed scale,

but as the level of the mercury in the cistern also changes slightly with every change of pressure, it is necessary to take this into account.

In Fortin's barometer the cistern has a leather bottom, which can be raised or lowered by means of a fine screw, until the surface just touches a fixed ivory point. After this adjustment of the cistern to a constant standard level, the upper level is read upon a scale marked upon the brass casing of the tube.

In the Kew barometer the necessity for the adjustment is obviated by graduating the scale in nominal inches, which are shorter than true inches, and exactly correspond to the displacement caused by a change of pressure to the extent of one inch of mercury. A single reading therefore gives the true vertical height of the column.

In the siphon barometer the cistern is dispensed with, and the tube is of U shape, one arm being short and open at the end. Both levels are read upon a scale. The movement in either arm is little more than half that occurring in a cistern barometer.*

Greater accuracy in the reading is obtained by the use of the "vernier," a small movable scale which slides upon the principal scale (Fig. 2). The vernier is so graduated that 25 of its divisions correspond to 24 of those upon the other scale, and each division is therefore only $\frac{24}{25}$ of the length of the standard divisions. The divisions marked upon a barometer being $\frac{1}{20}$ inch, the vernier will show differences of $\frac{1}{25}$ of $\frac{1}{20}$, *i.e.* ·002, or $\frac{1}{500}$ inch. When a reading is to be taken, the lowest mark on the vernier is accurately adjusted against the top of the mercurial column. If this level

* The ordinary wheel-barometer is a siphon barometer, the movements being transmitted by a string from a float upon the mercury in the open tube to an axis which carries a long finger like that of a clock.

exactly corresponds with one of the divisions of the principal scale, the vernier correction is not needed; its lowest mark will coincide with the mark on the scale. If, however, the level of the mercury does not exactly coincide with a scale division, the vernier helps us to measure accurately the fractional excess over the next division below. For this purpose we must follow the vernier scale upwards until we come to a mark upon it which does correspond to one on the fixed scale; calling this the xth mark, the correct reading is $\cdot002 \times x$ inch above the scale mark next below the mercury level. For example, the mercury stands above 29·85, but below 29·90, as read on the fixed scale, and upon inspection it is found that the sixth vernier division corresponds with a division of the fixed scale. This shows that the fractional excess above 29·85 is $6 \times \cdot002$, or ·012 inch, and the true reading is therefore 29·862 inches. Had the 20th division of the vernier been the one which coincided with a fixed scale mark, the fraction would have a greater value, $20 \times \cdot002 = \cdot04$ inch, and the barometric reading would be 29·89 inches. A little consideration will make it clear that as compared to scale divisions we lose ·002 inch for every vernier division as we follow the marks upwards, until we have exactly lost all the fractional excess over the 29·85 mark; and then the marks on the two scales must correspond.

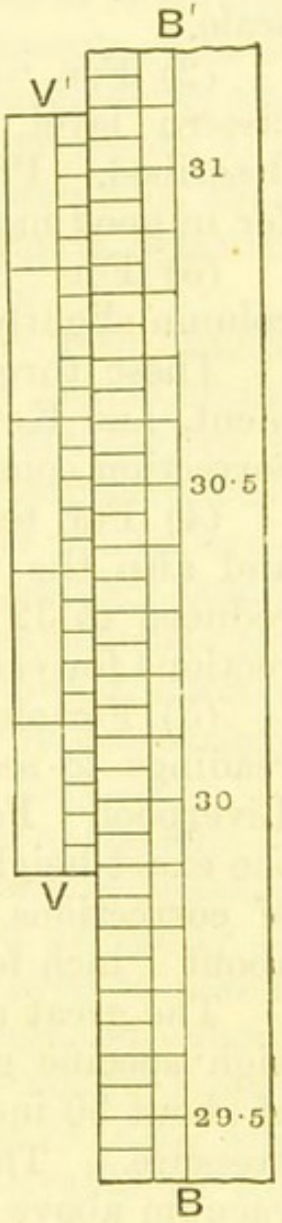

Fig. 2.—Barometer Scale and Vernier, showing a reading of $29{\cdot}85 + 18 \times {\cdot}002 = 29{\cdot}886$ inches.

The reading having been accurately taken with the aid of the vernier, it remains to apply certain corrections :—

(1) For "index error"—*i.e.* inaccuracies in the scale.

(2) For "capacity"—*i.e.* for the change in the cistern level, unless this is allowed for as already described. Practically, this correction is never called for in good modern barometers.

(3) For "capillarity," which tends to depress the column slightly.

These three corrections are special to each instrument, and Kew certificates give for each half inch a correction comprising them all.

(4) For temperature, which affects the mercury, and also the brass or other scale. All readings are reduced to 32° Fahr. by means of a table giving corrections for each temperature.

(5) For elevation. It is customary to reduce all readings to sea-level—*i.e.* the mean half-tide level at Liverpool. For this purpose it is necessary to know the exact height of the station, and to refer to a table of corrections. Roughly speaking, the correction is about 1 inch for every 1,000 feet.

The great advantage of mercury is, of course, its high specific gravity, 13·5, owing to which a column of about 30 inches in height balances the atmospheric pressure. The vapour-tension in the Torricellian vacuum above the mercurial column is trifling. The density of mercury renders the range of movement under varying atmospheric pressures small, and other liquids have been employed in order to secure greater sensitiveness of indication. Jordan's *glycerine barometer* is the most important of these; glycerine has a specific gravity of 1·26, and a column of 27 feet would about balance a mercurial column of 30 inches. A fall of 1 inch in a mercurial barometer is represented

by a fall of 10·7 inches in a glycerine instrument, and the latter is therefore far more sensitive to variations of pressure. *Water barometers* have also been constructed, and a column of 34 feet is required to balance 30 inches of mercury. These instruments are, of course, more sensitive than glycerine barometers, and magnify the range of a mercurial barometer 13·5 times; but in addition to the disadvantage of their height, the vapour tension in the vacuum is a source of error that varies with the temperature.

Aneroid barometers dispense entirely with liquids, and measure the barometric pressure by means of the elasticity of metal. A small air-tight metallic box is (nearly) exhausted of air, and is so constructed that the top is slightly forced in when the atmospheric pressure rises, and (aided by a strong spring) comes out when the pressure falls. These movements are conveyed by levers, etc., to a finger moving upon a dial; the dial is graduated empirically by comparison with a standard mercurial barometer.

There are periodic and non-periodic variations of pressure, but the former are so completely masked by the latter in the latitude of England as rarely to be perceptible except in averages. There is a tendency to a daily curve, with a range of about 0·02 inch. There are two maxima, about 9 a.m. and 9 p.m.; and two minima, about 3 a.m. and 3 p.m. This slight curve is only noticeable in the rare absence of non-periodic changes; but in the Tropics the daily range exceeds 0·11 inch, while in the Arctic regions it vanishes. The annual curve in England is somewhat irregular, but has a maximum at the end of May, and a minimum at the end of October. It is very different in other countries.

Rainfall is measured by a *rain-gauge*, consisting of a copper funnel leading to a bottle or other receiver. The funnel has a sharp, circular rim, usually 5 inches

or 8 inches in diameter, and its area in square inches is accurately known. The water collected in the receiver is measured in a graduated glass vessel, the divisions of which correspond to the fractions of an inch of rainfall. It is found that the amount collected is greatest at the ground level. Care must be taken to select an open site, and to place the rim perfectly level. "No object ought to subtend a greater angle with the horizon than 20° in any direction from the gauge" (*Scott*). Snow and hail may be melted for measurement by adding a known volume of warm water, which must be deducted from the total.

The daily curve of average rainfall has not been fully worked out. There are indications of three maxima, the principal of which occurs about 2 or 3 p.m. The annual curve varies with locality. In London and on the east coast of England the principal maximum is in October, and the minimum in February or March; but on the west coast January is the wettest month.

The average annual rainfall varies from about 20 inches on the east coast of England to 60 or 80 inches on the west coast of Ireland and Scotland; and at one point in Cumberland (Seathwaite) it averaged 154 inches during six years. The average for England may be taken to be about 25 inches.

The rainfall does not often exceed an inch in one day in Great Britain, but enormous quantities are recorded occasionally. At Camberwell, in 1846, 3 inches fell in $2\frac{1}{4}$ hours, and in Monmouthshire, in 1875, 5·36 inches fell in one day.

It is greatest on the westward (*i.e.* seaward) slope of English mountains, owing to the humid westerly winds depositing moisture as soon as they are forced to ascend into colder strata. Haughton calculates that one gallon of rainfall, by its condensation from vapour into the liquid form, gives out latent heat

sufficient to melt 75 lbs. of ice, or 45 lbs. of cast iron; and that on the west coast of Ireland the heat derived from the rainfall is equivalent to half that derived from the sun.

Evaporation from moist surfaces is regulated by the temperature of the water, the temperature of the air, the humidity of the air, and the wind. It is more rapid from moist soil than from water; and deep rooted crops, such as wheat, dry the soil to a greater depth than grass. No satisfactory instrument (*atmometer*) has been devised for measuring evaporation owing to the difficulty of excluding rainfall while allowing free exposure. A rough estimate may be obtained by exposing a measured volume of water in an open dish of known area, and deducting from the final measurement the ascertained rainfall. Another plan is to shelter the atmometer from rain by a cover, but this necessarily lessens the evaporation. Symons found that at Lea Bridge the mean annual evaporation per square inch of water-surface was 21 inches, the rainfall being 25 inches. In exceptionally dry years it exceeds the rainfall.

Wind may be measured, by *anemometers*, as regards either its pressure or its velocity.

Hooke's anemometer is a thin rectangular plate of iron, suspended from its upper edge, and set at right angles to the wind. The force of the wind is measured by the angular displacement of the plate. In Cator's anemometer the wind forces back a plate, the move ment of which is resisted by graduated weights. A pencil connected with the plate records upon a chart moved by clockwork the displacement. In Osler's anemometer the principle is the same, but the weights are replaced by a spring.

Robinson's anemometer is the only one in common use. It consists of four light arms rotating in a horizontal plane around an axis, through which their

movements are transmitted to a series of recording dials. Each arm has at its extremity a hemispherical cup, facing horizontally at right angles to the arm. In whatever direction the wind blows, the vanes revolve, the resultant pressure upon the concave surfaces being greater than that upon the convex. It was formerly believed that the cups moved with one-third the velocity of the wind, and the index-dials were graduated accordingly. It appears, however, that the proportion is greater than one-third, and has a direct relation to the size of the cups and the velocity of the wind.

Apart from the uncertainty as to the true value of the readings of each instrument, the records of different stations are not strictly comparable, since inequalities in elevation and in shelter from the wind are inevitable, and must materially affect the results. The position of the anemometer should be such as to secure the fullest possible exposure to wind from all quarters.

Pressure-anemometers have a great advantage in recording gusts and sudden changes in wind-pressure. So far as velocity and pressure are comparable, it may be said that the pressure varies as the square of the velocity. If v = the velocity in miles per hour, and p = the pressure in pounds per square foot, then, according to James,

$$V^2 = 200\ P.$$

The average velocity of wind in Great Britain shows a daily maximum and minimum closely corresponding to those of temperature, about 2 p.m. and 4 a.m. The annual curve of average wind-velocity has a maximum in July and a minimum in December or January.

In *Beaufort's scale* the force of the wind is stated by arbitrary numbers, ranging from 0 (calm) to 12 (hurricane).

Force.	Beaufort Scale.	Miles per hour.
0	Calm	Up to 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

In England the velocity is, upon an average, about 8 miles per hour, and rarely exceeds 40. Local winds may be caused by geographical configuration—*e.g.* upon coasts and mountains. A wind blows at noon from sea to land, from plains to hills, but at sunset the directions are reversed. Winds increase in force with elevation.

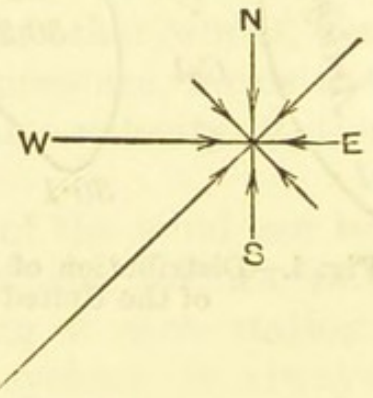

Fig. 3.—Wind-rose.

A "wind-rose" (Fig. 3) is a table or diagram showing the relative proportions of wind-observations from each point of the compass. The Greenwich wind-rose for 1861-70 was

N	NE	E	SE	S	SW	W	NW
10	12	7	7	8	33	15	7

If the readings of the barometer at any given moment at several stations dotted over a wide area, such as Europe, are recorded upon a map, and lines are drawn connecting together all the points where

the same pressure prevails, we obtain a "synoptic chart," and these lines, or **isobars**, are found to assume very commonly certain typical forms (Fig. 4).

1. *Cyclones*, formed by concentric isobars, the lowest pressure being at the centre.

2. *Anticyclones*, the isobars being roughly concentric, with the highest pressure at the centre.

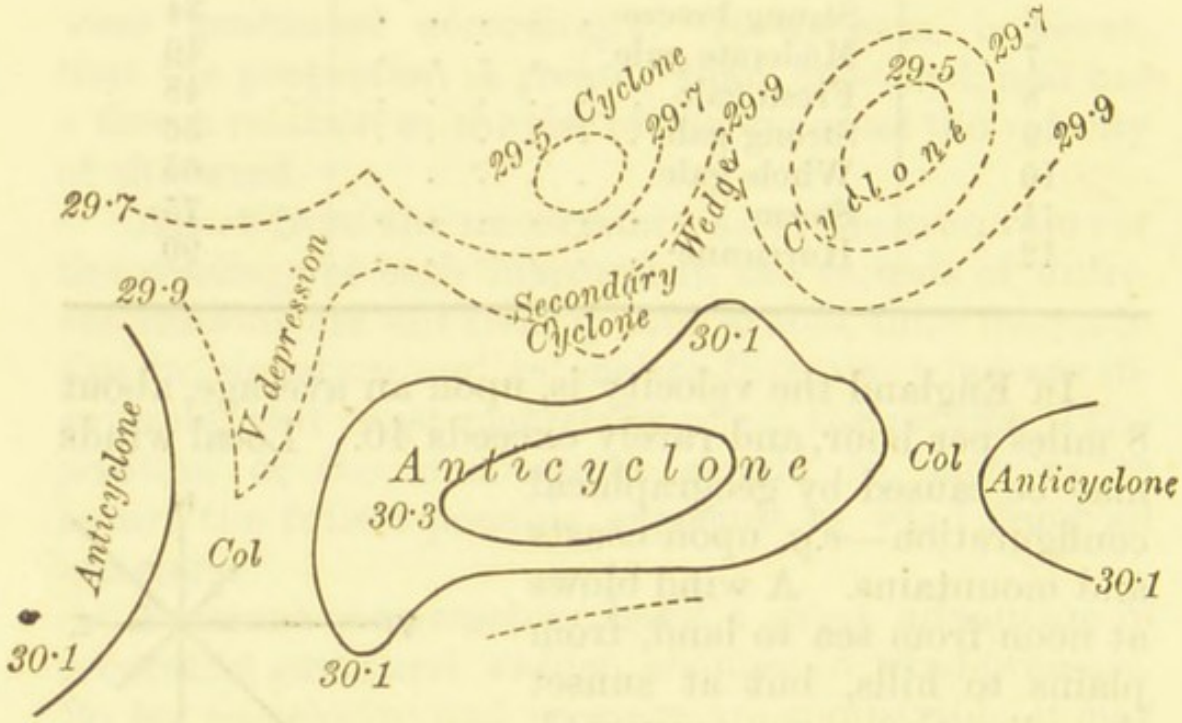

Fig. 4.—Distribution of Pressure over the North Atlantic, and Parts of the United States and Europe, Feb. 27th, 1865.
(*After Abercrombie.*)

3. *Secondary cyclones*, formed by looped concentric isobars (the circle being incomplete, and thus failing to form a true cyclone) with lowest pressure in the centre.

4. **V**-*shaped depressions*, with lowest pressure in the interior, forming, for example, the angular intervals between adjoining anticyclones.

5. *Wedges* of high pressure—highest in the interior—inserted between two adjacent cyclones, and usually pointing to the north.

6. *Cols* or necks of comparatively low pressure

between two adjacent anticyclones, like the pass or "col" between two Alpine peaks.

7. *Straight isobars.*

Cyclones, secondary cyclones, V-depressions, and wedges, usually travel eastward at the rate of about twenty miles per hour, but anticyclones often remain stationary for days, weeks, or even months.

If the direction of the wind at each station is marked upon the synoptic chart, it will invariably be found that its direction is roughly parallel to the isobars, and that in anticyclonic areas (in the northern hemisphere) it describes a circle in the same way as the hand of a watch, while in cyclonic areas this course is reversed.* The direction of the wind in these and in all other arrangements of isobars conforms to *Buys Ballot's law*—that an observer standing with his back to the wind always has lower pressure to his left, and higher pressure to his right.

The closeness of the isobars, or in other words, the rapidity of change of atmospheric pressure, forms the "barometric gradient," to which the velocity of the wind is directly proportionate.

Not only the force and velocity of the wind can be inferred from the arrangement of the isobars, but also the kind of weather prevailing at each station. The front part of an advancing cyclone is always associated with rain, stratiform clouds, and moist heavy atmosphere, while in its rear the opposite conditions prevail, namely, sunshine, clear "fresh" air, and cumulus clouds. Anticyclones are less intense, more stationary, and cover a wider area than cyclones. In front of them and at the centre are found sunshine, blue sky, haze, little wind, keen dry air, and

* The course of the wind is not exactly circular, or parallel to the isobars. The wind crosses the isobars obliquely, and may be described as blowing spirally into a cyclone and spirally out of an anticyclone.

free radiation, with great daily range of temperature. The weather changes which accompany secondary cyclones or V-depressions are the same as those of cyclones; wedges, like anticyclones, have fine weather in front and bad weather in their rear.

All these types are liable to break up or merge into new forms at any time, but it is often possible to "forecast" the weather in any given locality by learning from the synoptic charts the direction and velocity of cyclones approaching from the west. Synoptic charts are issued by the Meteorological Office in London, based upon the observations telegraphed from all parts of the kingdom and also from Continental stations. Daily weather forecasts are also published, in which advantage is taken of trans-Atlantic observations. The success of these has been very great, except in Scotland, which has no westerly outposts such as Ireland affords to England. Cyclones are often diverted from their course by meeting a coast line or mountain chain, or even an anticyclone; their course is not necessarily straight, nor their velocity by any means uniform. Lastly, their intensity—as measured by the steepness of the barometric gradient and consequent wind-velocity—may also change. Cyclones are much more numerous than anticyclones. The centre of depression usually passes to the north of Britain, and hence it is more common for the wind to "veer" (or "go with the sun") than to "back." It is only necessary to imagine a watch (with its hand moving in the reversed direction) passing over a given point upon a map to understand the successive changes in the direction of the wind at that point, during the passage of a cyclone.

CHAPTER III.

WATER.

Amount.—It is generally estimated that from ten to fifteen gallons of water per head per day are required for personal and domestic use, five to ten gallons for municipal purposes and a similar quantity for trade processes, but all these items are liable to very wide variation. About twenty to thirty gallons per head are supplied in most towns in Great Britain. The average daily amount taken in food is about half a gallon, but at least a pint of this is contained in solid food. Half a gallon more is used in cooking. Parkes allows in a middle-class household six gallons per head for domestic washing, five for ablutions including a sponge-bath, six for water-closets, four for general baths, and three for unavoidable waste.

Sources.—All natural waters are ultimately derived from the rainfall, which in its turn is due to distillation under the influence of the sun's rays from all humid portions of the earth's surface. Part of the rainfall is again evaporated from the surface upon which it falls, part flows along the surface to form streams and lakes. A third part sinks into the soil, descending vertically or obliquely through fissures or pores, until it reaches an impervious formation, and then either finds its way laterally to the surface in the form of springs, or accumulates in the porous strata overlying the impervious layer, where it may be reached by wells. It has been found that upon sand or gravel surfaces as much as 90 per cent. or more of the rainfall sinks into the ground, as compared with 40 per cent. on the

chalk, and 20 per cent. on limestone, while upon clay scarcely any infiltration occurs. For obvious reasons the proportion is less in hilly districts, which offer greater facilities for surface-flow, and less in summer than in winter owing to excessive evaporation. Experiments upon a gravelly loam indicated a penetration of only 2 per cent. in summer and nearly 100 per cent. in winter.

Rain-water is soft and well aërated, but its purity and fitness for drinking or even for washing depend upon the purity of the atmosphere through which it falls. Near the coast it often contains traces of chlorides and sulphates, due to its sea-origin. It acquires from the air not only oxygen, nitrogen, carbonic acid and ammonia, with a minute amount of nitric acid, but also microbes and any organic or other impurities that may be present in the air. In inland districts there is a marked increase in the sulphuric acid, ammonia, and organic matter, due to putrefactive processes and the combustion of coal. Near towns rain may become acid in reaction, from excess of sulphurous and sulphuric acids, and is liable to carry down considerable quantities of tarry and carbonaceous matter from the smoky air. Ammonia is found in largest proportion during the early part of a shower. A litre of rain contains about 25 c.c. of gases, namely, 8 c.c. of oxygen, 16·5 c.c. of nitrogen, and 0·5 c.c. of carbonic acid. Dew and snow-water have practically the same characters as rain-water, except that the dissolved gases are in less amount in snow-water.

Springs and wells.—The portion of the rainfall that sinks into the ground becomes heavily charged with carbonic acid from the air in the interstices of the soil, and aided by this and by the increasing pressure it dissolves out lime and various mineral salts from the strata through which it passes. From

the superficial strata it also receives organic matter, but the tendency of filtration through the soil is to remove this, or oxidise it with formation of nitrates. The nature and amount of the mineral matters in solution are determined by the soluble constituents of the various strata through which the water has passed, and the organic impurities are regulated by the facilities for pollution in the superficial soil and the completeness of purification by filtration lower down. Hence the water in shallow wells, especially if situated near dwellings or manured lands, is liable to contain much organic matter washed from the soil, with or without partial oxidation into nitrates or nitrites ; and also chlorides, which usually accompany organic impurities of sewage origin. In peaty districts the water acquires a brown tint due to vegetable matter.

According to the depth of the strata from which it is derived, the water may be warm, or of the mean temperature of the locality, or varying in temperature according to the season.

River-water is derived partly from springs, but chiefly from that portion of the rainfall which runs off the surface. Hence it contains a variety of mineral salts in solution, though in less amount than in spring or well water.

All streams are inevitably polluted to a certain extent by organic matter. Moorland waters contain peaty matter, sometimes in sufficient quantity to produce diarrhœa. Even in rural districts, drainage from manured land and farmsteads finds its way to the river, and in times of heavy rain much impurity of animal and vegetable origin is washed into the watercourses. Such slight degrees of pollution are not regarded as rendering water unfit for drinking purposes, especially if the precaution is taken of filtering it. Some of the organic

matter is oxidised by agitation and aëration, assisted by microbes and aquatic plants. When, however, the sewage of hamlets, villages, and towns is poured into the river, the pollution becomes far more serious, and the self-purifying agencies are soon overpowered. Even if the sewage added at any one point be insufficient to make a perceptible difference in the whole volume of water, it will contribute to it, and the risk of specific pollution, discernible neither by optical nor chemical tests, must always render such a stream a questionable source of supply. According to the Rivers Pollution Commissioners, no river in the United Kingdom is long enough to secure the oxidation of sewage introduced into it at its source. Trade effluents—for example, refuse from dyeworks, paper-mills, and bleach-works—cause even more discoloration and turbidity than sewage proper. From these combined causes the rivers in the manufacturing districts become foul, discoloured, and offensive, and are little better than open sewers. Matters are made worse by the refuse from slaughter-houses, solid household refuse, and even contents of privy middens being cast into the river. When the pollution reaches such a pitch as this, the purification by oxidation is insignificant. Putrefaction goes on, however, and the suspended matters are slowly deposited in the bed of the stream, so that there is still a tendency to self-purification. The magnitude of the evil at the present time is due not only to the enormous increase in population and manufactures, but to the better water supplies and the improved drainage, which in themselves have done so much to promote the public health. Even the introduction of water-carriage of excreta has added to the pollution of streams. The increasing foulness of rivers has rendered it necessary for the towns on their banks to impound pure water which formerly passed into the natural watercourses and helped to dilute the

impurities cast into them. Lastly, the flow is in many rivers to a great extent intermittent. Owing to the exigencies of trade purposes, volumes of water are impounded, and are only passed into the stream during work hours. In seasons of drought this may for a time almost entirely arrest the flow of pure water, so that sewage or other impurities that gain access to the stream remain undiluted. This evil is greatest on Saturdays and Sundays, but occurs daily, and continues until such time in the day as the reserved flow reaches the point in question. When water is abstracted from the head of a stream for the supply of a town, it is customary to provide a "compensation reservoir" in which the storm waters are impounded, and whence they can be delivered to supplement the remaining flow in the river in dry weather. As a means of regulating the flow these reservoirs are very valuable, but as for trade purposes the discharge is often made intermittent, the lower part of the stream may suffer from delay in the delivery of the "compensation" water, in addition to the loss of the water permanently abstracted from the channel. An intermittent flow may have some beneficial influence in flushing the bed of the stream, but where there is great impurity any interruption of flow causes increased nuisance by exposure of a foul foreshore.

Mode of supply.—In thinly populated districts water is obtained from streams, springs, or wells, supplemented by storage of rain-water. The depth to which it is necessary to sink a well depends upon the surface conditions as well as the arrangement of the strata beneath. Even shallow wells may yield good water unless exposed to pollution, as for instance by the proximity of leaking cesspools, ashpits, drains, or even dwellings. Water will usually be found collected as in a basin, above the first impervious stratum of clay, and as the surface of this subterranean reservoir will

vary according to season, the well must be deep enough to reach its level in times of drought. Such a well drains a wide area, and is liable to be polluted by any impurity of the soil within a considerable radius of its mouth, and as the supply is at best subsoil water, due regard must be had to the possibility of pollution at comparatively distant points. It should be lined with brick and puddled, and the brick lining should be brought a foot or two above the ground so as to exclude surface washings. If the soil is polluted, or if the

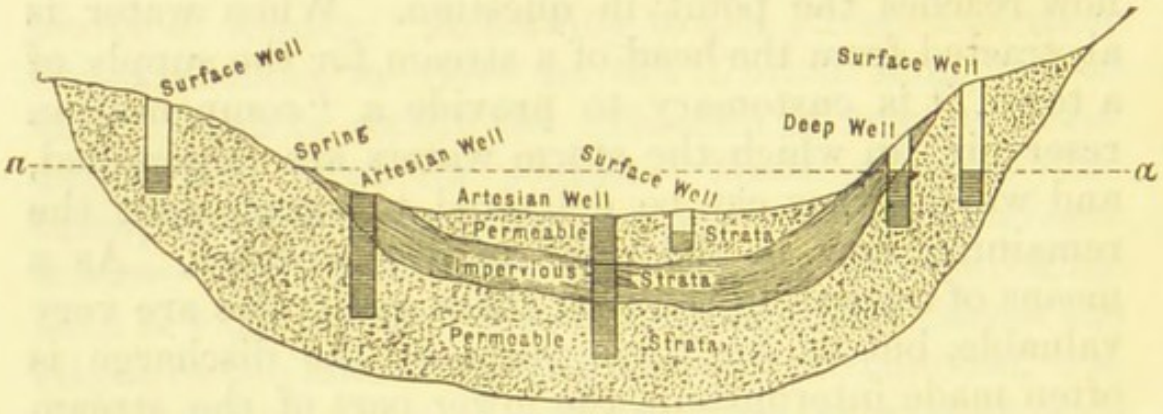

Fig. 5.—Diagrammatic Section across a Valley.
a a, Level of water in deeper permeable strata.

water found is impure or insufficient in quantity, the boring is carried through the first impervious stratum to other water-bearing strata deeper down. Sometimes the water in the deeper strata is under sufficient pressure to make it rise to the surface and overflow, forming an "artesian well" or artificial spring. The flow in dense strata being slow, each well exhausts a considerable area, and the yield of water cannot be greatly increased by multiple borings. Borings in sandstone or limestone give large and constant supplies, owing to the enormous accumulations of water they contain, but wells in superficial sand or gravel beds, or chalk, often fail in dry seasons (Fig. 5).

Tube wells are convenient for small or temporary supplies. A jointed iron tube is driven into the

ground, section by section, the lowest being pointed and perforated at the end. When water is reached, it enters the tube through the perforations and is pumped up if the pressure is insufficient to bring it to the surface.

In the country, and in certain towns where the air is free from smoke, the rain falling upon the roofs is collected and stored in cisterns for domestic use. It may, however, be collected from any other natural or artificial impervious surface. Its softness renders it valuable for washing, especially if the alternative supply is hard, but owing to sooty and other matters acquired from the air and from the roofs themselves, it is seldom obtained in a state of sufficient purity for drinking purposes. It has been estimated that on the average only about two gallons per head *per diem* could be collected in this way. The annual yield is found by multiplying the inches of annual rainfall by the square inches of sectional area of the building (not the slant surface of the roof). This gives the cubic inches of water per annum, and multiplied by 0·0036, the number of gallons. If rain is relied upon for more than an auxiliary supply, the collecting surface and storage capacity must be regulated by the minimum annual rainfall and the longest dry season.

Collection and storage.—Water is supplied to towns from reservoirs placed at a sufficient height to allow of its distribution by gravitation through open or closed aqueducts, leading to the street mains and through them to the service-pipes. Pumping stations may be requisite in order to gain this elevation, and if the source of water is of insufficient purity, settling tanks and filtering beds may also be required. When the yield is liable to intermission, large storage capacity in the reservoirs becomes necessary. Supplementary service reservoirs, fed by the main reservoirs, are often constructed in elevated parts

of the town, partly for convenience of distribution to certain districts, partly in order to supplement the supply during the hours of maximum demand, and so to avoid the necessity of regulating the calibre of the principal aqueduct by the greatest hourly consumption, which is double the average hourly consumption.

If water with a head of H feet flows through L feet of pipe D inches in diameter, the discharge W in cubic feet per minute will be

$$W = 4{\cdot}72\,\frac{\sqrt{H \times D^5}}{\sqrt{L}}. \quad \text{Hence } D = {\cdot}538\,\sqrt[5]{\frac{L \times W^2}{H}}.$$

The source of supply may be deep wells, springs, lakes, rivers, smaller streams, or artificial adits from gathering grounds. Some of these sources are immediately dependent upon the rainfall for their continuance, and in planning a water supply it is necessary to take into account the area of the gathering ground, the minimum annual rainfall, the longest rainless period, the proportion of rainfall available for collection, the storage capacity of the reservoirs, and the amount of water required by the district to be served.* Water of the greatest purity is obtained from deep wells, or from barren uplands, where the risks of animal or vegetable pollution are slight.

Reservoirs are constructed either by excavation or embanking, the simplest plan being to carry an embankment across a valley. A lining of concrete or clay puddle may be needed to render them watertight. The embankments, necessarily of great strength, have a core of clay puddle and are protected from

* In such cases the reservoirs should be large enough to hold at least 150 days' supply, and more in dry localities. If R = mean annual rainfall, E = evaporation (page 51), and A = acreage of gathering ground, then the mean daily yield in gallons is 62 A (R − E). In the driest year the rainfall will be $\frac{1}{3}$ less, in the wettest $\frac{1}{2}$ more, than the average. (*Symons.*)

disintegration by a covering of grass on the outer side and dressed stone on the inner.

Means are provided of diverting the tributary streams along a by-wash when they become foul in flood times. The reservoir has an overflow weir, and can be emptied for cleansing purposes by means of a pipe, controlled by a sluice, leading from its lowest point. Fish and aquatic plants are found to increase the purity of the water.

From the reservoirs the water passes to the aqueducts by an outlet pipe, which is bent upwards at its commencement so as to take the purest water, free alike from sediment and floating matters.

The aqueduct may be an open channel, but usually consists of iron pipes buried two or three feet in the ground as a protection against frost. The pipe aqueduct may be lined with pitch or other anti-corrosive, and being watertight, its course is not necessarily downward at all points. Means of access are provided at short intervals for cleansing purposes, and if its course is undulating, sluices are needed at the lowest points for scouring out *débris*, and air vents at the summit.

Distributing conduits and mains convey the water to all parts of the district, and pass beneath the streets. They are similar in construction to the main aqueducts, and have "scouring valves" at all dead ends in order to wash out sediment. They should be kept as far as possible from the sewers and gas mains.* Hydrants are provided at short intervals for use in case of fire.

Service pipes convey water from the street main to the house, and are controlled by means of stop-cocks. Lead piping is almost always used, owing to the many

* Buchanan has shown that there is danger of in-suction if a perforation exists in a descending pipe, and especially at a point of constriction, even if the pipe is constantly full.

bends and joints needed in distributing water within the house. If, as is sometimes the case, the water is of such quality as to act upon lead, other materials must be employed for domestic supplies (page 86).

Constant and intermittent service.—In almost all provincial towns, and in many parts of London, the water-supply is maintained constantly, save in times of exceptional drought. In some districts, however, the supply is only afforded for a certain number of hours in the day; and it becomes necessary for each household to store a sufficient supply for twenty-four hours, in elevated cisterns. The intermittent system, now becoming obsolete, is attended by many risks and disadvantages, and is only defended on the grounds that it incurs somewhat less waste, and that the substitution of constant service would entail considerable outlay in providing better fittings. On the other hand the cisterns, which must be large enough to meet the maximum (not the average) daily consumption, are costly, and are liable to become foul; the water stored in them is stagnant, and absorbs impurities from the air; coal-gas, sewer gases, or liquid filth are liable to be drawn into the mains and service-pipes when empty; and, apart from this, the alternate contact with air and water tends to corrode the pipes and promotes the absorption of lead. In the event of fire, a house or district under the intermittent system is at great disadvantage.

A cistern, if any is needed, should be placed at the top of the house, and fed by a supply-pipe controlled by a ball-cock. It must be large enough to contain at least a day's supply and must not directly supply the water-closet. It may be made of lead, lined with pitch or other protective coating, or of galvanised or Barff iron, or of slate slabs set in cement. It should be closely covered, but ventilated, and provided with an overflow discharging into the open air away from

any source of effluvia. Frequent inspection and cleansing are necessary.

Purification of water may be necessary on account of excessive hardness, excess of saline constituents, suspended matters, organic matter in solution, or, lastly, on account of suspicion of specific pollution.

Distillation is the most universally applicable mode of purification. Even sea-water can be utilised in this way. Distilled water has an unpleasant taste, and is said to be indigestible from its want of aëration. This can be remedied by exposure to the air in finely divided currents, as, for instance, by letting it fall from a sieve.

Boiling will remove temporary hardness and destroy all microbes, and therefore all specific contagia. Some of the organic matter is carried down with the calcic carbonate. Boiled water tastes flat, and needs aëration like distilled water. Lime is thrown down more completely if sodic carbonate is added.

Chemical processes are for the most part intended to remove excess of lime. Hard water may be softened, and at the same time deprived of all suspended matter, organic or mineral, by adding about six grains of alum per gallon. Calcic sulphate and a bulky precipitate of aluminic hydrate are formed, and carry down suspended matters. If no calcic carbonate is present, calcic chloride and sodic carbonate must be added previously. Perchloride of iron ($2\frac{1}{2}$ grains per gallon) acts similarly.

Potassic permanganate destroys effluvia and oxidises much of the organic matter in solution and suspension. Living organisms are for the most part unaffected by the quantities admissible in such a process. The permanganate should be added until a persistent faint pink tinge appears; it is advisable to supplement it by alum purification.

Clark's process.—Hard waters may be softened upon the large scale in reservoirs by adding one ounce of quicklime per hundred gallons, for every degree of temporary hardness. The lime and calcic bicarbonate react to form insoluble calcic carbonate, and this carries down with it suspended matters. A similar process may be employed on the domestic scale, using lime or washing-soda, or both.

The Porter-Clark process is a modification of Clark's. Instead of waiting for slow subsidence, which takes ten or twelve hours, the precipitated calcic carbonate is removed rapidly by filtration through cloth, under pressure.

Filtration aims at straining off suspended matters, and oxidising dissolved organic substances. Mineral salts in solution, such as sodic chloride or calcic sulphate, are at most only partially removed by filtration. As a rule, however, hardness is lessened, together with the nitrites and ammonia. Nitrates are increased.

A sand filter capable of removing suspended matters and some of the organic impurity may be constructed like a miniature filter-bed, in an ordinary flower-pot, with or without the addition of a layer of animal charcoal. Sponge-filters have deservedly fallen into disrepute; they remove suspended matters, but become foul, and harbour organisms.

Carbon is the commonest of all filtering media; and animal charcoal is believed to have a far greater purifying effect than vegetable charcoal. Many efficient patterns of filters are made essentially of animal charcoal; others, equally good, depend upon silicated carbon, manganous carbon, or "carferal" (charcoal, iron, and clay). Maignen's "filtre rapide" has no carbon block, but the water is made to pass through a mixture of powdered charcoal and lime (*carbo calcis*), supported upon an asbestos cloth; like

other animal charcoal filters, it seems to have the power of removing lead. Magnetic carbide of iron is another efficient medium. Bischof's spongy-iron filter, besides removing the organic matter, lessens the hardness, and often reduces nitrates to ammonia. Chamberland's filter is made of unglazed porcelain, through the excessively minute pores of which water is forced under pressure. It removes all microbes, and is therefore the most trustworthy if specific pollution be apprehended.

The use of domestic filters is only desirable when the purity of the water is open to suspicion. A filter should be emptied from time to time to promote aëration,* and requires frequent cleansing and occasional renewal of the carbon or other medium. Cleansing may be effected by scrubbing the carbon block, if removable, then running an acid solution of potassic permanganate through it, followed by copious washing with very weak hydrochloric acid, and finally several gallons of water. In the "filtre rapide" the medium can be renewed without trouble.

Filtration upon a large scale is necessary when a public water-supply is turbid or impure. The "filter-beds" constructed for this purpose are essentially shallow reservoirs, one or two feet deep, under-drained by perforated or loosely-jointed pipes, to reach which the water passes downwards† through successive layers of fine sand, coarse sand, oyster shells, fine gravel, coarse gravel, and pebbles, the total thickness being several feet. Vents are carried from the deeper layers to above the surface of the water, to allow of the escape of the air displaced by the water as it first descends. From time to time the beds are run dry, for the purpose

* This does not apply to Bischof's filter, which must always contain sufficient water to cover the spongy iron.

† At the rate of about six inches, or three gallons per square foot, per hour.

of aëration; and occasionally they are cleansed by scraping off the sediment and a little of the superficial fine sand, fresh sand being added when necessary. The suspended impurities are strained off by the upper portion of the filter, and a certain degree of oxidation of organic matter is effected in the lower part. Hardness is diminished somewhat, and iron is removed. Frankland has shown that filtration through sand removes 95 to 99 per cent. of the microbes present in Thames water.

Other materials may be employed in the construction of filter-beds. Magnetic carbide of iron gives excellent results, if covered by a layer of sand to intercept the suspended impurities. It must be worked slowly and intermittently, so as to renew the aëration. Filter-beds of this construction converted the black and offensive water of the Calder into a bright and palatable water, which was until recently supplied to Wakefield. Spongy iron can be used on the large scale, but not, of course, intermittently, like other filters. A new modification of filtration through iron is known as the "Revolving Purifier." The "purifiers" are cylinders containing small loose pieces of iron, and having many projections from the inner surface. Their long axis, upon which they rotate, is horizontal or inclined, and the surfaces of the iron masses inside are kept constantly bright and clean by mutual friction. Water is passed slowly through the cylinders as they revolve, and is exposed to the action of the constantly fresh iron surfaces. After subsequent sand filtration to remove the iron, the purification seems to be very complete.

If the source of supply is very impure—a polluted river, for example,—a preliminary purification by subsidence tanks may be beneficial, and floating matters may be excluded by admitting the water into the tank from the river through a submerged sluice.

Examination of Water.

Collection of samples.—The amount required depends upon the mode of analysis to be adopted. Half a gallon, or $2\frac{1}{2}$ litres, will suffice for almost all purposes, and this quantity is held by an ordinary stoppered "Winchester Quart." The bottle is rinsed out with a little hydrochloric acid, and then with water until the rinsings are no longer acid. At the time of collection it is again rinsed with sample water, and then filled up to the neck.

In order to obtain a fair sample, it is well, in the case of rivers or ponds, to plunge the mouth of the bottle under the surface of the water, at a distance from the margin, so as to exclude scum and *débris*, care being taken not to stir up any sediment. Tap water should be allowed to run for some time before sampling, unless it is desired to ascertain the maximum impurity. The water should be examined within a day or two of collection.

Physical characters.—Water should be clear and bright, free from turbidity or smell, and have a fresh agreeable taste, without perceptible saline or other accessory character. The colour, as seen by looking down upon a white surface through a column of the water two feet in depth, should be clear, or slightly green, or blue; a yellow or brown tint raises suspicion of organic pollution.

Natural Waters may contain—

In suspension—Particles of animal, vegetable, and mineral origin.
Microbes, and other living organisms, animal and vegetable.

In solution—Gases.
Mineral salts.
Soluble organic matter of animal and vegetable origin.

Suspended matters. — The water should be allowed to stand for a day in a tall glass, and the sediment then examined under the microscope.* Particles of sand have a sharp angular outline. Fragments of chalk and clay are amorphous, but a drop of acid introduced beneath the cover-glass will dissolve chalk, leaving clay unaffected. Shreds of cotton or linen are easily recognised under the microscope, and so are fragments of leaves, woody fibre, and other vegetable tissues, if not so decomposed as to be apparently structureless. Hair, wool, fragments of insects, and even epithelial scales may be found ; brown globular bodies attributed to sewage contamination are sometimes seen in polluted water.

For the most part suspended matters can scarcely be deemed injurious ; but some of them, cotton fibres for example, may supply important evidence of pollution by household waste, or even sewage.

Living organisms.— Rhizopoda, Infusoria, Hydrozoa, Rotifera, Scolecida, Entomostraca, and Insecta are found in water, together with Fungi, Algæ, Diatomaceæ, and many other organisms. For the most part these are believed to be harmless in themselves, though Infusoria (*e.g. Paramecium*, *Vorticella*) and Fungi indicate the presence of impurities. Among the parasites that are believed to be conveyed by water are certain tapeworms, the Guinea-worm, *Dochmius duodenalis*, *Bilharzia*, and leeches. They may be found in the adult or embryonic form, or as ova.

Microbes are always present in natural waters, even the purest; but their number is greatest in impure water. Both moving and motionless organisms are

* Wynter Blyth's sediment tube is shaped like a pipette, the point of which fits accurately into a little glass cup wherein the sediment collects. Finally a long rod is passed down the tube so as to stopper it from the inside at the point. The cup, containing the sediment and about 1 c.c. of water, can then be removed for examination.

found—micrococci, bacteria, bacilli, spirilla. Most of them multiply rapidly in water, especially if impure, at the ordinary temperature, and they are continually recruited by aërial microbes.* Hence the number is constantly changing, and affords only a very rough indication of the quality of the water.† If a small measured volume, 1 c.c. or less, of the water is added to nutrient gelatine, and a plate cultivation made, the number of colonies can be counted. Little is known of the significance of most of the varieties met with, but the great majority are doubtless perfectly harmless. Some pathogenic microbes have been detected in natural waters, among them those alleged to be the causes of cholera, enteric fever, and malaria. The *comma bacillus* thrives for months in sewage, but soon perishes in pure water. The same is true of *Bacillus anthracis*, but the spores retain their vitality even in distilled water. A bacillus, known as *Beggiatoa alba*, characterised by the presence of grains of sulphur in its substance, 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 and tanyards. The dense flocculent greyish-white masses of *Beggiatoa* have been regarded as evidence of the presence of sewage. They reduce sulphates, and will grow in water in which sulphates abound, whether derived from sewage or not.

Gases in water.—A litre of water can dissolve 25 c.c. of oxygen, 46 c.c. of nitrogen, and 1,000 c.c. of carbonic acid at ordinary temperature and pressure. These gases are usually present in natural waters, but the proportions are very variable, being largely

* A sample of water from a deep chalk well contained 7 microbes when fresh, 21 after standing for a day at 20° C., and 495,000 after standing three days. (*Frankland.*)

† Microbes in drinking water should not exceed 300 per cc. ; but, however numerous, efficient filtration will reduce them to 100. (*Koch.*)

dependent upon the source of the water, the degree of pollution and of exposure to air, and also upon vegetable growth; chalk and limestone waters contain excess of carbonic acid. The gases in a pure water often contain 30 per cent. of their volume of oxygen. They may be extracted for the purpose of quantitative analysis by means of a Sprengel pump, or by boiling the water for an hour, and collected over a mercurial trough. Potash will then absorb the carbonic acid, and potassic pyrogallate or sodic hyposulphite will remove the oxygen, leaving a residue of nitrogen alone.

For the determination of oxygen alone, Thresh's method is best. He adds measured quantities of sulphuric acid, sodic nitrite, and potassic iodide, to a measured volume of water (about 250 c.c.), in a vessel which must be full to the stopper, so as to exclude atmospheric oxygen. The nitrous acid acts as a "carrier" until all the dissolved oxygen is exhausted, liberating a proportionate amount of iodine. The water is then run into a bottle, through which a current of coal gas is being passed, and standard hyposulphite is added from a burette until the yellow colour due to iodine disappears, the final point being accurately determined by adding a little starch, which gives a blue colour as long as any trace of free iodine remains. The hyposulphite solution is of such strength (7·75 grammes per litre) that 1 c.c. corresponds to $\frac{1}{4}$ mgr. of oxygen. A correction is required for the oxygen contained in the reagents used, a blank test being made for the purpose. The amount of dissolved oxygen per litre of water is then readily calculated.

Sulphuretted hydrogen or marsh gas may be found, the former due to mineral sulphides such as pyrites, or to decomposition of sulphates by organic matter, the latter to fermentation of vegetable matter in stagnant pools, or to pollution by coal-gas. Traces of ammonia are usually present.

Well aërated waters are bright, lustrous, and agreeable to the palate. This is especially the case with water from wells or springs, of medium depth, in calcic carbonate formations—the low temperature and greater pressure combining to increase the charge of carbonic acid. The absence of dissolved gases in distilled water renders it flat, dull, and unpleasant to taste.

Mineral salts are derived from the strata with which the water has been in contact. They may include chlorides, sulphates, carbonates, silicates, nitrates, nitrites, and phosphates, the bases being lime, magnesia, soda, potash, alumina, or iron, and more rarely lead, zinc, copper, manganese, or arsenic.

The proportion of salts present ranges from practically *nil* in rain-water, or pure moorland water, to 3,000, or more, parts per million in "mineral" waters or brackish water from the coast. In water for drinking it should not exceed 400 parts per million, and a good water will not contain more than 100 parts. An excess of mineral salts in general leads to digestive disturbances, in the form of dyspepsia, diarrhœa, or constipation; but this effect is largely dependent upon the nature of the salts present.

Chlorides, estimated as chlorine, may reach the proportion of 100 parts per million in organically pure water from the New Red Sandstone, Greensand, and other saliferous formations. Brackish water also contains excess of chlorine. In general, however, good waters contain not more than about 20 or 30 parts per million, and rain-water and peaty waters little or none. Water from surfaces, shallow wells, or other sources open to contamination should be regarded with suspicion if it contains more than 100 parts of chlorine, especially if there is also excess of organic matter or oxidised nitrogen, all these being significant of animal pollution.

TESTS.—I. *Qualitative.*—A solution of argentic

nitrate gives a haze with 15 parts of chlorine per million, a turbidity with 60 parts, and a precipitate with 150 parts.

II. *Quantitative.*—A standard solution of argentic nitrate is employed, containing 4·788 grms. per litre, so that each c.c. corresponds to 1 mgr. of chlorine, according to the equation $AgNO_3 + NaCl = NaNO_3 + AgCl$. A hundred c.c. of sample water are taken in a white porcelain dish, a few drops of a solution of potassic chromate are added as an "indicator," and the silver solution is then dropped in from a burette, with constant stirring, until a faint permanent red tinge appears, showing that the chlorine is exhausted, and argentic *chromate* is beginning to be formed in place of *chloride*. If the 100 c.c. of sample water take x c.c. of silver solution before the red tint appears, there are x mgrs. of chlorine in the 100 c.c., and, therefore, $x \times 10$ mgrs. per litre.*

Sulphates are usually estimated as hydric sulphate, H_2SO_4. The most important are calcic and magnesic sulphate, which are liable to cause dyspepsia and diarrhœa, especially in persons unaccustomed to the use of water containing these salts. Hence limestone and dolomite waters, which may hold 50 to 200 parts per million of calcic sulphate, are less wholesome than chalk water, which contains none. Dolomite water differs from limestone water in containing magnesic sulphate, but less calcic sulphate. Some waters contain sodic sulphate. The acidity of certain peaty moorland waters that act upon lead has been attributed to the formation of acid sulphates by the oxidation of sulphides (pyrites) or of sulphurous acid absorbed from smoky air.

* 1 mgr. per litre = 1 part per million, and 1 grain per gallon = 1 part per 70,000. Hence x grains per gallon = $\frac{1000}{7}x$ mgrs. per litre, and y mgrs. per litre = $\frac{7}{1000}y$ grs. per gallon. Many chemists express their results in parts per hundred thousand.

TESTS.—I. *Qualitative.*—A solution of baric chloride with a few drops of hydrochloric acid will give a white precipitate with 40 parts (per million) of sulphates, but none with 20 parts until after standing.

II. *Quantitative.*—200 c.c. of sample water are boiled, treated with slight excess of baric chloride solution and a little hydrochloric acid, and then boiled again and filtered. The precipitate collected on the filter is washed, ignited, and weighed as barytic sulphate, $BaSO_4$. Given the weight of $BaSO_4$ from 200 c.c., the corresponding proportion of H_2SO_4 per litre will be readily calculated.

Carbonates. — Soluble calcic bicarbonate, $CaH_2(CO_3)_2$, is found in almost all well and spring-waters. It occurs in excess in chalk, limestone, and dolomite water, but it is wanting in rain and peaty water. It is precipitated by boiling, in the form of normal calcic carbonate, $CaCO_3$. Magnesic bicarbonate, $MgH_2(CO_3)_2$, found in dolomite water, behaves similarly, but partially redissolves on cooling. Sodic carbonate is occasionally found in natural waters, and may give them an alkaline reaction. Free carbonic acid exists in all waters, and if in excess renders them sparkling and palatable. Apart from this, the importance of the carbonates in water depends entirely upon the bases they contain.

TESTS.—It is scarcely necessary to enumerate here the ordinary chemical tests for carbonates, since they are not required for hygienic purposes. The determination of temporary hardness will show the amount of calcic and magnesic carbonates.

Silicates of soda or alumina are occasionally found in water.

TESTS.—Half a litre of sample water is evaporated to dryness; the residue is acted upon by strong hydrochloric acid, and washed with boiling distilled water; then it is once more dried, ignited, treated with acid,

and washed with boiling water. The final residue is silica, and may be weighed as such after drying.

Nitrates and nitrites, like chlorides, are harmless in themselves, but if found in a water exposed to risk of pollution may suffice to condemn it for use. Nitrates may be found in pure water from deep wells in the chalk, but as a rule they are due to oxidation of nitrogenous organic matter of animal origin. Even if accompanied by only a small proportion of organic matter, nitrates in water from a source open to suspicion must be regarded as oxidised filth, which may at any time be followed by unoxidised filth.

Frankland emphasises this view by recording all the inorganic nitrogen present, whether in the form of nitrates or nitrites, or ammonia, as due to *previous sewage contamination*, irrespective of its probable origin, recent or remote. He makes a deduction, however, of 0·032 part per 100,000, as the average amount of nitrogen in the rain-water which must have been the ultimate source of supply. Average London sewage is estimated to contain about 10 parts of nitrogen in 100,000 of sewage, so that 1 part of nitrogen represents "previous sewage contamination" to the extent of 10,000 parts. An example will make the mode of calculation clear. A sample of water is found to contain 3·1322 parts of oxidised nitrogen (*i.e.* nitrogen as nitrites and nitrates) per 100,000 parts of the water; and also 0·0034 part of ammonia, which is obviously equivalent to 0·0028 part nitrogen. The "inorganic nitrogen" is therefore 3·1322 + 0·0028, or 3·1350 parts per 100,000. From this must be deducted 0·032, as a correction for the nitrogen in average rain-water, leaving 3·1030 inorganic nitrogen, and this multiplied by 10,000 gives 31,030 (per 100,000) of "previous sewage contamination." In other words, if 31,030 parts of average London sewage had been diluted with 68,970 parts of average

rain-water, and all the nitrogen then converted into nitrates, nitrites, or ammonia, the result would be a water of the composition of the sample, so far as the proportion of inorganic nitrogen is concerned.

The process of nitrification, by which nitrogenous organic matter in water or in the soil is oxidised, with formation of nitrates, is due in great measure to the action of microbes. Under other conditions, which are not clearly understood, nitrates may be reduced by microbes or by contact with oxidisable matter, yielding nitrogen or even ammonia.

Nitrites, as a rule, indicate more recent, and therefore more dangerous pollution than can be inferred from the presence of nitrates. They readily pass into nitrates.

A variety of standard terms has been proposed for the quantitative statements of nitrates and nitrites. The expression "oxidised nitrogen" is adopted here, and is precisely equivalent to "nitrogen as nitrates and nitrites" and to "nitric nitrogen." "Previous sewage contamination" has already been explained. Wanklyn gives his results in terms of "nitric acid," HNO_3.

Water from springs and deep wells contains upon an average about 5 parts of oxidised nitrogen per million, shallow well-waters from 2 to 200 parts.

Tests for Oxidised Nitrogen.*

I. Qualitative.

a. *Diphenylamine test.*—A 2 per cent. solution of diphenylamine in strong sulphuric acid is spread out in a thin layer upon a white porcelain plate. A drop of the sample water is allowed to fall in the centre, and any trace of oxidised nitrogen is revealed in a few seconds by a blue tint throughout, or at the line of contact.

* That is, for nitrates or nitrites indifferently.

β. *Horsley's test.*—2 c.c. of pure sulphuric acid are added to 1 c.c. of the water, and then a drop of pyrogallic acid solution. A pink or blue tint appears, changing to brown; it disappears momentarily upon shaking, but soon returns.

γ. *Brucine test.*—A drop of pure sulphuric acid and a crystal of brucine added to the dry residue of 2 c.c. (or more) of the water will give a pink or yellow tint with even minute traces of oxidised nitrogen.

II. Quantitative.

δ. *Aluminium process.*—2 grammes of sodium are dissolved in 100 c.c. distilled water so as to obtain a pure solution of caustic soda free from nitrates; 100 c.c. of sample water are added and a piece of aluminium foil. In the course of a few hours all the oxidised nitrogen is converted into ammonia, which is distilled off and Nesslerised. Each mgr. of ammonia, after deducting the free ammonia originally present in the sample, corresponds to 0·82 mgr. of oxidised nitrogen in the 100 c.c. of sample.

ε. *Zinc-copper process.*—Zinc foil is coated with copper by exposure to a solution of cupric sulphate until it becomes black. It is then put into a bottle with 250 c.c. of the sample water and 0·5 grm. oxalic acid, and left for twenty-four hours. As in the aluminium process, all the oxidised nitrogen is converted into ammonia and measured as such by Nesslerising.

All the preceding tests are for nitrates and nitrites alike. The following apply to nitrites only :—

1. Ilosvay's solution, containing sulphanilic and acetic acids and napthylamine, is an excessively delicate test. A few drops added to water give a rose tint if any trace of nitrite is present.

2. One drop each of phenol and sulphanilic acid solution, and then ammonia, will give a yellow colour.

3. The addition of starch solution, potassic iodide solution, and dilute sulphuric acid causes a blue tint, due to liberation of iodine by nitrous acid and consequent formation of iodide of starch.

4. Meta-phenylene-diamine solution with dilute sulphuric acid (a few drops of each) will give a red colour after standing a few minutes.

Phosphates are not of common occurrence except in minute traces. They are, for the most part, indicative of remote animal pollution, but need not condemn a water if the other indications are satisfactory.

Tests. — The water is concentrated to $\frac{1}{50}$th, 250 c.c. being boiled down to 5 c.c. Nitric acid is added, and then solution of ammonic molybdate. If phosphates are present, a yellow colour will appear, and, on standing, a precipitate of ammonic phosphomolybdate.

Sulphides are said to result from the reduction of sulphates by *Beggiatoa*, and perhaps from contact with iron pyrites. Carbonic acid liberates sulphuretted hydrogen from sulphides. They are readily detected by smell, and by the following

Tests.—A solution of plumbic acetate (or, still better, a solution of plumbic hydrate in caustic soda) will give a black precipitate in presence of sulphides.

A solution of sodic nitro-prusside will give a purple colour with sulphides, but not with free sulphuretted hydrogen. It is therefore safer first to add caustic alkali.

Lime is the most important of the mineral constituents of drinking water. It occurs mainly as

bicarbonate and sulphate; a good water should not, as a rule, contain more than 200 parts per million of the former, or 50 of the latter. In excess it causes constipation when used for drinking and is wasteful for washing purposes, since it renders the water extremely hard unless previously boiled. On the other hand, absence of lime salts is held to be disadvantageous because lime is required in the system, and also for the more practical reason that soft waters are, as a rule, less palatable than those of moderate hardness, and often dissolve lead from household service pipes. Horses are said to become rough in the coat if supplied with very hard water. Calcic sulphate is undoubtedly injurious (as already stated), and renders water permanently hard. Calcic nitrate and butyrate have been found in waters that have caused diarrhœa and other symptoms of intestinal irritation.

Tests.—Ammonic oxalate solution will give a turbidity with 80 parts per million, and a precipitate with 250 parts. This precipitate from a measured quantity of sample may be collected on a filter, washed, dried, ignited, and then weighed as calcic carbonate.

Magnesia occurs chiefly as carbonate and sulphate, in water derived from magnesian limestone. It renders water hard, and although the carbonate is thrown down by boiling, it re-dissolves on standing. Magnesic salts cause dyspepsia and diarrhœa.

Tests.—All the lime is first removed by adding powdered oxalate of ammonia, and filtering.

(*a*) The filtrate is tested for hardness in the usual way. Any hardness beyond that of pure water is due to magnesia, and each "degree" corresponds to 0·56 grain of magnesic carbonate per gallon.

(*b*) To the filtrate are added sodic phosphate, ammonic chloride, and excess of pure ammonia. In twenty-four hours the precipitate of triple phosphate, NH_4MgPO_4, is collected, washed on a filter with strong

ammonia,* ignited, and weighed as magnesic pyrophosphate, $(MgO)_2P_2O_5$.

Soda salts are almost omnipresent, and few waters are free from sodic chloride in small amount. The sulphate occurs in excess in some mineral waters, and the carbonate also is common, sometimes in sufficient quantity to render the water alkaline.

Iron is an occasional ingredient in natural waters, to which it gives a characteristic inky (chalybeate) taste. It is also frequently derived from iron tanks or pipes through which the water has passed. Water is unsuitable for drinking if it contains more than one grain of iron per gallon—that is, 15 parts per million. Ferruginous waters are said to be liable to cause dyspepsia, headache, and malaise in those unaccustomed to their use. Iron adds to the hardness of water.

Tests.—I. *Qualitative.*—Ammonic sulphide gives a dark colour (lost on adding acid), potassic ferrocyanide a *blue*, and potassic sulphocyanide (after acidulating with nitric acid) a *red* tint.

II. *Quantitative.*—A standard solution containing 1 mgr. of iron in 1 c.c. is made by dissolving 4·96 grm. of crystallised ferrous sulphate in a litre of water; if greater precision is desired, the solution may be diluted to $\frac{1}{10}$, so that 1 c.c. $= \frac{1}{10}$ mgr. of iron. 50 c.c. of sample water and 50 c.c. of distilled water are placed in Nessler glasses (page 92) side by side, and to both a trace of ammonic sulphide is added. The black tint produced in the former is exactly matched in the latter by adding successive c.c. of iron solution until the right shade is reached. The amount added (to the 50 c.c.) being known, the proportion per litre (*i.e.* per 1,000 c.c.) will be just twentyfold, and will give, of course, the milligrammes per litre, or parts per million, of iron in the sample water.

* Triple phosphate is soluble in water. It is necessary to allow 1 mgr. of magnesic phosphate as lost for every 50 c.c. of wash.

Lead, rarely present in natural waters, is sometimes absorbed from leaden pipes or cisterns. The action is probably twofold, as Garrett has pointed out. First, the metal is acted upon by the oxygen dissolved in the water, aided possibly by oxidised nitrogen serving as a "carrier" of oxygen. Next, the lead oxide thus formed may be dissolved, more readily, of course, if the water be acid, or may be washed away by the current in a state of fine powder. If, however, the water contains calcic carbonate or sodic carbonate, there is formed on the surface of the lead a protective coating, insoluble and not very readily dislodged. Hence it is found that plumbo-olvent action is comparatively rarely associated with well or spring or river waters, but quite commonly with rainwater or soft moorland waters, especially if they have an acid reaction. Nitrates, chlorides, or excess of carbonic acid have been found to increase the corrosion, while silicates and many other substances exert some protective action. As to the nature of the acid which is occasionally found in moorland waters not much is definitely known, and contradictory views have been expressed. It has been asserted to be inorganic, possibly acid sulphates due to the oxidation of iron pyrites, or of sulphurous acid. Other chemists believe it to be organic, either acetic acid or the indefinite acid compound found in soil and sometimes termed "humic" and "ulmic" acid. In some instances it consists largely of carbonic acid. Whatever its cause, the acid reaction seems to be usually most marked in the first flow when rain follows drought. It varies with season, and apart from this there are striking differences in the plumbo-solvent activity of waters gathered from adjoining moors, apparently similarly circumstanced. Power has suggested that the action upon lead may be dependent directly or indirectly upon organisms, and is

in a sense an infective process. The organisms may conceivably occur in the peat or in the water. Kirker found that the solvent action is increased by the multiplication of certain microbes in water. Tidy and Odling attributed the lead-dissolving power to the absence of silica, and brought forward evidence to show that this inverse relation holds good in a number of water supplies.

In recent years this question has assumed great importance, owing to the disastrous effects of lead-poisoning by potable water in several of the large Yorkshire towns, and more especially since Sinclair White called attention to the prevalence of plumbism among the consumers of the high-level water at Sheffield.

Various remedial measures have been tried. One plan is to expose the water to fragments of limestone, and conduits have been lined with the same material, but it soon becomes inert, owing to incrustation, and frequent renewal of the surface is necessary. Measured quantities of lime have also been added. A more effective method, adopted at Sheffield and elsewhere, is to add powdered chalk, while at Wakefield carbonate of soda is used. In some towns reliance is placed upon filtration through calcareous sand, which, however, becomes exhausted in time. In pursuance of Tidy's hypothesis, the water has been charged with traces of silica by filtration through powdered granite or flint. It is at least possible that the mischief is not always due to the same cause, and that no one line of treatment is suitable in all cases.

Many waters, fortunately, are sufficiently protected by the salts they contain. Calcic sulphate is less protective than the carbonate, and magnesic less than calcic salts. A crust is formed upon the interior of lead pipes, composed of carbonate and sulphate of lead, lime, and magnesia (or such of them as are present in the water), and chloride of lead.

Carbonate of lead is difficult of solution except in water charged with excess of carbonic acid under pressure. Pipes which are new, which are bent against the grain, or which are alternately full and empty, are more attacked than others. The maximum amount of lead is found in water that has stood for some time in the pipes, over-night for example. Lead is now chemically purer than was usual in former years, owing to the profitable removal of silver and other metals with which it is found associated, and it would appear that the purer lead is more readily acted upon by water.

There are many substitutes for ordinary lead pipes now available, and where there is any tendency to solvent action one or other of these should be adopted. Compound pipes have long been in use, the interior of which is block tin and the exterior lead; the two metals are solidly united throughout, and the pipe can be bent without fracturing the tin. A less reliable protective lining to lead pipes may be found in tar, bitumen, or lead sulphide. Iron pipes are more satisfactory in every respect, except their rigidity, which renders them difficult to adapt to the bends and turns that are needed in houses. Plain iron pipes may be employed, with some risk of trouble from rusting. Tin-lined, glass-lined, or galvanised iron pipes are often used, and among other protective coatings may be mentioned Angus Smith's varnish and collodion. Theoretically, the rustless Barff iron offers the greatest advantages for this purpose; iron pipes of ordinary construction are exposed while hot to superheated steam, and thereby acquire a thin coating of magnetic oxide, Fe_3O_4, which renders them free from liability to rust as long as the coating is unbroken. Unfortunately the film is easily dislodged in the process of fitting, and the results are less satisfactory than those afforded by a lining of tin or glass. If it is not possible to change the supply of water, or to prevent

it by chemical means from acting upon lead, or to keep it from coming into contact with lead, recourse must be had to palliative measures. The water must always be run off for a few minutes in the morning, and again before drawing it for drinking purposes. All that is used for drinking or for cooking should be filtered through some medium containing animal charcoal. Such filters possess the power of removing lead from solution, owing probably to the phosphates which they contain forming an insoluble lead salt.

No water should be used for drinking that contains more than one part of lead per million, and any trace, however minute, indicates danger; for the sample may not represent either the seasonal or daily maximum.

Among the symptoms caused by lead-poisoning are anæmia, depression, dyspepsia, constipation, colic, paralysis of the extensor muscles of the hand leading to wrist-drop. A characteristic blue line appears along the edges of the gums, due to the formation of sulphide of lead in the tissue. Optic neuritis may be found. It has been observed that abortion is common in districts where lead-poisoning prevails, and sometimes to such a degree as to materially lower the birth-rate. The relation between lead-poisoning and gout and kidney-disease is referred to elsewhere.

TESTS.—I. *Qualitative.* — (*a*) Ammonic sulphide, or sulphuretted hydrogen, gives a brown tint if a trace of lead is present, and a black precipitate if the proportion is larger; neither colour nor precipitate is affected by acid. (*b*) A solution of potassic bichromate (about one grain to the ounce) dropped into a tall glass of water, falls slowly to the bottom, causing an opaque yellow cloud if there is any lead in solution.

II. *Quantitative.*—A standard solution containing 0·1 mgr. of lead in 1 c.c. is made by dissolving 0·1831 grm. of crystallised plumbic acetate in a litre

of distilled water. The procedure is the same as in testing for iron, but the water should be made acid.

Zinc, copper, and arsenic, although rarely occurring in natural waters, may occasionally gain access by means of trade pollution, or by the solvent action of water (especially water containing organic matter, nitrites, and nitrates) upon the pipes and vessels with which it comes into contact. Any trace of these substances renders a water unfit for drinking purposes.

Tests.—Copper, like lead, strikes a black colour with ammonic sulphide, not discharged by acid. It may be determined quantitatively by a colorimetric process similar to those for iron and lead, the standard solution containing 1 mgr. of copper in each c.c. being made by dissolving 3·93 grms. of crystallised cupric sulphate in a litre of distilled water.

Arsenic would be detected in the residue after evaporation, by Marsh's or Reinsch's test.

Hardness of water is caused by the presence of salts that decompose soap, preventing lathering until sufficient soap is added to exhaust them. The chief of these are lime salts, magnesic salts, and carbonic acid, but iron and alumina have a similar effect. By boiling the water, the free carbonic acid is driven off, and calcic bicarbonate is reduced to the insoluble carbonate and precipitated; magnesic bicarbonate is precipitated as carbonate in like manner, though it partially re-dissolves on cooling, and most of the iron is also thrown down. After removal of this *temporary* hardness, there remain in solution calcic and magnesic sulphates and chlorides, and a little iron—assuming all these to have been originally present. These, with the re-dissolved magnesic carbonate, constitute the *permanent* hardness. Soap consists of alkaline oleates, stearates, and palmitates, which form a viscid solution in water. The phenomena of hardness depend

upon the formation of insoluble calcic and magnesic oleates, etc.

Hardness is measured by a standard soap-solution, 1 c.c. of which exactly precipitates 1 mgr. of calcic carbonate. It is found that 1 c.c. suffices to give a lather when shaken with 70 c.c. of distilled water, and anything beyond this is due to the hardness, which is always stated in terms of calcic carbonate.

70 c.c. of the water are taken in a bottle of about 250 c.c. capacity, and the soap solution is added by degrees from a burette, with vigorous shaking after each addition, until a lather completely covers the surface and remains intact for five minutes. The number of c.c. added, deducting 1 c.c. for lathering, will give the hardness in mgrs. of calcic carbonate per 70 c.c., that is, in grains per gallon.* The permanent hardness is measured in exactly the same way, in 70 c.c. of the water, after boiling for half an hour and adding distilled water to make good the loss by evaporation. If more than 16 c.c. of soap-solution are consumed by 70 c.c. of water, it is better to dilute it by adding 70 c.c. of distilled water, in which event a deduction of 2 c.c. must be made instead of 1 c.c. for lathering. A "degree" of hardness upon Clark's scale corresponds to a grain of calcic carbonate per gallon.

The disadvantages attendant upon the use of hard water have already been referred to in speaking of lime and magnesia in water. Temporary hardness is of less moment, both for dietetic and washing purposes, than permanent hardness; it depends upon the

* Hardness, unlike other analytical data, is still commonly expressed in grains per gallon. The conversion into the standard terms of parts per million is readily effected (*see* note, page 76); but for this purpose it is best to use 100 c.c. ($\frac{1}{10}$ litre) of water for analysis, and then to multiply by 10 the number of c.c. of soap-solution used, after deducting 1 c.c. per 100 (according to some authorities 1·5 c.c.) for lathering.

comparatively harmless calcic carbonate, which is removed by boiling. Calcic and magnesic salts have been held responsible for goitre, which in certain districts, notably in India, seems to be limited to magnesian limestone formations. It is, however, by no means always prevalent in magnesian limestone districts, even when the water contains abundance of magnesic salts; nor is it always absent from districts free from limestone formations. Hence many authorities are inclined to attribute its causation to iron pyrites and other salts of iron and copper often found in limestone regions; while others consider that the concurrent agency of some organic material is necessary. Goitre appears to have been developed, under the use of certain drinking waters, in as few as eight or ten days. Urinary calculi are common in Norfolk and other chalk districts where the water is hard; but the dependence of the calculi upon the hardness of the water is far from being established. A good drinking water should not exceed 4 degrees of permanent, or 20 of total, hardness. It is estimated that each degree of hardness involves a waste of upwards of a pound of soap for every 1,000 gallons used in washing.

Organic matter in solution consists of animal and vegetable matters that have gained access to the water, and of the products of their decomposition. Little is known of its chemical composition, the variety and complexity of the components being so great as to defy analysis.

The presence of organic matter (or rather, of oxidisable matter) may be shown by adding a few drops of a solution of potassic permanganate, which is immediately decolorised; or by slightly acidulating the sample water and boiling it for 20 minutes with a few drops of solution of chloride of gold, which will give, according to the amount of organic

matter present, a rose, violet, or olive colour, or a violet or black precipitate.

A rough quantitative estimate is obtained by determining the combustible matter in the "total solid residue." 100 c.c. of sample water are measured into a platinum dish of known weight A. They are then evaporated to dryness over a water-bath (after which the drying should be continued in a water-oven at 100° C. for an hour more), and the weight B of the dish and its now dry contents is ascertained. B—A is the weight of the total solid residue, that is of the organic matter and mineral salts. The dish is next heated to dull redness, to burn off the organic matter, and weighed again (C) after cooling. The loss on ignition, that is B—C, will give the amount of organic matter in the volume of water taken.* The proportion of organic matter per litre, or per gallon, is readily calculated from these data. Thus,

100 c.c. volume taken.	:	1,000 c.c. a litre.	::	B—C mgrs. lost on ignition.	:	x

x being the proportion of organic matter expressed as parts per million, or milligrammes per litre. During ignition the organic matter turns brown, or even black, before disappearing, and if of animal origin it gives off pungent fumes.

This method is not sufficiently exact for most quantitative purposes, and recourse is had to other means, of which the chief are:—

Wanklyn's ammonia process,

Frankland's combustion process, and

Forchammer's oxygen process.

None of these profess to give the total amount of

* This is not strictly accurate, since water of crystallisation is driven off from the saline matters, and some small portion of the salts may be volatilised. Carbonates lose CO^2, and nitrates are reduced.

organic matter in water, but each fixes upon some one or more element, or compound, or property, which is determined with precision and taken as a measure or index of the total organic matter, to which it is assumed to bear a constant ratio.

Wanklyn's Ammonia Process.—Most nitrogenous organic matter, when heated with permanganate of potash in presence of excess of potash, gives off a certain proportion of its nitrogen in the form of ammonia. Most, if not all, of the injurious organic impurities occurring in water may reasonably be assumed to be nitrogenous, and as they yield a definite and fairly constant proportion of their nitrogen as ammonia we have a very convenient and delicate means of measuring them. It still remains, of course, in this, as in all other indirect processes, to establish empirical standards of purity, in terms of the ammonia index.

Certain standard solutions are required.

A. Standard solution of ammonic chloride, containing 0·01 mgr. of *ammonia* in 1 c.c.

B. Nessler's solution is a saturated solution of mercuric iodide in potassic iodide. It gives a yellowish tinge, with the faintest trace of ammonia, and a yellow-brown precipitate (NHg_2I,H_2O) if more is present.

"Nesslerising" is a process by which the free or saline ammonia in a sample of water can be readily determined with great accuracy. Two tall cylindrical, flat-bottomed glasses, marked at 50 c.c., are placed side by side upon a white surface. In one of them are placed 50 c.c. of the sample water, and in the other 50 c.c. of distilled water free from any trace of ammonia. Two c.c. of Nessler solution are added to each glass, and the tint struck by the sample is exactly imitated by adding to the second glass successive measured quantities of the standard

ammonia solution (*A*) from a burette, until the right tint is reached. Each c.c. of ammonia solution used corresponds to 0·01 mgr. of ammonia present in the 50 c.c. of the sample, from which data the amount per litre is readily calculated.

C. Alkaline permanganate solution. Eight grms. of potassic permanganate and 200 grms. of solid caustic potash are dissolved in a litre of distilled water.

The analysis is conducted as follows :—

Half a litre of the water to be examined is put into a large flask, connected with a Liebig's condenser by means of a bent glass tube passing through a perforated indiarubber stopper. The flask is heated by a Bunsen's burner, and the first 50 c.c. of distillate are collected and Nesslerised, and the amount of ammonia they contain is recorded. This ammonia is part of the free ammonia contained in the water as such, and it is found by experience that the first 50 c.c. contain three-quarters of the free ammonia. Hence, adding $\frac{1}{3}$ to the amount recorded in the first 50 c.c., we get the whole amount contained in the *half litre* of water under analysis, and, doubling this, the mgrs. of free ammonia per *litre*, *i.e.* parts per million.

Thus, if the first 50 c.c. strike a tint with Nessler, which is matched in the second glass by the addition of 1·2 c.c. standard ammonia solution, we must allow $\frac{1}{3}$ of 1·2, that is, 0·4, making a theoretical total of 1·6 c.c. This corresponds to 0·016 mgr. of ammonia in the half litre taken for analysis, or 0·032 part per million. Meanwhile 150 c.c. more are distilled over, to exhaust the free ammonia, but as already explained it is unnecessary to Nesslerise these.

There are then 300 c.c. left in the flask, and to this are now added 50 c.c. of the alkaline permanganate, and the distillation is resumed. The first, second, and third 50 c.c. are collected separately and Nesslerised.

Should the third 50 c.c. be found to contain noteworthy quantities of ammonia, a fourth 50 c.c. is distilled over.

The ammonia coming over at this second stage is called *albuminoid ammonia*, being derived from the albuminoid and other nitrogenous organic matter in the water. The second 50 c.c. contain much less than the first, and the third less than the second. Adding together the amount of ammonia found in the three lots, we have the total for the half litre of water; and twice this will give the proportion in parts per million. Thus,

1st 50 = 2·5 c.c. standard ammonia solution.
2nd 50 = 1·0 c.c. ,, ,, ,,
3rd 50 = 0·3 c.c. ,, ,, ,,

Total = 3·8 c.c. = 0·038 mgr. ammonia per half litre.
∴ Albuminoid ammonia = 0·076 part per million.

Interpretation of results.—Absence of any trace of albuminoid ammonia is suggestive of organic purity, even if free ammonia and chlorides are high. Albuminoid ammonia less than ·05 part per million is consistent with extreme purity; and if free ammonia is absent or scanty, albuminoid ammonia under 0·10 is no evidence of impurity. If, however, there is much free ammonia, 0·05 albuminoid ammonia is suspicious, and 0·10 is strong evidence of pollution; 0·15 or more should condemn a water absolutely.

In good waters the free ammonia usually ranges from 0·00 or 0·01 to 0·03 part per million, and rarely exceeds 0·05.

These general rules are subject to some modification according to the history and surroundings of the water, which should always be studied. Vegetable is much less dangerous than animal contamination, and may often be recognised by the slowness with which the

albuminoid ammonia comes over,* by the absence or small amount of chlorides and of free ammonia, and by microscopic examination of the sediment or knowledge of the source of the supply. Animal pollution is indicated if the albuminoid ammonia comes over rapidly, or if the chlorides or oxidised nitrogen are abundant. Pollution by absorption of effluvia, or by the presence of putrefying masses in the water, would, however, be unaccompanied by any excess of chlorides. It is important to take into consideration also the character of unpolluted water in the same district or geological field, since chlorides, oxidised nitrogen, and even a certain amount of free and albuminoid ammonia, may be found in waters that are free from recent and therefore dangerous pollution. It is quite possible, too, for an organically pure water to be unfit for use on account of its mineral constituents. Water from a shallow well, open to suspicion of pollution, should be condemned if the chlorides and oxidised nitrogen are high, even if albuminoid ammonia be scanty. A water that is pure at the time of sampling may still be liable to intermittent contamination. It must be remembered that Wanklyn's process tells us nothing as to the exact amount or specific nature of the pollution, or whether it is injurious or harmless. The solid matters of enteric or choleraic excreta probably do not greatly differ as regards their yield of albuminoid ammonia from those of healthy excreta, and minute proportions of either one or the other intentionally added to water in recent experiments by Cory and Dupré caused, as was to be expected, only a proportionately trifling addition to the albuminoid ammonia already present. Such minute but deadly pollutions, by enteric virus or any other poison, rarely occur in nature, but when they do the present mode of

* The second 50 c.c. containing little less than the first, and the third than the second.

chemical analysis will give us no intimation of them. Hence it is true that water analysis "can tell us of impurity and hazard, but not of purity and safety" (*Buchanan*); but to this it should be added that the circumstances are rare indeed in which a careful consideration of all the analytic data, together with a study of the source of supply and its surroundings, will fail to give warning of any danger that may exist.

Combustion processes involve costly and delicate apparatus, and a considerable degree of skill. The following is an outline of Frankland's process:—

To a litre of the water are added 20 c.c. of saturated solution of sulphurous acid, to reduce the oxidised nitrogen and liberate all carbonic acid. The water is evaporated to dryness. The dry residue is mixed with oxide of copper and heated *in vacuo* in a combustion tube for about an hour. The gases evolved are collected over a mercurial trough; they contain all the organic carbon as carbonic acid, and the nitrogen as such. They are measured volumetrically, and after the absorption of the carbonic acid by caustic potash the residue is read as nitrogen. The nitrogen present in the water as ammonia must be separately determined, and deducted from the total.

Interpretation of results of combustion processes.—The significant points are the absolute and relative amounts of organic carbon and organic nitrogen. The lower the proportion of nitrogen to carbon, and the less the amount of each, the more favourable is the verdict, other things being equal. A low proportion of nitrogen to carbon, 1 to 8, indicates vegetable organic matter; a high proportion such as 1 to 3 is pretty certain proof of animal pollution. A river or surface water should not contain more than 0·2 organic carbon or 0·03 organic nitrogen in 100,000 parts, and spring or well water is open to suspicion if the carbon exceeds 0·1, or the nitrogen 0·03, per

100,000. In forming conclusions, due weight must be given to the other analytic data, especially the determination of chlorides and oxidised nitrogen, and to the other evidence obtainable, such as the position and surroundings of the source of supply, the facilities for pollution, and the depth and geological characters of the strata from which it is derived.

The following table, taken from the Report of the Rivers Pollution Commissioners, gives the average results of a large number of samples upon Frankland's method, stated as parts per 100,000 :—

	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage Contamination.	Chlorine.	Hardness.			Number of samples analysed.
									Temporary.	Permanent.	Total.	
Rain Water . .	2·95	·070	·015	·029	·003	·042	42	0·82	0·4	0·5	0·9	39
Upland Surface Water. . . .	9·67	·322	·032	·002	·009	·042	10	1·13	1·5	4·3	5 8	195
Deep Well Water	43·78	·061	·018	·012	·495	·522	4743	5·11	15·8	9·2	25·0	157
Spring Water. .	28·20	·056	·013	·001	·383	·396	3559	2·49	11·0	7·5	18·5	198

Kjeldahl's process, applied by Blair to water analysis, is based upon the conversion of the nitrogen of organic substances into ammonic sulphate if charred by heating with strong sulphuric acid. 250 c.c. of water are distilled down to 50, with addition of sodic carbonate if acid ; the first 100 c.c. of distillate contains all the free ammonia. Then 10 c.c. of pure sulphuric acid, and a little arsenious acid, are added, and the distillation is continued. Presently the acid begins to fume, and becomes darkened by the charring of organic matter. The heat is continued for two hours after this, or until the colour disappears again. After cooling, a slight excess of pure solution of soda is added ;

and the ammonia thus liberated is distilled over, and measured as in Nessler's process.

This method, like Wanklyn's, gives us a record of the "free ammonia" and "organic ammonia" at two stages; but the yield of the latter is more constant and more complete than that obtained with alkaline permanganate. The results are converted into terms of "organic nitrogen" by multiplying by 0·824. Blair finds, by this process, less than 0·06 part of organic nitrogen per million in very pure water, and 0·06 to 0·12 in ordinary drinking water; he regards as suspicious any water containing more than this, unless peaty, and condemns any over 0·32.

Oxygen process.—There are many modifications of the Forchammer method, of which Tidy's is the best known. For the sake of uniformity the metric system is substituted for "septems" in the following description :—

The standard solutions required are—

A. Potassic permanganate, 0·395 grm. in a litre of distilled water. Every 10 c.c. yields 1 mgr. of oxygen to oxidisable matter.
B. Sodic hyposulphite, 1 grm. per litre.
C. Potassic iodide, 1 part in 10 of water.
D. Starch, 1 part boiled with 20 parts of water, and filtered.
E. Sulphuric acid, 1 part to 3 parts of water.

The object is to determine the amount of oxygen absorbed in 1 hour and 3 hours respectively. As the hyposulphite solution is liable to change, it is necessary to perform a blank test with distilled water every time.

Four flasks are employed, two of which contain 250 c.c. of sample water, while the other two contain 250 c.c. of distilled water for the control experiments. To each flask are added 10 c.c. of permanganate

solution (A), and 10 c.c. of dilute sulphuric acid (E). If the water is very bad, the pink colour due to the permanganate may soon entirely disappear, and in this event a second and even a third 10 c.c. of permanganate must be added, so as always to have a pink tinge throughout the experiment. At the end of an hour one of the samples and one of the control flasks are tested to ascertain how much undecomposed permanganate remains to be deducted from the total used. For this purpose 2 c.c. of iodide solution (C) are added, and the remaining permanganate immediately acts upon it, liberating a proportionate amount of free iodine. The iodine is measured with precision by dropping in the standard hyposulphite solution until no more free iodine remains, the exact point of disappearance of the last trace of iodine being ascertained by adding 2 c.c. of starch solution (D) near the end of the process, and noting the disappearance of the blue iodide of starch.

In the blank test the 10 c.c. of permanganate should remain unaltered at the end of the hour, so that if x c.c. of hyposulphite are used, these x c.c. correspond to 10 c.c. of the permanganate solution, that is, to 1 mgr. of oxygen. If, therefore, the sample flask, which has, of course, lost some of its permanganate, takes only y c.c. of hyposulphite, it is clear that the oxygen consumed by oxidisable matter must have been $\frac{x-y}{x}$ mgr. If a second 10 c.c. of permanganate had been employed, the formula would obviously become $\frac{2x-y}{x}$ mgr.

As a quarter of a litre of the sample was taken for each analysis, four times this result will give the "oxygen consumed" in milligrammes per litre—that is, in parts per million.

The determination of oxygen consumed in three

hours is conducted in exactly the same way, at the end of that time.

Interpretation of results of the oxygen process.—Not only organic matter, but also nitrites, ferrous salts, or sulphuretted hydrogen will reduce permanganates, and these latter, if present, must be removed or allowed for. No distinction is made between nitrogenous and non-nitrogenous organic matter. In London waters the organic matter is said to be about eight times the "oxygen consumed." It seems that putrescent matters, notably urine and other animal matter, are readily oxidised by permanganate, so that while the three hours' experiment gives information as to the total amount of organic matter, the one-hour reaction is important as indicating the proportion of putrescent and, therefore, presumably dangerous impurities. Sometimes four hours are allowed instead of three, and quarter or half an hour instead of one hour. Peaty waters consume much oxygen.

As in all other modes of estimating the organic matter in water, the results of the oxygen process must be considered together with the other analytic data and the source of the water. In a general way, Tidy classifies waters as of great organic purity if the oxygen consumed does not exceed 0·5 part per million, of medium purity if not exceeding 1·5 part, of doubtful purity up to 2·0 parts, and as impure if the oxygen consumed exceeds 2·0 parts per million. Upland surface waters, however (the organic matters being less likely to be harmful), are judged by a more lenient standard, the degrees of which are double those given above, namely, 1·0, 3·0, and 4·0, in place of 0·5, 1·5, and 2·0.

Blair's oxygen process at 100° C. gives very satisfactory results. The reagents are similar to Tidy's, but the following differ in strength :—

Potassic permanganate, 1·975 gramme per litre, so that 10 c.c. yield 5 mgrs. oxygen.
Sodic hyposulphite, 3·875 grammes per litre.
Sulphuric acid, 100 c.c. to 900 c.c. distilled water.

Half a litre of water is taken for analysis, and after the addition of 10 c.c. of permanganate and 10 c.c. of acid, is boiled gently for two hours, further charges of permanganate being added if necessary. After cooling, the procedure is the same as in Tidy's process (page 99). Iodide is added, and the iodine set free by the unconsumed permanganate is measured by hyposulphite solution with the aid of starch.

The method of calculation also is substantially the same. Since the 10 c.c. of permanganate yield 5 mgr. of oxygen instead of 1 mgr., the formula becomes $5 \times \frac{x-y}{x}$, or if n charges of permanganate have been added, $5 \times \frac{x \times n - y}{x}$. This gives the mgrs. of oxygen absorbed per half litre, and doubling the result we have mgrs. per litre, or parts per million. Blair's process has obvious advantages over Tidy's, since the conditions as to temperature are constant, and the oxidation of organic matter practically complete. The empirical standards of purity necessarily range higher. Exceptionally pure waters take less than 2 parts per million, waters of medium purity 2 to 4 parts, and suspicious waters 4 to 6 parts. Even a peaty water should not be recommended if it takes much more than 6 parts.

The subjoined summary is slightly modified from a table given by Parkes and De Chaumont. It shows in a general way the value to be attached to each analytical datum *per se*, but it will be evident that the interpretation is subject to material modification according to the other information available :—

SYNOPSIS OF CHARACTERISTICS OF GOOD AND BAD WATERS.

DATA.	Pure Water.	Usable Water.	Suspicious Water.	Impure Water.
A. CHEMICAL (*in parts per million*):				
1. Total dissolved Solids	Under 100.	Under 400.	400 to 700.	Over 700.
2. Loss in do. on ignition	Under 15. (*Solids should scarcely blacken on ignition.*)	Under 40. (*Solids may blacken slightly on ignition, but no fumes should be given off.*)	Over 40. (*Much blackening, or nitrous fumes given off.*)	Over 70. (*Much blackening, with nitrous fumes, or smell of burnt horn.*)
3. Chlorine	Under 15.	Under 50.	Over 50.	Over 100.
4. Nitrites	nil.	nil.	Present.	Marked.
5. Nitrates	nil, or trace only.	Present.	Marked.	Large.
6. Hardness, Permanent	2° Clark.	Under 4° Clark.	Over 4° Clark.	Over 6° Clark.
7. Ammonia, Free	Under 0·02.	Under 0·05.	Over 0·05.	Over 0·10.
8. Ammonia, Albuminoid	Under 0·05.	Under 0·10.	Over 0·10.	Over 0·15.
9. Organic Carbon	Under 1·0.	Under 2·0.	Over 2·0.	Over 3·0.
10. Organic Nitrogen	Under 0·2.	Under 0·3.	Over 0·3.	——
11. Oxygen taken from Acid Permanganate	Under 1·0.	Under 1·5.	Over 1·5.	Over 2·0.
12. Sulphides	nil.	nil.	nil.	Present.
13. Metals	nil.	Trace of iron.	Trace of iron.	Much iron. Presence of other metals, especially lead.
B. PHYSICAL:				
1. Transparency	Clear, bright.	Clear, bright.	Turbid.	Turbid.
2. Suspended Matter	nil.	nil, or separable by subsidence or coarse filtration	Much.	Much.
3. Colour	nil.	faint blue or green tinge only.	Yellowish tinge.	Yellow.
4. Taste	Palatable.	Palatable.	Any marked taste.	Any marked taste.
5. Smell	nil.	nil.	nil.	Any marked smell.
6. Microscopic Characters of Sediment	nil, or as in next column.	Mineral matter. Vegetable forms with endochrome. Large animal forms. No organic débris.	Colourless vegetable forms. Organic débris. Fibres of cloth, or other evidence of house-refuse.	Abundant animal and vegetable forms. Fungi. *Beggiatoa.* Epithelial scales. Evidences of sewage. Ova of parasites.

Vegetable matter in suspension and even in solution may cause diarrhœa. In small quantity, however, dissolved peaty matter is harmless, although it gives a brownish tinge to the water. Malaria seems to be transmissible by means of water from malarious marshes, although the evidence as to this is somewhat conflicting.

Animal matter in suspension or solution, whether due to percolation from cesspools, leaking drains, farmyards, or manured fields, or to direct pollution of streams by drains or sewers, or to presence of decomposing animal tissues in the water, or to absorption of effluvia, is always dangerous to health.

The products of simple decomposition of animal matter are in themselves capable of producing diarrhœa and other acute alimentary disturbances, or of insidiously undermining the general health, and so possibly preparing the way for other diseases not directly dependent upon water-borne poison. In tropical countries polluted water is a frequent cause of dysentery, sporadic or epidemic. Many sudden localised outbreaks of diarrhœa in Great Britain have been proved to originate in contamination of drinking water by effluvia from sewage, even without the entrance of liquid or solid filth. Apart from all this, the presence of organic filth in water shows that the way is open for the access of more specific poisons, such as those of cholera, enteric fever, and dysentery. The tendency of any such pollution is to increase in amount, while percolation through soil loses in course of time whatever purifying effect it may possess at first.

Further reference will be made to pollution of water in speaking of cholera and enteric fever. Diphtheria and scarlet fever have not been shown to be capable of dissemination by means of water, although some authorities think it possible; and there is no reason to suspect that small-pox, measles, or the other exanthemata are ever conveyed in this way.

CHAPTER IV.

FOOD.

THE useful constituents of all food substances, animal, vegetable, and mineral, are classified as—

1. Nitrogenous, including the animal and vegetable albuminoids (proteids) and gelatin.
2. Fatty, including animal and vegetable fats and oils.
3. Carbohydrates, including starch and the sugars.
4. Salts, organic and inorganic.
5. Water.

Nitrogenous food.—Proteids are converted by the action of the gastric and pancreatic juices into soluble peptones, which are absorbed. Some of the peptone becomes "tissue albumen," being used for the nutrition and repair of the nitrogenous tissues; the rest constitutes a reserve store of "circulating albumen," which is necessary for the functional activity and well-being of the system. During life the nitrogen is eventually eliminated as urea or urates, and in the fæces; fat is another product of the splitting-up of albumen, and its hydrogen and carbon ultimately go to form carbonic acid and water. Muscular exertion does not increase the demand for nitrogen or the excretion of urea, these being fairly constant in a given healthy individual under suitable diet, whether working or not. Assimilation of excess of nitrogen, in the absence of exercise, is apt to lead to imperfect oxidation, with formation of urates and uric acid, rather than urea. Other consequences are engorgement of the liver and general plethora, pyrexia, tendency to diarrhœa, and ultimately to a gouty condition; the urine contains excess of urea, uric acid, and urates, and even albumen.

Deficiency of nitrogen leads to diminution of circulating albumen, anæmia, loss of weight, and impairment of energy and stamina. Ultimately the tissue albumen, and especially that of the muscles, is reduced.

Nitrogenous food is therefore essential for the growth, maintenance, repair, and functional activity of the tissues, and contributes in some measure to the production of heat and force.

Gelatin appears to be capable of replacing the circulating albumen, but not of forming tissue albumen or repairing its waste. Its nutritive value is said to be about one-fourth of that of albumen. Digestion converts it into a sort of peptone, which does not gelatinise.

Fats and carbohydrates supply the oxidisable material for the production of heat and force, and are ultimately eliminated as carbonic acid and water. They aid in the nutrition of the tissues and in the excretion of waste material. An excess of either lessens oxidation of nitrogenous matter and leads to storage of fat in the tissues ; deficiency causes increased metabolism of circulating albumen, loss of weight, and impairment of nutrition. Sugars, starches, and certain other substances are termed *carbohydrates*, because their molecule contains (besides carbon) twice as many atoms of hydrogen as of oxygen, and may therefore be represented empirically as $C_x(H_2O)_n$, or carbon *plus* water. Glucose is $C_6H_{12}O_6$, cane sugar $C_{12}H_{22}O_{11}$, starch $C_6H_{10}O_5$. Fats and oils (animal or vegetable) contain much less oxygen in proportion to their carbon and hydrogen, stearin, for example, being $C_{21}H_{40}O_6$. Carbohydrates are more readily assimilated than fats, but have a lower nutritive value by at least 40 per cent. They are converted into grape-sugar by the digestive processes. As a rule, nutrition ultimately suffers if either fats or carbohydrates are withheld; but to a certain extent they are

interchangeable, and the diet of the Eskimo contains little or no carbohydrate.

Fat as a tissue is useful for its mechanical properties—namely, non-conduction of heat, lubrication, and soft elastic pressure; in excess it becomes a source of inconvenience or danger, as in extreme obesity and in fatty infiltration of the heart.

Muscular contraction is the source of animal heat as well as of force, and the heat generated is four times the heat-equivalent of the work done. Although the hydrocarbonous matter supplies the "fuel" for these purposes, it is necessary that a certain amount of nitrogenous matter shall be associated with it. Fat or carbohydrate alone is not sufficient.

Salts.—Lime, potash, and soda are essential—lime for bone-formation and cell-growth, potash for nutrition of formed tissues, soda for fluid tissues.* Iron in small quantity is required for formation of the colouring matter of the blood, and a little magnesia also is believed to be necessary.

Chlorides and phosphates are indispensable. Salts of organic acids (lactates, tartrates, citrates, malates, acetates), which are oxidised into carbonates in the system, are important as maintaining the alkalinity of the blood.

Water constitutes two-thirds of the whole weight of the body, and forms part of every tissue. By its agency food is dissolved and carried to the tissues, waste products are removed and excreted, nutrition and chemical changes are rendered possible, and the temperature of the body is regulated by means of evaporation.

Stimulants and condiments are sometimes regarded as a distinct class, but they are not essential constituents of a complete dietary.

* A vegetable diet calls for additional sodium salts, to make up for the increased elimination of these due to the excess of potassium salts supplied.

Dietaries.—Adopting an average of the statements of various authorities, it would seem that a daily dietary for a male adult should be composed somewhat as follows :—

	Nitrogenous Food.	Fat.	Carbohydrates.	Salts.	Such a diet would contain	
					Nitrogen.	Carbon.
Rest	3 oz.	1½ oz.	12 oz.	1 oz.	200 grs.	4000 grs
Moderate work .	4½ ,,	3 ,,	15 ,,	1¼ ,,	300 ,,	5000 ,,
Hard work	6 ,,	4½ ,,	18 ,,	1½ ,,	400 ,,	6000 ,,

These amounts are only roughly approximate. The necessity for so great an increase of nitrogen during hard work is open to question, and on the other hand the hard work standard of carbon in the above table is low. More food, especially fat, is needed in cold climates, less in hot.

All the ingredients are supposed to be water-free, but would, in practice, be combined with at least their own weight of water, raising the total daily weight of solid food to 40 or 50 oz. Besides this, other 50 to 80 oz. of water are taken as drink. A man consumes daily about $\frac{1}{100}$ of his weight of *dry* solid food and $\frac{3}{100}$ of water. Women are said to require about 10 per cent. less than men, both of carbon and nitrogen. Infants require nitrogenous and fatty foods with only a small proportion of carbohydrates, which is supplied by milk-sugar. A child of ten years of age needs half as much, and at fourteen years quite as much, as a woman.

The following table supplies the means of determining how far a given dietary complies with the requirements stated above, and conversely of constructing a dietary that will satisfy these conditions.

Chemical Composition of Certain Food Substances.
(*Parkes.*)

	Per Cent. of					Grains per lb.	
	Water.	Nitrogenous.	Fatty.	Carbohydrates.	Salts.	Nitrogen.	Carbon.
Good meat,* beef or mutton, with little fat	75	20	3·5	...	1·5	190	1900
Average meat*	75	15	8·5	...	1·5	...	...
Cooked meat (roast: no dripping lost)	55	28	15	...	3	...	...
Very fat meat*	63	14	19	...	4	...	...
Fat pork	40	10	50	...	2·	100	4000
Salt pork†	45	25	7	...	25	290	1360
Salt beef†	50	30	0·2	...	20	325	1115
White fish	78	18	3	...	1	200	875
Eggs	74	14	11·5	...	1	...	...
New milk	87	4	3·5	5	0·5	45	600
Skim milk	90	4	2	5	0·8	45	450
Cheese	37	33	24	...	5·5	300	3300
Butter	6	0·3	90	...	2·5	...	6500
Bread	40	8	1·5	50	1·5	90	2000
Flour	15	11	2	70	1·7	120	2700
Oatmeal	15	13	6	65	3	140	2800
Indian meal	14	10	7	65	1·5	120	3000
Peas (dry)	15	22	2	55	2·5	250	2700
Green vegetables	90	0·2	0·5	6	0·7	14	420
Carrots	85	0·6	0·2	8·5	0·7	14	500
Potatoes	75	1·5	0·1	23	1	22	770
Rice	10	5	0·8	83	0·5	70	2700
Sugar	3	...	...	96	0·5	...	3100‡

* 20 per cent. should be allowed for bone, and 20 to 30 per cent. more is lost in cooking.

† Brine dissolves out myosin and other important constituents. The nutritive value of salt meat is not more than $\frac{2}{3}$ that of fresh meat.

‡ Milk-sugar yields only 2,800 grains of carbon per lb.

Thus, if the question should arise whether a daily allowance of 2 lbs. of bread and $\frac{1}{2}$ lb. cheese is a sufficient

diet for a man in easy work, the calculation may be made as follows :—

100 oz. bread contain				therefore 32 oz. contain			
	Nitro.	Fat.	Carb.-hyd.		Nitro.	Fat.	Carb.-hyd.
	8 oz.	1½ oz.	50 oz.		2·5 oz.	0·5 oz.	16 oz.
100 oz. cheese contain				therefore 8 oz. contain			
	33 oz.	24 oz.	0 oz.		2·6 oz.	1·9 oz.	0 oz.
					5·0 oz.	2·4 oz.	16 oz.
Whereas the theoretical amounts required for moderate work are . .					4·5 oz.	3 oz.	15 oz.

The conclusion to be drawn is that such a diet is sufficient as regards the nitrogenous matter and carbohydrates, but somewhat wanting in fat.

A still readier method is to calculate the amount of carbon and nitrogen, thus :—

1 lb. bread contains			therefore 2 lbs. contain		
	Nitrogen.	Carbon.		Nitrogen.	Carbon.
	90 grs.	2000 grs.		180 grs.	4000 grs.
1 lb. cheese contains			therefore ½ lb. contains		
	300 grs.	3300 grs.		150 grs.	1650 grs.
				330	5650
The theoretical amounts of carbon and nitrogen required for moderate work being				300	5000

Hence, if we leave out of consideration the differences between fats and carbohydrates the diet more than satisfies the theoretical requirements.

The problem may also be presented the other way round. What quantity x of bread and y of cheese would be sufficient for an ordinary diet? The requirements are 300 grains of nitrogen, and 5,000 of carbon ; and x lb. of bread contain $90 \times x$ grains of nitrogen and $2{,}000 \times x$ grains of carbon, while y lb. of cheese yield $300 \times y$ grains of nitrogen and $3{,}300 \times y$ grains of carbon. Hence we have a simultaneous equation

$$90x + 300y = 300$$
$$2000x + 3300y = 5000$$

giving as approximate values $x = 1{\cdot}7$ lb., and $y = \frac{1}{2}$ lb.

It has been found experimentally that the energy which is developed by oxidation is for one ounce of lean meat about 50 foot-tons,* carbohydrates 150 foot-tons, and fats 300 foot-tons. These determinations of potential energy have, of course, no close relation to nutritive values. The oxidation of food in the system is by no means complete, even as regards that portion which is assimilated.

In calculating the **mechanical work** done, that of respiration, circulation, and locomotion must be taken into account, as well as the load carried or lifted. According to Haughton and Parkes the force exerted daily in respiration, circulation, and other "internal" work is about 260 foot-tons; and in addition to this a strong man can do external work equivalent to 300 to 500 foot-tons more per day. Walking along a level road at three miles per hour is equivalent to climbing vertically $\frac{1}{20}$th of the distance traversed; at 4 miles $\frac{1}{17}$th. Hence, if a man weighing W lbs. carries a load of X lbs. on a horizontal track for D feet, at 3 miles per hour, he exerts energy equivalent to $\frac{(W+X)D}{20 \times 2240}$ foot-tons in so doing. A march of 20 miles along the level involves work equivalent to 350 foot-tons, taking the weight of the body as 150 lbs. If a load of 60 lbs. is added, the work is 500 foot-tons. The whole work done, estimated in this way, represents only $\frac{1}{7}$th of the force theoretically obtainable from the food by combustion. The energy expended in a fair day's work is about one-fifth mechanical labour to four-fifths heat (*Martin*).

* A *foot-ton* is the force required to raise 1 ton to a height of 1 foot.

Animal is generally held to possess certain advantages over vegetable food, of which the most certain are the ready supply of blood-pigment, the greater digestibility of animal fats, and the smaller bulk required. A vegetable dietary, unless carefully selected, is apt to contain insufficient nitrogen. The supposed inferior nutritive value of vegetable albuminoids is not so clear, although they are probably less rapidly digested; and a well-fed vegetable eater * may display as perfect health and energy as a meat-eater. On the other hand, the argument from analogy with the herbivora, some of which are types of activity, loses weight from the inability of man to digest cellulose. It is at least open to question whether the average meat-eating individual could, without long training at all events, maintain his full mental and bodily vigour on the comparatively dilute and less nitrogenous diet of the vegetarian.

Morbid conditions dependent upon diet.—An excess of food, due to too large or too frequent meals may accumulate in the intestine, causing fermentation or putrefaction, and also dyspepsia, with constipation or ineffective diarrhœa. Absorption of the products of putrefaction may give rise to a septic condition marked by pyrexia, furred tongue, fœtid breath, heaviness, and possibly jaundice.

The effects of excessive or deficient assimilation of nitrogenous and carbonaceous food have already been considered.

Protracted insufficiency of diet is followed by wasting of the tissues. Adipose tissue is naturally the first to suffer, and may be almost completely absorbed, the other tissues following mainly in the inverse order of their importance to life. The urine still contains

* Vegetarianism as ordinarily practised does not exclude animal fats, or even albuminoids; milk, butter, and cheese being used freely.

urea and urates, from oxidation of tissue, first of the circulating albumen, afterwards of tissue albumen. Physical and mental weakness ensue, followed by anæmia and an adynamic condition that powerfully predisposes to certain diseases, notably typhus, relapsing fever, malaria, phthisis, and pneumonia, and perhaps to all infectious diseases. Diarrhœa is apt to occur, adding still further to the general emaciation and prostration. Ophthalmia, stomatitis, ulcers, and skin diseases of various kinds are common; and any disease that may have obtained a hold upon the system is aggravated by the impairment of nutrition. Death ensues when the loss reaches about 40 per cent. of the normal weight of the body.

Reference will be made later to several more or less specific diseases that are sometimes caused by toxic matter or parasites present in food; but there are two well-marked morbid conditions that are almost always attributable to the absence of essential elements of diet. These two are rickets and scurvy.

Rickets rarely occurs in children fed upon milk without undue admixture of starchy food, provided only that digestion is not deranged. Starch cannot be digested by infants under seven months, and its administration is not only useless but liable to cause diarrhœa, which interferes with the digestion of other food. Even apart from this, an excess of starch or other carbohydrate has an injurious effect upon nutrition. It is probable that in milk the lime and phosphates are supplied not only in the needful amount but in a readily assimilable form.

Scurvy does not occur when the diet includes plenty of fresh vegetables and fruits or their juices, or even preserved vegetables and fruits. The blood or raw flesh of recently killed animals is credited with considerable anti-scorbutic power. Citrate, tartrate, and malate of potash are also preventives, and to a less

degree lactate and acetate. Carbonate of potash is inert. The disease affects under-fed men more readily, but cannot be checked by increase in the supply of nitrogenous food, carbohydrates, or fat. The fault must probably rest with the supply of salts, and as scurvy occurs when there is no lack of phosphates or sodic chloride, potash and organic acids alone of the ordinary salines are missing. The salts of organic acids differ from those of mineral acids in one important particular—namely, their oxidation in the blood to form carbonates with alkaline reaction, although they may have been neutral or acid originally. Thus the citric acid and citrate of potash, which are the principal constituents of lime-juice, are oxidised into carbonic acid, which is removed by the lungs, and (alkaline) potassic carbonate. Potatoes are efficient anti-scorbutics, and contain a large proportion of organic acid, salts of potash, soda, and lime. The Merchant Shipping Act, 1867, requires that after ten days at sea each person shall receive an ounce of lime-juice daily.

The absence of land scurvy at the present time may not unreasonably be attributed in great measure to the universal use of potatoes as an article of food.

Meat varies considerably in its nutritive qualities according to the age of the animal, the state of its nutrition at the time of slaughter, and the proportion of fat. Well-fed prime meat contains more albuminoids and less connective tissue than that which is taken from animals that are badly fed, diseased, or too old or young. The proportion of fat, roughly speaking, ranges from 50 per cent. in fat pigs or sheep to 33 per cent. in fat oxen or lambs, and 16 per cent. in calves. Absence of fat is largely compensated by presence of additional water, so that the nitrogen remains fairly constant. As a rule, "white meat," such as fowl and rabbit, is less nitrogenous, more

tender, and more digestible than "red meat," such as beef, mutton, and game. The latter become more tender if kept until *rigor mortis* gives place to incipient putrefactive changes.

Relation to disease.—The flesh of animals suffering from any inflammatory disease is watery and innutritious, and decomposes rapidly. It is said to cause diarrhœa. The same applies, more or less, to animals emaciated from any cause. In some persons acute dyspepsia and diarrhœa are caused by apparently normal meat of certain kinds, usually pork or mutton. As a rule, meat in an advanced stage of putrefaction is liable to cause acute gastro-intestinal irritation, and other manifestations of septic poisoning, the prominent symptoms being vomiting, diarrhœa, cramps, prostration, pyrexia, with weak and irregular pulse. It is not easy to account for the impunity with which certain kinds of food, venison and game for instance, are habitually consumed in a state of decomposition. It is possible that for some reason toxic products are wanting in the latter case, or the putrefactive organisms may not be the same. Certain parasites, to which further reference is made in a later section, are clearly transmissible to man, and therefore suffice to render the whole carcase unfit for food; the chief being the *Tæniæ* in beef, mutton, and pork, and *Trichinæ* in pork. Sheep are liable to *Strongylus filaria* in the lungs, *Distoma hepaticum* in the liver, and *Cœnurus cerebralis* in the brain; but these are held to require only the removal of the affected organs.

The flesh of animals affected with any acute specific disease should be rejected, not only upon the grounds already stated in reference to inflammatory diseases, but also on account of the risk of imparting the specific malady. Anthrax has been proved to be so transmitted, and there is strong suspicion that

the same may be true of tuberculosis, although it has been customary to pass for food carcases that present only incipient and local signs of tuberculosis (page 348). Boiling, roasting, or pickling affords but imperfect protection against the dangers attendant on the use of flesh of animals suffering from any of the above-mentioned diseases, or pleuro-pneumonia, foot-and-mouth disease, cattle plague, farcy, glanders, sheep-pox, rabies, septicæmia, pig-typhoid, or hog-cholera. Ballard and Klein have discovered in samples of bacon the specific microbe that gave rise to infectious pneumonia at Middlesborough, but whether these microbes are to be regarded as indicating diseased or only infected meat remains to be proved. The "Welbeck disease" is another transmissible malady, the symptoms of which (if any) in the pig during life are not known. Accident, parturition, or purely local diseases, such as apoplexy or intestinal obstruction, do not necessarily render a carcase unfit for food, provided that the animal has been slaughtered before any inflammatory or other constitutional mischief has occurred. The flesh of over-driven animals is said to be injurious. Drugs, tartar emetic for example, administered to the animal before death may remain in the tissues, and cause ill effects in those eating the flesh.

An animal that has died with the blood in it was presumably diseased, and it is customary to condemn such a carcase.

The "Welbeck Disease."—At Welbeck, Notts, in June, 1880, a large number of persons were taken ill after eating some ham at a public luncheon. Ballard found that this was the only condition common to all the sufferers. The onset occurred in some cases suddenly, for the most part between twelve and thirty-six hours later. The symptoms included violent diarrhœa, vomiting, and abdominal pain, usually accompanied or followed by pyrexia, thirst,

headache, cramps in the limbs, cold sweats, and great prostration. Particulars were obtained of seventy-two cases, of which four were fatal. The ham was observed to have a disagreeable taste, but was not suspected to be tainted. It had been exposed to sewer air. Samples of the suspected ham were examined by Klein, who found peculiar sporules and bacilli in the muscular fibres, and similar bacilli in the kidney of a man who died of the disease. Dogs, cats, rabbits, guinea-pigs, and white mice were fed upon the ham, and nearly all developed pneumonia and other symptoms; inoculation of white mice and guinea-pigs gave the same result. Cultivations of the bacilli were made, and guinea-pigs and white mice fed or inoculated with the cultivations presented the same symptoms.

A second series of cases occurred in Nottingham, in February, 1881, among persons who had partaken of some hot baked pork. Fifteen were attacked, and one died. The time and mode of onset, and the general character of the symptoms, were similar to those noted in the Welbeck outbreak. The mischief was traced to one particular joint, which was well cooked, and sold from a cookshop to several families; nothing abnormal was made out as regards its appearance, taste, or antecedents. Not all the persons who ate of it were taken ill, but where one member of a household was attacked, all who had partaken of the same portion suffered also. Klein examined the tissues of the fatal case referred to above, and found the Welbeck bacilli in the blood, pericardial fluid, lungs, spleen, kidney, and elsewhere. The kidneys and lungs were affected, and showed hæmorrhagic infarcts. Cultivations of these bacilli inoculated into mice and guinea-pigs caused pneumonia and other symptoms in all; and the bacilli were found in the blood and exudations of these animals.

A similarly sudden and localised outbreak of diarrhœa among a number of persons at Carlisle in 1889, was traced to the consumption of a particular sample of pork. Here again Klein found the pork to cause a definite and fatal illness in mice fed upon it, and from their tissues he obtained a bacillus, differing in character from the Welbeck bacillus. It was cultivated upon gelatine, and mice inoculated with the cultures succumbed with the same symptoms.

Characters of good meat.—It should be firm and elastic, but not tough; not watery, but a thin red fluid will often exude in small quantity on standing; red throughout, not pale, or purple, or green; marbled by veins of fat; free from purulent or gelatinous fluid in the septa between the muscular bands; fresh and not unpleasant in smell, as tested by a knife which has been plunged into the interior. The reaction should be slightly acid. The meat should "set" within twenty-four hours.

The flesh is pale in young animals, and in those suffering from exhausting diseases; dark in old animals, or those which have died with the blood in them, and in inflamed parts; wet in dropsy, and often in inflammatory diseases. With commencing putrefaction the colour becomes pale, and the smell disagreeable; later the meat softens in parts and turns green.

The liver, lungs, and flesh should be examined for parasites; the mouth, stomach, and intestines for evidences of specific diseases. The microscope would detect *Cysticerci* (usually visible to the naked eye) and *Trichinæ* in muscle, and *Stephanurus dentatus* in the brain. To demonstrate *Trichinæ*, a thin section should be put into liquor potassæ for a few minutes only until the muscle becomes translucent. The coiled embryo will be seen inside a capsule.

Fat consists of olein, palmitin, and stearin, which are respectively oleic acid, palmitic acid, and stearic

acid, combined with glycerine as a base. Stearin, $\left.\begin{matrix}(C_{18}H_{35}O)_3\\C_3H_5\end{matrix}\right\}O_3$, melts at about 65° C.; palmitin, $\left.\begin{matrix}(C_{16}H_{31}O)_3\\C_3H_5\end{matrix}\right\}O_3$, at a variable point between 35° C. and 60° C.; olein, $\left.\begin{matrix}(C_{18}H_{33}O)_3\\C_3H_5\end{matrix}\right\}O_3$, at 5° C. Fats with a high melting-point, such as mutton fat, consist mainly of stearin; those with a low melting-point, such as bacon fat, principally of olein.

The fat should be firm, white, and free from hæmorrhages; not yellow or gelatinous.

Sausages are liable to convey the same diseases as the meat from which they are made, but there are no longer any microscopic signs to guide us. In a fatal case at Chester, investigated by Ballard, violent symptoms of gastro-intestinal irritation came on within half an hour of eating some sausage, which was found upon experiment to contain an organic chemical poison. Decomposition may be detected by the smell, which is brought out powerfully by boiling with water and adding lime-water.

Preservation of meat may be effected for a time:

(1) By exclusion of air. The meat is dipped into boiling water so as to form an impervious layer of coagulated albumen on the surface; or coated with paraffin, or simply with fat.

(2) By exclusion of germs. The meat is cut into pieces and heated in a large vessel, the mouth of which is then tightly closed with pure cotton wool.

(3) By injection of preservative solutions. The blood-vessels are injected first with water, then with a solution of alum and aluminic chloride—or even sodic chloride.

(4) By application of preservatives to the surface. The meat may be covered with salt, sugar, boracic acid, boroglyceride, powdered charcoal, weak carbolic

acid, or other fixed antiseptic. Or it may be kept in a closed vessel containing sulphurous acid, or oil of mustard, or other volatile antiseptic.

(5) By pickling. Common salt, with a little potassic nitrate, is rubbed into the meat, or the latter is immersed in strong brine. Water is abstracted and the salt acts as a preservative.

(6) By drying. Meat is exposed in somewhat thin layers to dry air, or, still better, to the smoke from a wood fire.

(7) By continuous exposure to cold. Meat can be kept in ice for an indefinite period, but decomposes rapidly upon thawing if *rigor mortis* had set in before freezing. It is better to keep the temperature a little above freezing-point, that is, somewhere about 38° F.

(8) By hermetically sealing in tin cases *in vacuo*, or in sterilised air. Various devices are adopted to sterilise the contents of the tins. Before sealing, air may be drawn off and replaced by nitrogen and sulphurous acid, or by air which has been heated to 500° F., or by steam. Other processes aim at complete exclusion of air, or exclusion of part and removal of oxygen from the remainder by means of sodic sulphite.

The dangers attending the use of preserved meat are those depending upon the original character of the meat, already referred to, together with risk of putrefaction if the process is imperfectly carried out. Tinned meat sometimes gives rise within twelve hours to symptoms of acute gastro-intestinal irritation, viz. vomiting, purging, cramps, some degree of pyrexia, irregular pulse, and prostration. These ill effects may result from decomposition due to imperfections in the process; and in this case the tin will show signs of pressure in place of the usual vacuum, and the meat may have an offensive smell and taste. Not infrequently, however, no such changes are noticed, but salts

of tin, zinc, or lead are found in the meat and jelly, due, no doubt, to the action of sodic chloride or organic acids upon the tin or solder, perhaps aided by galvanic action.

Cooking brings about coagulation of the myosin and other albuminoids, and renders the meat soft and tender by converting the connective tissue into gelatin. Boiling in the ordinary way causes a loss of 25 per cent. or more, but most of the salts and soluble substances may be retained by plunging the meat for five minutes into boiling water, and then continuing the cooking at a low temperature. The various albuminoids coagulate at temperatures ranging from 85° to 170° F., hæmoglobin at 160°. If, therefore, the temperature at any part does not reach 160° the meat is underdone ; and if it exceeds 170° the tissues shrink and become hard and indigestible. The best temperature is about 160°. Roasting also entails a loss of about 25 per cent., but mainly of water, with some fat and a little gelatin. It is advisable to first expose the meat to an intense heat and afterwards cook it slowly.

Fish are, as a rule, nutritious and digestible but deficient in fat, though eels contain it in abundance, and salmon and herrings also. They should be fresh, firm, and free from offensive smell. The least decomposition renders them unfit for food, and liable to cause gastro-intestinal irritation if eaten. Similar symptoms occasionally follow the use of apparently sound fish. The liver of the halibut, and probably that of other fishes also, sometimes causes diarrhœa and vomiting, and within a few hours a vivid red rash may appear over the upper part of the body, followed by profuse desquamation lasting several days. Fish are largely preserved by the means already referred to, and especially by drying, curing, salting, or canning. Oysters eaten raw are almost self-digesting, but **shell-fish** as a rule are indigestible,

and not infrequently cause dyspepsia and urticaria. Mussels are especially prone to be poisonous, the symptoms including not only dyspepsia and urticaria, but also swelling of the tongue and fauces, numbness of the limbs, and weak, irregular pulse. Very severe and often fatal attacks have been attributed to eating mussels gathered upon shores polluted by sewage. Many of the cases of mussel-poisoning are believed to be due to simple acute dyspepsia, but others have been traced to an alkaloidal poison (*mytilotoxine*) contained in the liver of the mussel.

Milk contains nitrogenous substances, fat, carbohydrates, salts, and water, and may be regarded as a complete diet in itself. The chemical composition varies somewhat according to the species and breed of animal, and the diet and physical conditions.

	Average Country-fed Milk.	Average Town-fed Milk.	Alderney Milk.	Fore Milk.
Water . . .	88 %	86 %	87 %	90 %
Fat	3	4	3·2	0·2
Casein . . .	4	5	4·5	9·7
Milk Sugar . .	4·5	4·3	4·1	
Salts (Ash) . .	0·7	0·7	0·7	0·7

It is usual and convenient to include all the albuminoids in milk under the heading of casein.

The fat is suspended in milk in microscopic globules, which upon standing rise slowly to the surface, forming cream. The facility with which this occurs depends upon the size of the globules, and is increased by addition of water. The proportion of cream averages about 8 per cent., but ranges from 6 per cent. in very poor milk, to 12 per cent. or 15 per cent. or more; in Alderney cows it may reach 40 per cent. One part of cream is said to correspond roughly to 0·2

part of fat. A much more complete separation of cream is effected upon the commercial scale by the *separator*—an apparatus in which the milk is rotated rapidly, with the result that the light, fatty globules remain at the centre, while the comparatively heavy "separated milk" is carried by centrifugal force to the margin. When the apparatus is at work, milk is added constantly, cream being drawn off from the centre and separated milk from the margin. Skim milk retains 1 per cent. or more of fat, separated milk scarcely any. Both contain the casein, sugar, and salts of the milk from which they were made, and have, therefore, considerable nutritive value.

The first part of the yield of milk, known as the "fore milk," contains very little fat; the last part, the "strippings," is rich in cream.

Milk-sugar undergoes fermentation, like other sugars, upon the introduction of a suitable microbe. Under the influence of the *Bacterium lactis*, which abounds in the vicinity of dairies, milk will turn sour if kept under suitable conditions, owing to the conversion of the sugar into lactic acid, which latter coagulates the casein. If milk is sterilised by heating, and then kept in tubes guarded by plugs of cotton wool to exclude air-borne organisms, it remains good for an indefinite period; but if the cotton wool plug is omitted, the *Bacterium* gains entrance from the air, and lactic fermentation results. Several other microbes have the power of forming lactic acid when grafted on a solution of milk-sugar. After the lactic fermentation of milk, a bluish tint is produced by the growth of *Bacillus syncyanus*;* and still later the casein is attacked by putrefactive bacteria, and ordinary decomposition ensues. Alcoholic fermentation of milk, or rather of milk-sugar, can also be set up by adding certain microbes

* Other microbes occasionally turn milk yellow (*Bacterium synxanthum*), or red (*Micrococcus prodigiosus*).

and excluding air. In this way "koumiss" is prepared from the mare's milk, and "kefir" from that of cows, goats, and sheep.

Milk becomes sour much more rapidly in hot weather, or if the cow is diseased. If kept cool and in the dark, it absorbs oxygen and gives off carbonic acid, and the fat increases, owing to the slow conversion of a part of the casein. Milk exposed to sewer gas absorbs it readily, and soon decomposes: upon distillation it yields an offensive and poisonous liquid, causing headache and diarrhœa.

Adulterations.—Addition of water and abstraction of cream are by far the most frequent frauds. Sodic carbonate, sodic chloride, borax, or salicylic acid are occasionally added, either as preservatives or in order to mislead the analyst, but the traditional chalk and calves' brains are now unknown. Skim milk or separated milk is sometimes fortified by the addition of condensed milk.

Addition of water lowers the specific gravity, the percentage of fat, "solids not fat," and salts; it also makes the cream rise more readily to the surface.

Abstraction of fat, by skimming or by the use of the separator, increases the specific gravity and the percentage of salts and "solids not fat," but of course reduces the fat and therefore the yield of cream.

The addition of condensed milk to skim milk may give an appearance of extreme richness, but the salts and "solids not fat" will be in excess.

Preliminary Tests.

I. *Specific gravity* of milk is measured by the *lactometer*, an instrument that is similar in construction to an ordinary hydrometer, but graduated on the stem from about 1020 to 1040. The specific gravity averages about 1029; it is increased by skimming, and lowered by watering.

II. *Cream.*—A cylindrical graduated glass is filled up to a certain mark with the milk, and after standing for twenty-four hours the depth of the layer of cream is read off by means of the graduations. As already stated, it averages about 8 per cent., but varies from 6 per cent. to 12 or 15 per cent. or more. Solid impurities will subside to the bottom of the vessel.

III. *Opacity.*—Several rapid optical tests of the proportion of fat have been based upon the opacity that is caused by the fat globules. Feser's "lactoscope" is the most convenient. It consists of a graduated glass cylinder, into which 4 c.c. of the milk are placed and diluted with successive quantities of water until certain black lines upon a central porcelain stem become faintly visible through the milk. When sufficient water has been added for this purpose, its level is read, and the corresponding graduation upon the lactoscope shows empirically the percentage of fat in the sample milk, and also the percentage (if any) of water fraudulently added. The indications of the lactoscope are by no means exact, but they furnish a very convenient rough preliminary test, by means of which most watered milks will give suspicious results.

IV. Microscopic examination is rarely necessary, but may reveal pus-cells, fungi, or added impurities.

V. The addition of a drop of solution of diphenylamine in sulphuric acid may reveal adulteration by water, if the water contain nitrates, by giving a blue tint.

Qualitative analysis.—The points determined are the percentages of *water*, *fat*, and *solids not fat* (*i.e.* casein, milk-sugar, and salts). The result of many thousands of analyses shows that, although the fat varies greatly, the percentage of "solids not fat" in unadulterated milk does not fall below 8·5 with very rare exceptions. Hence 8·5 per cent. is adopted as a standard. If a given milk contains x per cent.

"solids not fat," and x is less than 8·5, we can affirm that however poor the milk might have been originally, it must contain added water to the extent of at least $\left(\frac{8{\cdot}5 - x}{8{\cdot}5} \times 100\right)$ per cent. of the sample; or, in other words, it is $\left(\frac{8{\cdot}5 - x}{8{\cdot}5} \times 100\right)$ per cent. worse than the worst known natural cow's milk. If it was originally milk of fair quality, the adulteration must have been much greater.

Similarly, the fat in unadulterated milk is never less than 2·5 per cent., unless the "fore milk" alone is taken. When skimming as well as watering is suspected, the ratio 2·5 : 8·5 may be taken as the minimum proportion of fat to "solids not fat"; so that if the "solids not fat" are x, the fat should be *at least* $\frac{2{\cdot}5}{8{\cdot}5}x$, and if the ascertained amount y of fat falls short of this, it is concluded that at least $100 \times \left(\frac{2{\cdot}5}{8{\cdot}5}x - y\right) \div \frac{2{\cdot}5}{8{\cdot}5}\ x$ per cent. of fat has been abstracted.

Milk in relation to disease.—Milk has been proved beyond doubt in a large number of instances to act as the carrier of infection of scarlet fever, enteric fever, and diphtheria, and cholera must now be added to the list. It is believed that the scarlet fever poison gains access to the milk in the form of epithelial scales from an infected person; enteric fever by the use of specifically polluted water for adulteration or for washing the cans; and diphtheria by the breath or sputa. But it is open to question whether the virus is not sometimes derived from a morbid condition in the cow itself. The Hendon outbreak goes far to prove this as regards scarlet fever; and there is reason to believe that diphtheria (page 300), and even enteric fever, may be dependent upon disease in the cow. Whether the other infectious diseases, such as measles, whooping

cough, and small-pox, are ever conveyed by milk remains to be proved. If they are, it is strange that no well-authenticated instance has yet been recorded. An inflammatory affection of the udder, known as *garget*, has been suspected of causing outbreaks of diphtheria in those using the milk. Milk from cows suffering from foot-and-mouth disease is capable of producing illness with aphthous stomatitis, swelling of the tongue, and fœtor of the breath, especially in children; in other cases a severe form of sore throat has been the chief feature. Similar symptoms may attend the use of milk from cows affected with inflammation or abscess of the udder.

Tuberculosis, too (page 348), is transmissible by milk. The evidence is less clear in regard to other specific diseases to which cows are subject, and indeed in most of them the secretion is suppressed, but the milk should never be used for food. Certain fungi, some of which cause a blue layer to form upon the surface, occasionally gain access to milk and multiply in it, giving rise to stomatitis, dyspepsia, and severe gastric or gastro-intestinal irritation in those who drink the milk. In the Western States cows are subject to a disease called the "trembles," supposed to be due to their devouring *Rhus toxicodendron*, and the milk from such cows causes in children vomiting, constipation, swelling of the tongue, and prostration, with abnormally low temperature. The milk of goats that had fed on *Euphorbium* or Meadow Saffron has been known to induce severe diarrhœa. Even in the human subject it is well known that bitter and purgative drugs, not to mention morphia and other alkaloids, if taken by the mother, act upon the infant through the milk. Milk that from long standing, warmth, absorption of effluvia, or want of cleanliness, has become sour or offensive, is liable to cause gastro-intestinal irritation, and is beyond doubt an important factor in the etiology

of epidemic diarrhœa in children. The colostrum, or milk yielded by cows immediately after calving, may give rise to indigestion and diarrhœa; after a week it may safely be used. Occasionally outbreaks of illness occur that appear to be due to milk, but no evidence can be obtained of disease in the cow or in persons having access to the milk, or of fermentative change in the milk. Thus at Aberdeen, in 1881, there was an undoubted milk epidemic of a disease characterised by severe rigors and pyrexia, followed by much enlargement of the glands of the neck, but without the usual symptoms of diphtheria.

Boiling the milk removes all danger of transmission of specific disease, but is inoperative against toxic substances.

The "Hendon Disease." In December, 1885, a sudden and extensive outbreak of scarlet fever occurred in Marylebone, and was found by the Medical Officer of Health to be associated with a particular milk supply derived from a farm at Hendon. The milk was also distributed in St. Pancras, Hampstead, Hendon and St. John's Wood; in each of these districts, except the last, scarlet fever suddenly became prevalent 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 15th and 16th; a few days later, from December 20th onwards, a number of cases of scarlet fever occurred among those who had drunk the milk, and at the same time there was a sudden decrease in the number of attacks in Marylebone. There was, therefore, no room for doubt that the disease was conveyed by the milk, but it remained to be shown how the milk became infected. The whole outbreak was investigated by Power and Klein, and led to the important discovery that the cow itself was the source of infection.

There had been no case of scarlet fever among the employés or their neighbours that could reasonably be suspected of having infected the milk. Attention was next directed to the cows, and many of them were found to be suffering, or to have recently suffered, from vesicles or ulcers upon the teats and udder. These were clearly infectious, and had been first seen upon a cow that 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 cowsheds 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. By cultivation a streptococcus was obtained, supposed to be identical with that of scarlet fever, and having the property of solidifying milk if kept for two days at 35° C. It was not found in the milk from unaffected teats. Inoculation of calves with pure

cultivations of the streptococcus produced a constitutional disease that had many points of analogy with scarlet fever, the condition of the kidneys especially differing in no respect from acute scarlatinal nephritis.

The theory of "bovine scarlet fever" is rejected by the veterinary profession and by some medical authorities, but it does not now rest solely upon the evidence arising out of the Hendon outbreak. Morbid conditions in the cow, recalling the "Hendon disease," have been found in association with other milk epidemics of scarlet fever. Subsequent observation has extended the suspicion of bovine disease to diphtheria also.

Milk epidemics.—Power and other observers have pointed out certain general characteristics of outbreaks of disease transmitted by milk which it may be well to indicate here.

1. The outbreak is usually sudden; and the cessation often almost equally so, if allowance is made for late cases in infected households, which have probably been infected from the earlier cases and not by the milk.

2. A large proportion of the attacks are simultaneous or nearly so. The outbreak reaches its maximum too rapidly to admit of satisfactory explanation by the hypothesis of infection from the first cases; thus, in the outbreak of scarlet fever at Wimbledon in 1886–7 the daily number of attacks was as follows:—

Date .	Dec. 25	26	27	28	29	30	31	Jan. 1	2	3
Attacks .	1	11	39	53	75	118	65	86	25	15

3. It will often happen that two or more persons in the same household are taken ill at the same time. This may also occur apart from milk or water infection, but it is very exceptional, especially as regards the first invasion of the household.

4. The average number of cases per infected household is usually greater than occurs under ordinary conditions, but this is of course dependent upon the number of persons who consume the milk. An *average* of two attacks per household may be considered high.

5. A very large proportion of the households attacked will be found to have a common milk supply, which, however, may not be distributed by the same retailer.

6. Conversely, if (A) the number of households supplied by the suspected dairy be ascertained, and also (B) the number of such households attacked, it will be found that the proportion of B to A is much greater than the proportion which the total number of infected households bears to the total number of inhabited houses in the district. Although in some cases 50 per cent. or more of the houses supplied with the implicated milk are attacked, in other instances the proportion is far lower.

7. If the households supplied by the dairy in question are classified according to the quantity of milk bought daily, it will be found that invasions are proportionately more numerous among households taking a larger supply.

8. A similar calculation, substituting individuals for households, will give similar results. Classifying the consumers according to the average consumption per head in the households to which they belong, a heavier incidence upon the larger consumers will be manifest. Hence the wealthier consumers, upon the average, suffer more than the poorer class in milk outbreaks, and a classification according to rental will usually confirm this.

The Wimbledon outbreak, already referred to, illustrates these relations (*Cooper*) :—

I. Incidence on Consumers, according to Supply per Head.		II. Incidence on Houses, according to Supply per House.		III. Incidence on Houses, according to Rental.	
Milk supplied per Head (Pints).	Percentage of Persons supplied attacked.	Milk supplied per House (Pints).	Percentage of Houses supplied invaded.	Rateable Value of Houses supplied.	Percentage of Houses supplied invaded.
·05 to ·1	14	·25	40	£10 to £12	21
·1 to ·2	23	·5	40	£13 to £15	39
·2 to ·3	41	·75	50	£16 to £20	50
·3 to ·4	39	1·0	49	£21 to £25	64
·4 to ·5	46	1·5	58	£26 to £30	66
·5 to ·6	57	2·0	70	£31 to £35	57
·6 to ·7	40	3·0	67	£36 to £40	76
·7 to ·8	46	3·5	74	£41 to £50	73
Over ·8	49	Over 3·5	78	£51 to £60	74
				£61 upwards	80

9. Among persons who drink little or no milk, or only take it in tea or coffee, or always have it boiled, attacks will be rare, except after exposure to infection from earlier cases.

10. As a corollary to this, there will be found to be a much heavier incidence among children and women than among men. This would be especially significant in regard to enteric fever, which under ordinary conditions chiefly affects adults.

11. So far as scarlet fever is concerned, the type of disease in milk epidemics has been noticed to be usually mild and attended with low mortality.

12. Cream, or milk kept overnight, is often more virulent than milk used in the fresh state.

Preservation of milk may be effected by boiling,

by exclusion of air, or by the addition of sugar, boroglyceride, or other antiseptic. *Condensed milk* is prepared by evaporating down *in vacuo* at a low temperature to about one-third or one-quarter of the original volume, and most manufacturers then add sugar as a preservative. The added sugar renders it too carbonaceous and fattening, but apart from this the nutritive value of condensed milk seems to be inferior to that of fresh milk, especially in regard to bone-formation and stamina. Condensed milk is, as a rule, free from suspicion of adulteration or pollution, but in one instance it was believed to be the means of spreading scarlet fever.

Butter.—When cream is violently agitated, the fat globules are ruptured and their contents clot together as butter. The water is expelled by pressure, and salt is added. The flavour of butter is due to the butyrin, caproin, and caprylin, which together constitute about 7·8 per cent. of the fat, the rest being composed of olein, stearin, and palmitin. Besides fat, butter contains water, casein, and salts. The casein averages 2·5 per cent., but may reach 7 per cent. if the butter is carelessly made; such a butter keeps badly. The water ranges from 8 to 12 per cent. in good butter, and should never exceed 16 per cent. The ash should not exceed 8 per cent.; in pure fresh butter it is usually about 2 or 3 per cent. or less, and includes calcic phosphate and sodic chloride.

Adulterations.—The addition of annatto or other harmless colouring matter is not regarded as adulteration. Starch is sometimes added, and may be recognised by its blue reaction with iodine. The chief and only important adulterations practised are the substitution of foreign fat and the addition of water.

The *analysis* of butter turns chiefly upon the proportion and composition of the fat and the proportion of water.

1. The fat should exceed 80 per cent. of the whole. (If the butter is melted in a tall glass, the water and curd will collect at the bottom, leaving the pure fat above.)

2. The specific gravity of the pure fat should be at least ·91100.

3. The melting-point of the fat should be about 35·8° C., but it is liable to variation, not only with variation in the relative proportions of normal constituent fats, but also with repeated meltings. Adulteration with dripping, lard, or other animal fat raises the melting-point, while vegetable fats lower it.

4. The soluble fatty acids (butyric, caproic, caprylic) should not be less than 5 per cent. of the fat, and the insoluble fatty acids should not exceed 89·5 per cent. Butter fat differs from all others in containing fatty acids that are soluble in water, and their partial or complete absence denotes substitution of foreign fat.

5. Pure butter fat is readily soluble in ether, whereas other fats dissolve slowly and leave a residue.

6. Fat crystals may be visible under the microscope, and serve to show that the butter has been melted, presumably for the purpose of adulteration.

7. Water is estimated by heating a weighed quantity of butter over a water-bath until it ceases to lose weight. Anything over 16 per cent. is to be regarded as fraudulent admixture.

Nothing has been made out very clearly as to the convection of specific disease by means of butter. An outbreak of diarrhœa in a large hospital was shown by Shirley Murphy to be in all probability due to the consumption of a particular kind of butter. The symptoms resembled those of tyro-toxicon poisoning, to be mentioned presently, and it is highly probable that butter, as well as cheese and cream, may contain this poison.

Margarine has recently been the subject of special legislation, which will be referred to in another section. The term is applied generically to fats, for the most part of animal origin, treated so as to resemble butter in appearance and flavour as far as possible. For this purpose a certain proportion of genuine butter is frequently mixed with it. It may possess nutritive value little inferior to butter, especially if manufactured from pure animal fats. The tests have been sufficiently described under the head of butter.

Cheese is formed by the action of rennet upon milk, and consists of coagulated casein with a variable proportion of fat and salts. The best, such as Cheddar, Cheshire, double Gloucester, and most American cheeses, are made from entire milk, the poorer from skim milk, or a mixture of skim and entire milk. Stilton cheese is made from entire milk, to which cream has been added. A good cheese, if kept under suitable conditions of temperature, undergoes a change, known as "ripening," that improves its flavour. Oxygen is absorbed, ammonia and carbonic acid are given off. The casein undergoes fatty metamorphosis, and the calcic phosphate reacts upon the fats and the casein, giving rise to lime salts of fatty acids, and a soluble compound of casein with phosphoric acid. Lactic acid, valerianic acid, and leucin are also formed.

Tyro-toxicon (diazo-benzene butyrate) is a poison discovered by Vaughan in cheese that has undergone a peculiar fermentation. Such cheese is not necessarily altered in appearance or taste, but has a much stronger acid reaction than usual. Tyro-toxicon can be detected chemically by neutralising with sodic carbonate, exhausting with ether, evaporating the ethereal solution, and dissolving the residue in water. The aqueous solution strikes an orange, red, or purple

colour when treated with a mixture of equal parts of carbolic and sulphuric acids. It is intensely poisonous, causing dryness of the mouth and fauces, a sense of constriction in the throat, nausea, vomiting, diarrhœa, and great nervous prostration. The symptoms usually pass off in a few hours, but may end in death from collapse. Butter and cream, as well as cheese, have given rise to tyro-toxicon poisoning.

Adulterations are unimportant. Starch is said to be added sometimes. The use of skim milk or colouring matter is not regarded as adulteration. Cotton seed oil or other foreign fat is sometimes added in place of the abstracted cream.

Analysis.—The proportion of fat to casein should not be less than 1 to 2 at the very lowest ; sometimes the fat exceeds the casein. Water ranges from 20 to 35 per cent., fat from 35 per cent. down to 22 per cent. in good cheese, and to 1 per cent. in skim milk cheese. Casein varies between 25 and 50 per cent., and salts between 3 and 6 per cent.

Lard should be absolutely free from water and from foreign fat. The addition of water is detected by melting the lard in a tall glass and allowing time for the water to collect at the bottom. Watered lard is said to have a "colder" taste and a more opaque whiteness than pure lard.

Cotton seed oil is the other important adulterant. It is detected by its low melting-point, high power of absorbing iodine, and reduction of nitrate of silver.

Eggs.—The average weight of a hen's egg is about two ounces, of which 10 per cent. is shell, 60 per cent. white, and 30 per cent. yolk. The white consists of albumen, with 86 per cent. water, and the yolk of albumen and fat with 52 per cent. water. The percentage composition may also be stated thus :—Shell 10 per cent., albumen and fat 23 per cent., water 67 per cent.

Preservation.—Air may be excluded by coating the shell with butter, lard, oil, wax, gum, etc., or by boiling for half a minute so as to coagulate the surface albumen. Antiseptics are also employed, *e.g.* the eggs are immersed in lime water, salt water, or solution of boro-glyceride.

Tests are only necessary for the detection of stale or rotten eggs. Two ounces of salt in a pint of water form a solution in which good eggs sink and stale ones float. Fresh eggs are transparent at the centre, stale eggs at the top.

Vegetable Foods.

Wheat-flour is rich in albumen and carbohydrates, poor in fat and salts of organic acids. It contains 8 to 12 per cent. of gluten, and can therefore be made into bread. The salts are chiefly phosphates of potash and magnesia.

Examination of flour.—Flour should be free from acidity or mouldy smell. The colour should be white, a yellow colour indicates age, fermentation, or conversion of starch into dextrin and sugar.

The microscope may reveal any of the following :—

(1) *Foreign starches*, especially potato and rice, the characters of which will be described presently. (2) *Fungi*, the most common of which are sporangia of *Puccinia*. One species of *Puccinia* produces "caries" or "smut" of wheat; smut gives the flour a disagreeable smell, and the bread a blue colour. It is said to cause diarrhœa.

(3) *Vibriones* and other organisms in fermenting flour. (4) *Acarus farinæ*, common in damp, inferior flour which is beginning to change.

Weevils (*Calandra granaria*) can also be seen with the naked eye.

Adulterations and impurities.—The chief are the additions of foreign starches and mineral matters.

Analysis.—*Water* should not exceed 16 per cent. The more the water the greater the liability to change. *Gluten* should not be less than 8 per cent., and may reach 12 per cent. It is separated by making the flour into a paste and working it with the fingers in a stream of water until all the starch is washed away. *Ash* should not be less than 0·8 per cent. or more than 2 per cent. If excessive, it should be tested for iron (indicating addition of clay), calcic sulphate, and magnesic carbonate. A simple test is to shake the flour with chloroform; the flour floats, but mineral matters sink. *Alum* is sometimes added during grinding.

Ergotised flour is detected by making it into a paste with dilute alkali, adding slight excess of dilute nitric acid, and then neutralising; ergot gives a reddish violet colour, changing to red in presence of nitric acid, and to violet in presence of alkali. Potash gives a herring-like smell with ergotised flour.

Foreign starches will be recognised under the microscope, but a few other tests are available. Bean meal gives off a characteristic smell when drenched with hot water, and may also be detected by the successive addition of nitric acid and ammonia, which strikes a deep red colour. Potato starch grains swell up on the addition of a trace of potash in solution, which scarcely affects wheat starch grains. Pure wheat flour, made into a dilute solution in water, is turned pink on addition of iodine; but if any potato starch is present, a dark purple colour will appear.

The flour should also be put to the practical test of bread-making.

Bread is made by mixing flour with water, and kneading it, so as to form dough by the cohesion of the moistened gluten. The dough is charged with carbonic acid, which occupies innumerable lacunæ and renders the mass porous. It is then baked and

becomes bread. The carbonic acid is supplied by the use of yeast ("leaven") or baking-powders (dry alkaline carbonates mixed with tartaric or other acid), or by forcing the gas by pressure into the dough (Dauglish's "aërated" bread). 100 lbs. of flour make about 130 to 150 lbs. of bread.

During baking a certain proportion of dextrin and sugar is formed from starch, and there are traces of lactic and butyric acid. Alum checks these changes, which are especially prone to occur if bad flour is used. Mechanically aërated bread is the whitest and most free from dextrin and sugar.

Examination.—Bread should be white. A yellow or dark tint may be due to old or inferior flour, bad yeast, admixture of rye, or merely to presence of bran. Acidity may be caused by old or inferior flour. Bread is heavy and sodden if from any cause the dough has not risen sufficiently ; such causes are bad yeast, bad flour, too much or too little heat, or other defect in manipulation. The loaf should be permeated in every part with closely set, small, regular cavities.

Water should not exceed 45 per cent. An excess lowers the nutritive value, and favours the growth of fungi. The *ash* ranges from 1·3 to 2·0 per cent. *Alum* is detected by pouring upon a slice of bread a freshly-made decoction of logwood chips, and then a solution of ammonic carbonate. If alum is present it acts as a mordant, and after the lapse of half-an-hour, or less, a strong blue colour is manifest, which is quite distinctive for practical purposes, so far as bread analysis is concerned, although magnesic carbonate would, if present, give the same reaction. Pure bread is merely stained pink by the reagents, and on drying this changes to a dirty brown. The blue given by alumina salts is permanent on drying—much more so than in the magnesic carbonate reaction.

For legal purposes it is necessary to determine

the alumina quantitatively, and then a deduction must be made for the maximum amount of phosphate of alumina which may be present in pure bread. It is usual to deduct 6 grains (of alum) per 4-lb. loaf,* anything in excess of this being regarded as adulteration. In exceptional cases pure flours may contain more than this, and many analysts now allow 8 or 10 grains per 4 lbs. Alum used for purposes of adulteration usually amounts to from 20 to 40 grains per 4-lb. loaf.

Foreign starches, especially rice and potato starch, may sometimes be detected under the microscope even after baking, but as a rule they are beyond recognition in bread. Potato makes the bread damp; the percentage of water is high, and the ash is alkaline instead of being neutral. Rice has in itself a low ash (0·85 per cent.). Excessive moisture and low ash should raise suspicion of foreign flour. High ash, on the other hand, is suggestive of mineral adulteration.

The seeds of *Lolium temulentum* (darnel grass) are liable to be ground with wheat flour, and cause vertigo, vomiting, convulsions, and other symptoms of poisoning.

Barley is in the main similar to wheat in chemical composition, but contains more nitrogen, iron, and phosphates. It is liable to cause diarrhœa. Actinomycosis is now regarded as due to eating raw barley or other cereals, upon which the *actinomyces* is epiphytic. **Oats** contain more fat and more nitrogen than wheat does, and are more readily cooked, but gluten is wanting, and hence bread cannot be made of oatmeal.

Rye contains less gluten than wheat, and makes a dark sour bread, which is apt to cause diarrhœa in those unaccustomed to its use. Ergotism results from the use of rye attacked by *Claviceps purpurea*.

* More precisely 0·005 per cent. of phosphate of alumina.

Maize (Indian meal) contains much fat, and its albumen to be made digestible requires careful cooking. Pellagra has been attributed to a fungus (*verdet*) attacking maize. **Rice** is poor in nitrogen, fat, and salts, but is very digestible.

Leguminosæ contain much nitrogen, chiefly in the form of legumin. Peas and beans are less digestible than cereals and require prolonged gentle boiling.

Potatoes are antiscorbutic and very digestible. Good potatoes sink in a saline solution of specific gravity 1,100; bad ones float.

Starch is not a simple chemical substance, but a mixture of three bodies—*granulose*, *erythro-granulose*, and *cellulose*, which are respectively turned blue, red, and yellow by iodine. Granulose is the most important of these. Boiled in water, or with oxalic or other organic acid, it is converted into "soluble starch" or *amidulin*, a soluble dextro-rotatory substance chemically indistinguishable from granulose, and giving the blue iodine reaction. If instead of organic acid a 2 per cent. solution of sulphuric acid is boiled with the granulose or starch, the soluble starch first formed is converted into *dextrin* or *erythro-dextrin*, a sort of gum, which is dextro-rotatory, and is reddened by iodine; it is precipitated by alcohol and acetic acid, but not by tannic acid. Still further heating with sulphuric acid produces *achroödextrin*, which gives no colour reaction with iodine, and *glucose*.

Erythro-granulose is in small proportion in wheat starch, and almost absent in potato. Its affinity for iodine is greater than that of granulose, but the red tint is completely hidden by the deep blue of the iodine-granulose. If a minimal proportion of iodine is employed, the red colour appears. Both the red and blue disappear on heating, owing to dissociation of iodine and starch, but reappear on cooling.

The starch occurs in the various farinacea in microscopic granules, which in many cases have a sufficiently characteristic appearance to indicate their origin. The granules vary greatly in size. Some are roundish, others oval, pyriform, truncated, polyhedral; some have distinctive markings, especially faint concentric rings or a hilum.

Microscopic examination of starches.—A little of the starch, in a state of fine powder, should be mixed with a drop of water, preferably containing 30 per cent. of glycerine, and put under the microscope. The principal varieties may be arranged in five classes (*Muter*).

1. *Large oval or pyriform grains with hilum and concentric rings.*—This group includes potato starch, and several varieties of arrowroot. *Tous les mois*, or Canna arrowroot, has the largest grains of all; Maranta (Jamaica or St. Vincent) arrowroot is characterised by a linear hilum at the larger end.

Potato starch grains vary greatly in size and shape; the hilum is minute, but distinct, and is placed at the smaller end.*

2. *Irregular, round, or oval grains with stellate hilum, but no rings.*—Maize starch grains are round, or polygonal with rounded angles. Bean and pea starch grains are oval and very much alike, but the former are far more uniform in the size of the grains.

3. *Round or oval grains without hilum or rings.*—Wheat starch grains differ greatly in size, and there is a characteristic absence of medium sizes; they are round and flattened. Polarised light shows a cross.

Barley starch is much more uniform. Rye starch

* Potato starch may also be distinguished from arrowroot by certain chemical tests. When mixed with twice its weight of hydrochloric acid, the former gives a transparent jelly, the latter a white paste. Potato starch gives an offensive odour when heated with sulphuric acid. Potato starch jelly made with water turns thin and sour in twelve hours, maranta not for three or four days.

granules, if old and dry, often present a large stellate hilum.

4. *Grains truncated at one end.*—Sago starch has a round hilum at the convex end, and faint rings ; the starch grains of prepared sago have a large depression. Tapioca starch grains are smaller than sago, and some of them show signs of alteration by heat.

5. *Angular grains.*—Oat starch is often massed into little balls or clusters of grains fairly constant in size. Rice starch is smaller than oat, and pepper starch the smallest of all. Under very high power both rice and pepper show a hilum. Tahiti or Tacca arrowroot is larger than oat starch, and less uniform in size ; it resembles maize, but has sharp angles.

Summary.—From what has been said it will be seen that there are many ways in which health may become affected by articles of food.

1. Certain essential constituents of diet may be deficient or in excess.

2. Flesh may contain some poisonous substance administered as a drug or eaten as food.

3. Poisonous substances may be derived from the vessels in which the food has been kept. Thus tinned provisions (fruit, fish, or meat) may become poisonous, and cider kept in lead-glazed vessels may cause lead-poisoning.

4. Injurious substances may be added or substituted accidentally, or by way of adulteration.

5. Certain kinds of food are liable to be occasionally poisonous even in the fresh state, under unknown conditions (mussel-poisoning).

6. Putrefactive or fermentative changes may have commenced.

7. Poisonous substances may be developed, either as a result of parasitic growth ("verdet," ergot) or from unknown causes (tyro-toxicon).

8. The flesh or milk of an animal suffering from certain specific or parasitic diseases may impart the disease (*e.g.* tuberculosis, trichinosis, hydatids). Actinomycosis affords an instance of somewhat parallel danger from vegetable food.

9. Food, and especially milk, may become infected by virus of human origin (diphtheria, enteric fever, scarlet fever).

10. Disease, or more rarely idiosyncrasy apart from disease, may render certain kinds of food injurious, which to ordinary persons are wholesome.

11. Certain accessories of diet may be injurious if used injudiciously (alcohol, tea).

In the systematic investigation of suspected cases of poisoning by food, much help may be obtained by the use of a suitable tabular form, of which an example is given below. A separate line is devoted to each item of food consumed in the household, with separate columns for each day and for each inmate, *whether ill or not.*

	M. 36. Ill.			F. 34. Ill.			M. 12. Not ill.			F. 5. Not ill.		
	Mon.	Tu.	Wed.	Mon.	Tu.	Wed.	Mon.	Tu.	Wed.	Mon.	Tu.	Wed.
Beef	×	..	×	×	..	×	×	..	×	×	..	×
Pork	..	×	..	..	×	..	..	..	..	..	..	..
Fish	..	×	..	..	..	..	..	×	..	..	×	..
Potatoes	×	×	×	×	×	×	×	×	×	×	×	×
Cabbage	×	×	..	×	×	..	×	×	..	×	×	..
Bread	×	×	×	×	×	×	×	×	×	×	×	×
Butter (fresh)	×	×	×	×	×	×	..	..	..	..	..	..
,, (salt)	..	..	..	..	..	..	×	×	×	×	×	×
Cheese	×	×	×	..	..	..	×	×	×	..	..	..
Milk (cooked)	×	×	×	×	×	×	×	×	×	×	×	×
,, (uncooked)	×	×	×	×	×	×	..	×	×	×	×	×
etc. etc												

The list should be as complete and detailed as it can be made by the most careful inquiries. When the table is filled up, it will be seen at once what articles of diet (if any) were consumed by all the sick and by none of those who escaped attack.

CHAPTER V.

SOIL.

THE chemical and physical constitution of the soil and the configuration of its surface have an important bearing upon many hygienic questions, especially as regards climate, disease, sites of houses or towns, water supplies, and burial-grounds.

Temperature.—The daily variation of temperature ceases to be perceptible at about three or four feet from the surface. The annual variation is unimportant below six or eight feet, very small below 24 feet, and vanishes at 40 feet* (*Galton*); the maximum is later and later as the distance from the surface increases, and at Edinburgh it was found that in trap-rock at a depth of 24 feet the maximum was in January and the minimum in July. The absorption of heat, assuming that the exposure is equal, is determined mainly by the nature of the soil and the presence or absence of vegetation. The absorption on sand being taken as 100, that of clay is about 70, chalk 60, and humus or mould 50. Radiation varies in like manner, but is generally greater than absorption. Trees and shrubs intercept the sun's rays, and on the other hand check evaporation from the surface of the soil, the net result being to render the ground cool and moist in winter, and cool and dry in summer when the leaves are out. The evaporation from leaves is enormous, and tends to moisten and cool the air, and abstract water from the soil. Pettenkofer calculated that an oak tree with 750,000 leaves had in the summer months an evaporation equal to eight times the rainfall, and in Algeria the *Eucalyptus globulus* has been found to

* 50 to 100 feet (*Parkes*).

absorb and evaporate twelve times the rainfall.* Herbage lessens absorption of heat by the soil, and also true radiation, but increases evaporation and convection owing to the vast surface of the blades of grass. Grass, therefore, like trees, renders the soil cooler and drier, and more equable in temperature. Earth-temperatures are usually determined by thermometers protected by open wooden covers, suspended by a chain at the required depth in the soil, and withdrawn at daily or other intervals for reading. An iron tube driven vertically into the ground affords a passage for the thermometer. Systematic records are usually kept of the daily readings of two earth-thermometers, at depths of one foot and four feet. At greater depths the internal heat of the earth produces an appreciable effect, causing a rise of about 1° Fahr. for every 55 feet.

Moisture.—At a certain point below the surface in permeable soil, all the interstices are full of water, to the complete exclusion of air. At and below this level there is therefore a continuous sheet of water, known as the *subsoil water* or *ground-water*, which extends downwards to the next impermeable stratum. In marshy ground the surface of the subsoil water may coincide with that of the ground itself, and under ordinary conditions it may be from two or three feet to a hundred feet or more below the ground level. The surface of the ground-water is not necessarily horizontal, nor parallel with that of the ground. It flows (usually towards the nearest watercourse or the sea) with a velocity that varies with the permeability of the soil, the steepness of the gradient, and the absence of obstruction by roots of trees.† The level is

* As regards the air, forests render both the daily and annual temperatures more equable, and increase the humidity (*Galton*).

† In Munich Pettenkofer estimated the velocity of the ground-water to be 15 feet per day.

affected by rainfall, or rather by that portion of the rainfall which percolates through the soil; also by the height of water in adjoining streams or seas, and other conditions modifying the facility of outflow—artificial drainage, for example.* Sometimes the range of rise and fall does not exceed a few inches, but it is more usually several feet.

Above the level of the ground-water the soil, though aërated, is still kept moist by capillary attraction, by evaporation from below, by rainfall, and by the movements of the ground-water. The soil constantly loses moisture by evaporation from the surface, both directly and through vegetation.

The moisture of a sample of soil is estimated by weighing it before (B) and after (A) drying it on a water-bath. Then $\frac{B-A}{B} \times 100 =$ percentage weight of water in sample. The level of the subsoil water is necessarily that of the water in surface wells, and may be gauged by lowering into the well a cord or rod bearing little cups at short intervals, or more simply by means of an index connected by a cord with a float.

When the ground-water rises, it forces air out of the soil, and at the same time may pollute wells by bringing into them the washings of impure soil. As the ground-water falls again it leaves the soil moist and aërated, conditions favourable for fermentative and putrefactive processes in polluted soil.

Damp ground is rendered dry, and the level of its ground-water permanently lowered, by subsoil drainage. For this purpose "agricultural" pipes, *i.e.* unglazed porous pipes, are laid loosely end to end at the bottom of deep trenches, and covered in. The interval to be

* De Chaumont found the tide affecting the level of a well 140 feet above mean water level, at a distance of 2,240 feet.

allowed between the parallel drains will depend upon the openness of the soil.

Air ("ground-air") is present in all rocks except the very hardest, above the ground-water level. It fills all the space unoccupied by water or solid particles. The proportion by volume varies greatly with the porosity and other conditions of the soil; loose sand may contain 50 per cent., and humus several times its own volume of air.

Ground-air contains moisture, organic matter of animal or vegetable origin, and sometimes NH_3, H_2S, or CH_4. Carbonic acid is in excess, and increases with the depth, it also varies greatly according to the nature of the soil and the intensity of the local chemical changes that are going on in it. Oxygen is in relatively small proportion, and decreases with the depth. At 13 feet Fodor found 14 per cent. of CO_2 and 7·5 per cent. of oxygen. Many causes combine to keep the ground-air in constant movement, among them being wind, percolation of rain, variations in temperature and barometric pressure, and rise and fall of ground-water.

The percentage volume of air in a sample of rock of specific gravity G may be determined by finding its weight when dry (A), and when saturated with water (B). Then $\frac{B - A}{A} \times G \times 100 =$ percentage of air. For loose soils Pettenkofer used two graduated burettes connected together at the bottom by a clamped tube. One burette was filled with water, and the other with dried and crushed sample soil. Water was then allowed to pass upwards through the soil, displacing all the air until it just reached the surface.

$$\frac{\text{No. of c.c. of water used}}{\text{No. of c.c. of dry soil}} \times 100 = \text{percentage of air.}$$

All rocks are more or less permeable, and therefore capable of containing air or water in their interstices. A cubic yard of granite or marble holds about a pint of water, sandstone 25 gallons, sand 50 gallons.

Chemical composition.—The mineral constituents of soil are of the utmost variety, but only the organic matters will be considered here. The soil undergoes constant pollution by dead animal and vegetable matter and excreta, which are as constantly being removed by putrefaction; nitrification, and the influence of vegetation. Apart from such obvious examples as graveyards, manured fields, sewage-farms, and the like, unintentional pollution of the soil goes on upon an enormous scale, especially around dwellings. Nitrates are commonly found in abundance in the soil of any long-inhabited place. Carbonic acid and other simple compounds are formed concurrently; offensive gases are given off during putrefaction, but are deodorised and oxidised by passing through aërated soil.

Vegetable matters are more persistent. They may undergo putrefaction and slow oxidation, but it is not certain that nitrification takes place. One of the objections to heavy wooden coffins is their durability when buried.

Sometimes the natural level of the ground is artificially raised, constituting what is known as "made soil." This may be ordinary earth, but in the neighbourhood of towns it is a common practice to fill up hollows, and to elevate low-lying sites by trade refuse, ashes, household refuse, and even excremental refuse. From such soil the impurities slowly disappear, owing to oxidation and washing by rain. Sanderson and Parkes found that in about three years most of the vegetable matters in cinder refuse had disappeared; wood, straw, and cloth were rotten, but still distinguishable. Free exposure to air and rain and

free outlet for drainage will accelerate the process of purification.*

Nitrification.—Nitrogenous organic matter is oxidised to some extent by filtration, with formation of nitrates. In the upper layers of the soil, to a depth of one to two feet, nitrification of a different kind takes place, by the action of certain microbes. They require oxygen and an alkali or alkaline earth. Calcic sulphate increases their activity ; boiling or the presence of an antiseptic destroys it.

Besides the putrefactive and nitrifying organisms already mentioned, the soil abounds in other microbes, concerning most of which little or nothing is definitely known. Some at least of the pathogenic organisms are known to be able to live and multiply in the earth, and the same may be inferred as regards several others. Among the more important specific diseases anthrax, tetanus, malaria, enteric fever, cholera, diarrhœa, and yellow fever, are closely concerned with telluric conditions. Dampness of soil is favourable to phthisis and diphtheria, and, according to some authorities, to rickets also. Goitre is often credited with a more indirect relation to the soil (page 90).

Enteric fever and cholera exhibit in certain localities a very definite inverse relation to the fluctuations of the level of the ground-water. In Munich, Leipsic, and elsewhere, it has been found that a fall in the subsoil water, and especially a rapid fall after an unusually high level, is followed by an outbreak of enteric fever. These observations, extending over several years, have led Pettenkofer to the conclusion that the conditions requisite for an enteric outbreak are (1) a rapid fall (after a rise) in the ground-water,

* In examining cinders that had been used for elevating the site of some houses in Nottingham, I found at the end of four years many fragments of leather, wool, cotton, and bone. The cinders were dry and covered only with tiles set loosely.

(2) pollution of the soil with animal impurities, (3) a certain earth temperature, and (4) the presence of a specific organism in the soil. These conditions imply a warm, moist, and well-aërated soil, containing pabulum suitable for the supposed microbe. On the other hand, the association of falling ground-water with enteric outbreaks is not observed in other localities. It has not been traced in England, as a rule, and, indeed, outbreaks have occurred with rising ground-water. Although the existence of some direct or indirect relation between the two phenomena in Munich cannot be doubted, Pettenkofer's hypothesis is not the only possible explanation. Buchanan has suggested that the connection between them may be found in pollution of drinking-water in the wells, but Pettenkofer finds no evidence of this from analysis of the water in Munich.

The same conditions, according to Pettenkofer, are necessary for the appearance of cholera in an epidemic form.

Malaria, including under that term the various forms of intermittent and remittent fevers, is the most typically "telluric" disease. The specific microbes have their normal habitat in the soil, and require air, moisture, a certain degree of warmth, and decomposing vegetable organic matter. A rise of ground-water due to heavy rainfall, or impeded or insufficient outflow, is a common antecedent of severe outbreaks in malarious districts, and many such districts in England and elsewhere have been permanently freed from malaria by improved drainage. Superficial desiccation is said to be favourable to the appearance of malaria, and outbreaks have frequently been observed to follow disturbance of the soil. Land that has gone out of cultivation is prone to be malarious if the other conditions are favourable. Marshy land, especially if covered with rank vegetation, is the most common

locus, and estuarial marshes are said to be worst of all. Either permanent flooding or drainage will, as a rule, render them healthy.

Enteric fever, cholera, and yellow fever are often endemic, a fact that in itself is strongly suggestive of telluric relations. They are also found to flourish best where the soil is polluted with excremental or other animal matter. The same may be said of diarrhœa, and Ballard has shown that outbreaks of summer diarrhœa have a close relation with the earth temperature at a depth of four feet. Soil may become infected by anthrax or tetanus, and retain the infection for an indefinite time.

The specific diseases mentioned above may be regarded as having (occasionally or permanently) their habitat in the soil, whence they are transmitted to man by exhalations (miasm), by water, or by inoculation. For diphtheria this has been made out less clearly, though there is some connection with damp. Damp soil has a very great influence upon phthisis. Buchanan has shown not only that phthisis mortality bears a direct relation to dampness of subsoil, *i.e.* to height of ground-water, but also that when the ground-water is lowered and the soil dried by artificial drainage, the recorded phthisis mortality falls, in some instances as much as 30 or even 50 per cent. The term phthisis is, of course, to be taken in a broad sense. It appears, also, that dampness of soil is favourable to all affections of the respiratory system, including bronchitis and pneumonia, whether "simple" or symptomatic of specific maladies, such as measles or whooping cough. In the absence of definite evidence the popular theory that all damp and cold soils are conducive to rheumatism and neuralgia, and all manner of catarrhs, may be provisionally accepted.

A high level of ground-water (say within five feet of the surface) is, therefore, objectionable, and it is

decidedly preferable that it should be fifteen feet or more from the surface; but frequent and extensive fluctuations of level are probably worst of all. The presence of clay, like high ground-water, renders a soil cold. Porous soils, like sand or gravel, with low ground-water, are the warmest, and in the main the most healthy; but it must not be forgotten that they are also the most liable to organic pollution, and that the ground-air moves freely in their interstices. Clay, and especially a clay slope, affords a far more healthy site than gravel or sand containing organic matter, the impure ground-air from which is constantly forced out of the soil, and is also liable to be drawn into the interior of houses through the basement. The most unhealthy site of all would be a hollow with impure gravelly soil and high and fluctuating level of ground-water; the most healthy, the summit of a slope with dry, pure, sandy or gravelly soil, and low and stationary level of subsoil water. The foot of a slope often receives the drainage from the higher ground, and there is the same liability to damp at the junction of an upper porous and a lower impervious bed, especially if the strata dip towards the point in question. In malarial or tropical regions it is necessary to take into account the tendency of winds to pass up valleys and ravines, from lower to higher levels, during the day, and in the reverse direction at night. The proximity of marshy or malarious ground may be dangerous, even if the site itself is otherwise free from objection. Herbage is beneficial, for the reasons already stated, and so too are trees unless they are allowed to interfere with light and circulation of air. Parkes regards brushwood as often harmful. Manured lands have not been proved to be hurtful; but irrigated lands, and especially rice fields, which give off organic matter and much moisture, are injurious; and in Italy rice-grounds are not

allowed within 14 kilometres of cities, or 1 kilometre of small towns (*Parkes*). There seems to be no good evidence against well-managed English sewage farms. "Made soil" is usually impure and unfit for building sites. The objection is greatest when the deposit is recent and contains excremental or other organic refuse, and is so placed in hollows that drainage and aëration are impeded. In many English manufacturing towns houses are still being built (and without air-proof basements) upon sites in which all these conditions exist.

The following is a summary of Parkes's conclusions in respect to the healthiness of certain geological formations, but, as he points out, they are of less importance than the immediately local conditions:—

Granitic, Metamorphic, and Trap rocks, Millstone Grit and Clay Slate are impervious and generally healthy. The slope is great, vegetation not excessive, air dry, and water pure. Marshes are infrequent. These rocks, when weathered and disintegrated, are alleged to be unhealthy.

Limestone, Oolite, and Magnesian Limestone (*Dolomite*) have also much slope, and water passes off readily. Marshes may occur, even at great heights. Magnesian limestone is the worst and oolite the best. Goitre and calculus may be met with.

Chalk is healthy if permeable and free from clay. The air and water are pure. Goitre and calculus are less common than in limestone districts. Marly chalks are impermeable, and therefore damp and cold, and may be malarious.

Sandstone, if permeable, is healthy. The air and soil are dry, but the water is often impure. An admixture, or substratum, of clay may render the site damp.

Sand is healthy if pure and dry. Many sandy soils are unhealthy, and even malarious, *e.g.* when the

subsoil water is high and organic impurities are present. The water is liable to contain salts of the alkalies, lime, magnesia, and iron, and is often unfit for drinking purposes.

Gravel is healthy, except in hollows where the ground-water is high. Gravel hillocks are the healthiest of all sites. The water is usually pure.

Alluvial soils, including Clay and dense Marl, are usually unhealthy. Water neither runs off nor through them, marshes are common, the air is moist, and the water often impure with lime and soda salts. The deltas of great rivers present these alluvial characters in the highest degree, and should not be adopted for sites without thorough drainage.

Much may be done to improve a site not naturally healthy. If damp it may be drained, or trenches may be cut around it so as to intercept the subsoil water on its way from higher ground. By such means the level of the ground-water will be lowered and its fluctuations lessened. Damp places near the site may be drained or filled in, and the site itself may be artificially elevated if necessary. Trees are often desirable for shelter or ornament, but should not be allowed to interfere with light or circulation of air. Rank or superabundant vegetation must be cleared away, but short grass is beneficial.

CHAPTER VI.

BUILDINGS.

Most of the ordinary building materials are pervious to air and water to a greater or less extent. Galton states that with a temperature of 40° F. outside, and 72° F. within, the volumes of air passing through a square yard of wall vary according to the material, as follows :—

Sandstone . . .	4·7	cubic feet	per hour.
Quarried Limestone .	6·5	,,	,,
Brick	7·9	,,	,,
Limestone . . .	10·1	,,	,,
Mud	14·4	,,	,,

The thickness of the wall is supposed to be the same in all cases. Mortar, cement, and concrete are also permeable, and the caustic lime they contain absorbs carbonic acid until it becomes saturated. Wood in its natural condition absorbs water, and the inevitable joints and crevices admit of the passage of air and water.

By painting, varnishing, and other means the inner surfaces of walls, floors, and ceilings can be rendered impervious, and walls lined with glazed bricks or the finer cements (Parian) are scarcely permeable.

The disadvantages of porous materials are obvious, and the air admitted in this way is insignificant in amount and at least doubtful in purity. Pervious walls are liable to be damp and cold. Air passing through them in either direction is filtered, and the wall becomes charged with organic impurities. This is specially the case with the inner surfaces, and in hospitals it is now customary to render the walls and floors impervious as far as possible. The exclusion

of damp and impure ground-air, by means of impervious basements, is absolutely necessary in all inhabited buildings. This may most conveniently be effected by covering the basement in every part with a layer of concrete six inches thick, as required by the Model Byelaws, but other materials may be employed. Richardson proposes to cut off the communication with the soil still more thoroughly by elevating the house upon pillars and arches, thus allowing free play of fresh air beneath it. If there are no cellars, the same result may be attained in some degree by constructing the lowest floor a foot or two above the ground level, and freely ventilating the space beneath by means of large air-grates. In houses built without precautions of this kind the entrance of ground-air through the basement is inevitable whenever the air in the interior of the house is warm, and therefore lighter than that outside.

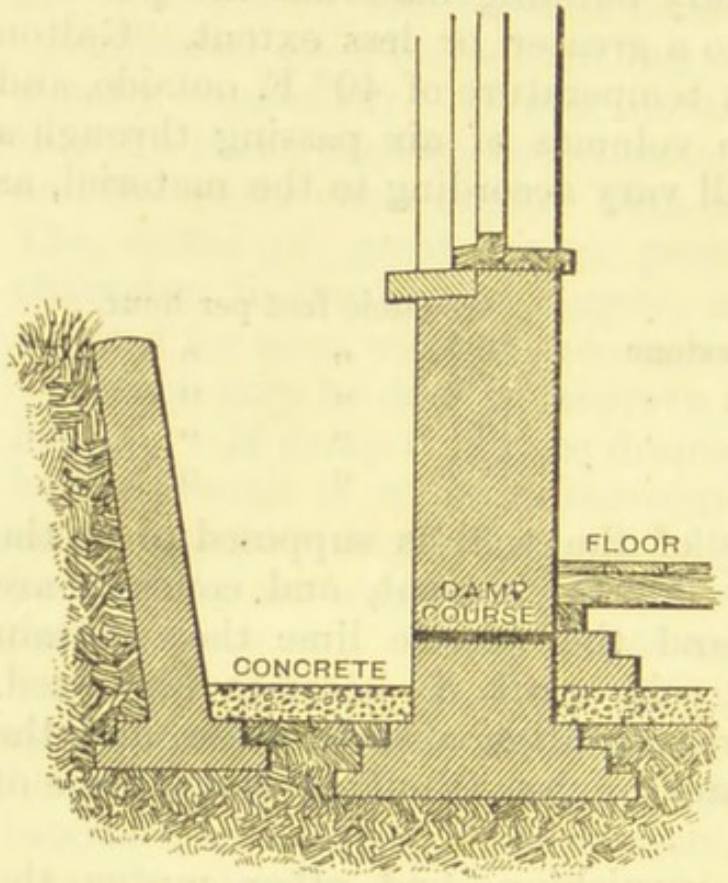

Fig. 6.—Damp-course.

Measures must also be taken to prevent damp from rising in the walls by capillary attraction. For this purpose a "damp-course" must be provided, that is, a continuous horizontal course of glazed earthenware, slate, or other impervious material, of the full thickness

of the wall, above the highest point at which the wall is in contact with the earth, and below the lowest timbers or floor supports (Fig. 6). It is undesirable to allow the soil to be in contact with the wall of any room or cellar, and this can usually be obviated by excavating it on the outside to below the level of the floor so as to form a "dry area," but if this is impracticable the device shown in the Model Byelaws may be employed; the wall is made hollow up to a point above the ground level, and two damp-courses are inserted, one at the level of the bottom of the cavity, and of course beneath the floor level, the other at the top of the cavity, and, therefore, above the level of the ground outside (Fig. 7). In this way the inner wall is completely isolated from the soil.

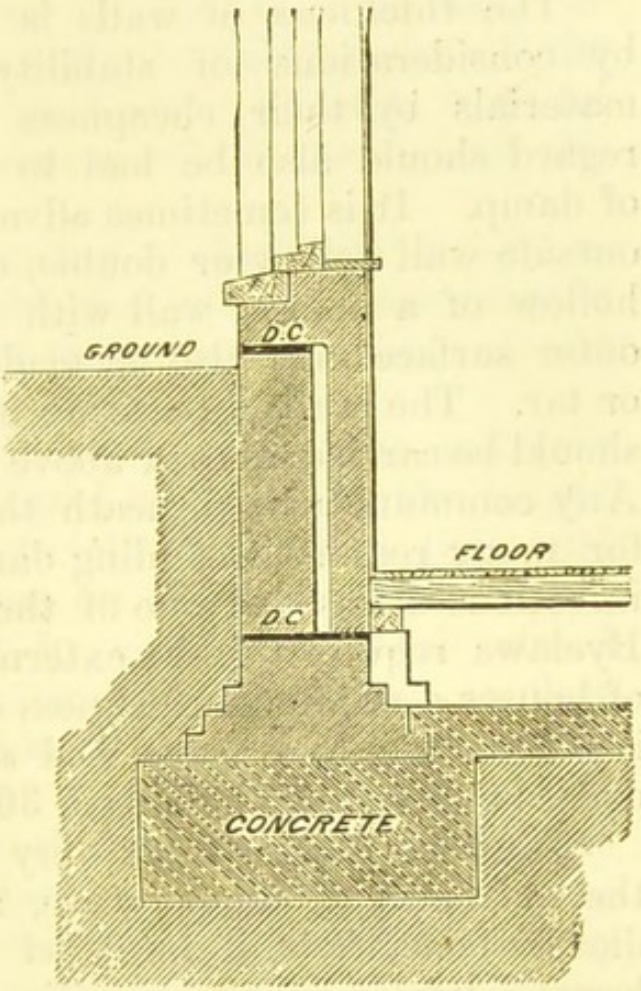

Fig. 7.—Double damp-course. Soil abutting upon hollow wall.

The necessity for free ventilation extends to all closed spaces, including those below floors. There is a tendency among builders to use air-grates so constructed and arranged as to allow but little air to pass. If the ventilation is insufficient, the air becomes damp and musty, and the fungous growth misnamed "dry-rot" is liable to set in. As regards the upper

storeys, however, the ventilation through the boards and ceiling is usually sufficient to prevent dry-rot, unless the floor is covered with oilcloth or otherwise rendered impervious. Fireproof floors are now becoming common.

The thickness of walls is often regulated solely by considerations of stability, and the choice of materials by their cheapness and convenience, but regard should also be had to warmth and exclusion of damp. It is sometimes advantageous to make the outside wall hollow or double, or even to fill in the hollow of a double wall with pitch or cement. The outer surface may also be made impervious by paint or tar. The walls separating one house from another should be carried up to or above the roof in every part. Any communication beneath the roof is objectionable for many reasons, including danger in case of fire or infectious disease in one of the houses. The Model Byelaws require for the external walls or party-walls of houses a minimum thickness of nine inches, increasing according to a prescribed scale when the height exceeds 25 feet or the length 30 feet.

The roof itself affords very little protection from the extremes of temperature, and the rooms immediately beneath it, if intended for occupation, should have a "false roof" or ceiling over them, so as to leave an intervening air-space below the slates.

The size of the rooms will, of course, be regulated by convenience and by the purpose for which they are intended. As a rule, the height should not be less than ten feet, but extreme height is not desirable unless means are provided for carrying away the hot and impure air from the upper part before it condenses and falls again. A window opening top and bottom and placed in an external wall is essential in every inhabited room, and as far as possible a due northern, and therefore sunless, aspect is to be avoided.

Besides the window, every room should have an open chimney, or at least some permanent and effectual means of ventilation not entirely under the control of the occupant. Rooms beneath the ground level are liable to damp, stagnation of air, and deficiency of sunlight, and should never be used as bedrooms. A central hall or staircase of the full height of the house, with ventilating windows at the top, is useful in promoting free circulation of air throughout the building.

For the sake of securing a share of sunlight in every room, it is preferable that rows of houses should run north and south, and that square buildings should have angles in those directions.

Every house should have both in front and rear an open space at least equal in length to the height of the building, so as to allow sufficient light and ventilation for the rooms on the lowest floor. The arrangement of houses in courts or small closed squares is objectionable, since the air cannot circulate freely. Back-to-back houses are still being erected in some of the northern manufacturing towns. In such dwellings through ventilation cannot be obtained, and the absence of curtilage at the back is in itself a serious inconvenience. They have usually dark and ill-ventilated sculleries, pantries, or storerooms, and it is often difficult to secure the satisfactory disconnection of sink wastes The closets have to be built in blocks, often at an inconvenient distance, and in a public position.

Sanitary condition of dwellings.—New houses are, or ought to be, constructed under the supervision of the Sanitary Authority, and in accordance with bye-laws prescribing all details necessary for sanitary purposes. Old houses are very often wanting in many points now regarded as essential for the health of the inmates, and it becomes a matter of considerable

difficulty to decide how far it is practicable to enforce modern requirements in such houses. If the defects are such as to be prejudicial to the health of the inhabitants, it is the duty of the Sanitary Authority to require the necessary repairs or alterations to be carried out, and it is incumbent upon the Medical Officer of Health and Inspector of Nuisances to bring such cases to the notice of the Authority for that purpose. Very often it is not possible to effect such alterations as would be considered satisfactory in new premises, and a certain degree of latitude has to be allowed. No hard and fast line can be drawn between that which is essential and that which is desirable, and a similar difficulty frequently arises in deciding whether a house is or is not fit for habitation. Sometimes the question is only one of degree, in matters regarding which fixed standards are impossible. Several causes may combine to render a house unhealthy.

Inspection of houses.—The following schedule includes the principal points that may require attention. The headings are numerous, but are meant to be chiefly suggestive, so that no important detail may be overlooked. A very few notes will often suffice in practice. As in all other investigations, it is wise to make explicit written notes on the spot, and to insert negative as well as positive results of inspection.

Address.
Occupier.
Owner.—Name and address.
Site.—Elevation, aspect, slope. Proximity to hills, valleys, watercourses. Nature of soil. Dryness.
Surroundings.—House detached, semi-detached, in a row, back to back. Access of light and air. Obstruction by trees, high grounds, or other buildings. Open space at front, back, sides [stating area]. Proximity [stating distance in feet] of stables, cow-sheds, pig-styes, manure heaps, foul ditches, stagnant water, offensive accumulation, offensive trades, or other sources of effluvia.

Yard and Outbuildings.—Condition as to cleanliness, paving, drainage.

Foundations.—Damp-proof course, dry area, banking of soil against walls. Dryness of basement. Exclusion of ground-air. Ventilation of space beneath ground floor.

Walls.—Materials, thickness. Party walls carried up to roof? Dilapidations. Evidence of damp at any part; source of such damp.

Roof.—Construction. Soundness.

Floors, Staircases, Windows, Doors, Ceilings.—Soundness.

Rooms.—Number on each storey, including basement.

Length, breadth, and height
Windows. Total window-space. Space made to open. Opening top and bottom?
Other means of ventilation. Chimney
} of each room.*

Drainage—

Sink wastes
Bath wastes
} Construction and course of waste-pipes.
Lavatory wastes
Floor gullies
} Description and efficiency of traps. Disconnection.

Soil-pipes. Construction, dimensions, position, course, ventilation.

Gullies. Construction and trapping.

Gutters around eaves. Efficiency.

Rain-pipes. Course, trapping, disconnection, destination. Leakage?

House drains. Course, construction, dimensions, gradients, ventilation, means of access, disconnection from sewer. Flushing, cleanliness. Soundness, as tested by smoke, peppermint water, etc. Drains under basement.

Cesspool (if any).—Position, construction, dimensions, ventilation, overflow, watertight.

Closets.—Number, position, cleanliness, lighting, ventilation. If out-door, note distance from nearest door or window. If more than one house using same closet, note the number.

W.C., trough-closet, slop-closet, hand-flushed closet. Kind of apparatus, efficiency, source of water-supply, sufficiency of flush.

Pail-, pan-, tub-, or box-closet. Size of receptacle,

* *As regards sleeping-rooms in basement*, certain further details are necessary, namely, depth of floor below level of adjoining street; width, depth, and lateral extent of area in front; depth of drain below floor. Position of window in respect to steps (if any) bridging across open area.

material, floor-level, means of access, with or without ashes or other admixture.

Privy-midden, privy with cesspit, earth-closet. Dimensions of receptacle, relation of floor to ground-level, materials, watertight, covered, arrangement for applying ashes or earth to excreta. Connected with sewer?

Household Refuse.—Means of storage. Position.

Scavenging.—Mode, frequency, and efficiency of removal of excreta and household refuse. By whom performed.

Water Supply.—Public or private, from mains (by tap or stand-pipe), spring, stream, canal, dip-trough, well, rain-water cistern; distance from house, constancy, sufficiency, purity. Note any obvious risk of pollution. If from well, note depth, construction, lining, cover; distance in feet of nearest possible source of pollution, or filth accumulation of any kind. If from cistern, note position, construction, cover, cleanliness, connection with W.C., discharge of overflow pipe.

Cleanliness of Premises.—Light. Ventilation.

Animals kept.—Description. Number. Where kept. Nuisance resulting.

Inmates.—Number of residents. Age, sex, occupation of each. Number of families; distinguishing tenement occupied by each.

Number sleeping in each room, if there is suspicion of overcrowding. Number sleeping in basement.

Hospitals.—All that has been said in respect of the site, surroundings, and construction of houses applies with still greater force to hospitals. Pure air and light are of especial importance in sick wards, that are occupied day and night. The site should be as dry and open as possible, not exposed to smoke or miasm borne by wind, and not unduly sheltered by trees, buildings, or hills. Long wards should face east and west so as to admit sun on each side alternately, and if any deviation is necessary it should preferably be such as to give a south-east and north-west aspect (*Thorne Thorne*). Single-storey hospitals are preferable, as affording the freest circulation of air. Each ward is then completely detached from the rest, and the absence of stairs is advantageous; but from

motives of economy and convenience of concentration two or more storeys are usually built.

Small wards are inevitable in cottage hospitals, and, indeed, in all hospitals, since provision has to be made for the isolation of severe or infectious cases, and for the classification of patients according to sex, and sometimes according to disease.

As a general proposition, however, large wards are more readily ventilated, warmed, and lighted, more economical in construction and management, and more convenient as regards nursing. For long wards the width should be 24 to 30 feet, the height 13 to 14 feet, and the length such as to allow a cubic space per patient of at least 1,200 feet. Not less than 2,000 feet is considered necessary in a fever or lying-in hospital, or for severe surgical cases. It is not permissible to obtain this space by increasing the height. As already explained, extreme height is of little utility as regards ventilation, and in hospitals it is essential to have plenty of floor space around each bed. For nursing purposes at least 90 square feet per bed is necessary, and more will be required if the ward is largely used for clinical teaching. Wherever there is any possibility of septic or other infection, as for example in surgical wards, lying-in wards, and wards for infectious diseases, wide separation of beds is important. In such cases 12 feet of wall and 130 to 140 feet of floor space should be allowed. It is found that for convenience in nursing the number of beds in one ward should not exceed 32, and usually 24 or 28 would be preferable.

The beds are arranged with their heads to the wall, facing into the ward. Each bed should be placed between two adjoining windows, the space between the windows being not less than a foot wider than the bed. At most two beds may be allowed in one space, the interval between them being at least three feet. The intervals between the windows of a

ward should be such as to allow of this arrangement. The windows should reach to within a foot of the ceiling.

All the surfaces should be impervious and washable, and all ledges, crevices, and stagnant corners in which dust may lodge must be avoided. The floors may be paraffined or waxed, the walls lined with tiles or glazed brick, or Parian cement, or in the absence of such materials simply painted.

The heating may be effected by open fire-places, or ventilating stoves, or both, and it is well to have in addition coils of steam or hot-water pipes. Ventilation must be provided for to the extent of at least 3,000 feet per head per hour, and it may be taken as a safe rule that the whole air of the ward ought to be changed thrice hourly, so that the hourly supply of fresh air should be three times the cubic capacity of the ward. Extraction is provided for by fire-places, stoves, windows opening at the top, Sheringham valves near the ceiling, and in other ways. Special extraction shafts, with inlets at or near the ceiling, are desirable. Such shafts may be carried up alongside, or surrounding the chimney or stove flue, so as to utilise the waste heat as a motive power ; or, independently of these, with a gas jet in the inlet to create an upward current. Some of the most modern hospitals for infectious diseases have an extraction shaft upon a larger scale, the foul germ-laden air being made to pass through a gas furnace. Most, if not all, of the germs are no doubt destroyed in this way, and the rest are prevented from diffusing horizontally. This precaution was suggested by the Hospitals Commission, and is especially important in regard to small-pox hospitals, which have been shown to be capable, under certain conditions, of acting as foci from which infection spreads through the air.

It is desirable to make arrangements for warming the air passing into the wards. This may be done by

means of ventilating fire-grates, ventilating stoves, or coils of hot pipes at the inlets. Windows, Sheringhams, and Tobins may suffice in warm weather. It is a common practice to place the inlets under beds, with the intention of avoiding draughts, and supplying the purest air close to the patients.

In the most approved plans a cross-ventilated corridor or ante-room leads from one corner of the ward to the water-closets and slop sinks, and the bath-room and lavatory are similarly placed at the adjoining corner. At the opposite end is a nurse's room, with a window overlooking the ward.

Hospitals for infectious diseases.—Reference has already been made to the need for greater cubic space and ventilation in such hospitals, and to the importance of guarding against the tendency to aërial spread of infection in certain diseases. The communication with the outside has also to be kept under strict control. It is desirable that "Isolation Hospitals" should themselves be isolated from other buildings, and even from thoroughfares, by reserving as wide an open space as possible. The boundary walls should be $6\frac{1}{2}$ feet high, all round the hospital area. Each disease must be isolated separately, and if possible in separate blocks, not less than 40 feet apart, and the same distance from the boundary. There should be no communication whatever between the different blocks, and the intercourse with the common administrative department should be as little as possible. A special block containing at least two or three small wards is necessary for doubtful cases, or cases not received into the principal wards. (*See* pages 562-563, and footnote p. 568.)

The essential parts of a hospital for infectious diseases are—

1. An administrative block, including rooms for the medical officers, matron, nurses, and servants; dispensary, kitchen, scullery, larder, and pantry;

laundry, linen-room, store-room, coal-place, bathrooms, closets, etc., etc.

2. Hospital blocks, namely, at least one for each disease to be isolated, and in each block at least two principal wards, one for each sex. Additional small wards for one or two beds are desirable. An "isolation block," consisting entirely of small wards, is most useful. Besides the wards, closets, sinks, and bathrooms, each block should contain a nurse's room, overlooking the ward, and so arranged as to serve as a scullery and ward-kitchen for minor cookery; linen-room, store-room, and coal-place. The nurse's sleeping-room must be away from the wards; it may be in the same block, but is more usually placed in the administrative block. Arrangements must be made for the patients from each block to take exercise in the grounds without coming into contact with each other. Small-pox hospitals should be entirely independent of those for other diseases.

3. Mortuary and post-mortem room; disinfecting room; stable and ambulance shed; porter's lodge, etc. etc. The drainage, water supply, and arrangements for heating need no special mention.

The great cost of permanent hospitals—rarely less than £200 per bed—has led to the substitution in many cases of temporary structures, more especially in the presence of an epidemic, when rapidity of construction is the first consideration. Wooden hospitals are common, and can be run up in two or three weeks. The walls must be made double, and it has been found advisable to fill up the hollow with sawdust. The dimensions and arrangements can be made the same as in permanent buildings. The same may be said of galvanised iron huts, which are often used for hospital purposes. Tents can be erected still more rapidly, upon a wooden floor raised above the level of the ground. The

canvas should be double. Recently other forms of temporary hospitals have come into use, especially those of Dœcker and Ducker types. Both of them are convenient in use, and can be erected at a few hours' notice. They consist of a stout waterproof material stretched upon wooden frames, so shaped and numbered that they can be speedily put together to form a complete and weather-proof hut, ready for the reception of patients. Willesden waterproof paper is also used for the construction of huts.

Their comparative cheapness and the rapidity with which they can be erected are important points in favour of temporary hospitals, but nevertheless their proper function is to supplement, and not to supersede, permanent buildings of brick or stone. They are less attractive in appearance than the latter, less comfortable, and more difficult to ventilate efficiently, and to keep warm or cool. True disinfection, such as to fit them for the reception of cases of different diseases, if not impossible, is at least less easy and less certain than in buildings with hard non-absorbent surfaces, free from pores and crevices. Their durability is far less than that of a permanent building, and an annually increasing outlay is needed in order to keep them in habitable repair. It is often claimed on behalf of temporary hospitals that no disinfection is necessary, since they can be burnt at the end of the epidemic, and renewed; but this plan, which would very soon prove more costly than the erection of permanent hospitals, has rarely, if ever, been put into practice. The economy in first cost is great, but is usually exaggerated. It must be remembered that the cost of erecting a permanent hospital, as ordinarily stated, includes the preparation and laying out of the site, fencing, drainage, water and gas supply, erection of accessory buildings, such as mortuary, disinfector, lodge, etc., and the whole cost of the administrative

block. These are not usually included in the stated cost of "temporary" hospitals, although just as essential in the one case as the other. Furthermore, the cost *per bed* largely depends on the number of beds that are allowed in a given cubic space, and it will be found that, if the standard adopted in permanent hospitals is applied to all, the nominal accommodation in temporary hospitals will often be reduced by one half, or more. If the comparison is made upon equal terms, the saving in first cost is insufficient to compensate for the want of durability, and for every purpose of use permanent hospitals have great advantages. The liability to fire must not be forgotten. The only real advantage of temporary hospitals is, therefore, the rapidity of erection, and (except as a supplementary provision) this can only be important when the Sanitary Authority has failed in its obvious duty of providing a hospital without waiting for an epidemic. It is then frequently too late, however speedily the hospital is got ready. Means of isolation are needed at all times, in every large community, and it is even more important to endeavour to delay and prevent outbreaks by secluding the few "sporadic" cases than to grapple with epidemics already in existence.

Temporary erections are most valuable as extensions of permanent hospitals, in case of wide-spread epidemics. All the administrative and other arrangements are (or should be) ready for the additional work thrown upon them, and the simple provision of additional wards, in huts or tents, is all that is necessary, and can be effected in a few hours or days. It is well to have the sites made ready beforehand, and covered with concrete.

Schools.—The general principles as to site, surroundings, construction, and drainage are, of course, the same for schools as for most other buildings. The minimum cubic space per head allowed in Board

Schools is 80 cubic feet, and the floor-area 8 square feet. These standards are very low. A higher standard is adopted for new schools, except infant schools, and the London School Board now require 130 cubic feet per head. The window area should be not less than one-tenth of the floor area, and may with advantage be one-fifth, or more. Every window should be carried up to the ceiling, and should be made to open. Schools should not face a narrow street, or one in which the opposite buildings are lofty, on account of the difficulty of efficiently lighting the rooms on the ground floors.

"Natural" ventilation is rarely sufficient to maintain the purity of the air in schools, and fans or other artificial means are needed, as Carnelley has shown. Open fires do not distribute the heat sufficiently, and are less satisfactory than hot-water pipes.

The seats should be arranged so that the strongest light comes from the left. The edge of the desk should be vertically over the front edge of the seat, and about the height of the scholar's elbow. The seat should be at least 9 inches wide, and about the height of the knee. The desk should slope, and the seat be provided with a back; it is desirable to provide for a little horizontal adjustment of either the seat or the desk, so that they may be slightly separated for writing, and brought together for reading.

Separate closets are required for boys and girls, and there should be at least one for every twenty scholars. Flush-closets are best adapted for the purpose. No dry system works very well in schools, as the admixture of ashes is insufficient for dryness and deodorisation. It is, of course, possible to make pails, earth-closets, or even privies serve the purpose, but only by constant supervision and far more frequent cleansing and scavenging than are usually available can they be prevented from becoming a serious nuisance in schools.

CHAPTER VII.

REMOVAL OF REFUSE.

THE waste matter from households may be classified as

1. Liquid refuse, including water used for washing, and slop-water.
2. Ashes, and vegetable and animal refuse.
3. Excreta.

Drainage is necessary for dealing with the first, and some system of dry removal for the second. The excreta may be disposed of in conjunction with the former ("water-carriage"), or with the latter (privy-middens, ash-closets), or independently (earth-closets, privies, or pail-closets without admixture of ashes).

Drainage.—We may leave for the moment all consideration of the final disposal of the sewage, for whether the house drain is to discharge into a cess-pool or into a sewer, the arrangement is the same.

Drains are intended to remove from the house the liquid and much of the solid filth that is produced within it, and they should be so constructed that in no circumstances can their contents, liquid, solid, or gaseous, escape from them at any but the points specially provided for this purpose. This result is attained by the choice of proper materials for their construction and by sound workmanship, by trapping all inlets so as to prevent the egress of drain-gases, and lastly by efficient ventilation at suitable points.

The traps that serve the second purpose are of various kinds, dependent upon the particular use to which they are put.

A **trap** in its simplest form is a mere bend in a pipe which retains water and thus prevents air from passing through it. For this purpose it is only necessary that the bend shall be sufficient to place

some portion of the roof of the pipe below the water level, the *seal* of the trap being the difference between the surface of the water and the depression at this point. Thus, in the annexed diagram (Fig. 8) the seal is the water between *a* and *b*.

A water-seal alone will not always prevent the passage of gases and particulate matter through it. Gases in the drain undoubtedly can be absorbed by the trapping water and given off from its upper surface. Ammonia has been found to become perceptible through an unbroken trap in fifteen minutes. Moreover, when the water remains stagnant, bubbles of putrefactive gases may be formed, and, by their bursting, particulate matter may be discharged to a considerable distance. The occasional changing of the trapping water is, therefore, necessary to guard against it becoming charged with noxious matter, and the ventilation of the drain is necessary to prevent its air contents from becoming saturated with this matter or subjected to so much pressure that the water-seal is forced.

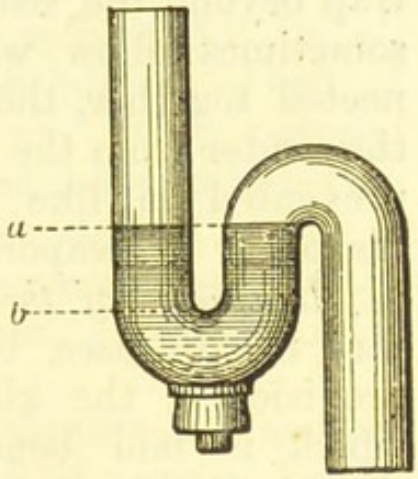

Fig. 8.—Siphon Trap (S-trap) with access screw-plug for cleansing.
a, *b*, the seal.

A trap to fulfil all these requirements must be self-cleansing and must maintain an effectual seal between the drain and the outer air. For the former it must be free from all angles and corners that can retain filth, and for the latter it must have a water-seal not less than $1\frac{1}{2}$ inch deep.

The seal is liable to be broken by a number of circumstances. First, pressure within the drain may force its air contents through the trap. This can be prevented by ventilation of the drain. Second, if the momentum of the water discharge be great, the

water in the trap may be driven out. This can be obviated by shaping the trap so that the water-holding portion is contracted, and the descending arm is larger and square in section. Third, if the discharge pipe below the trap be long, the water discharge may fill it, and suck out the water in the trap by siphon action. This can be avoided by ventilating the top of the trap beyond the seal. Fourth, the same result will sometimes follow when two or more pipes are connected together, the discharge from one sucking out the water from the trap of the other. This can be prevented in like manner. Lastly, the seal may disappear by evaporation, if the trap is little used.

Drainage of the subsoil of a house is not necessary in all cases, but when the site is damp some provision of the kind should be made. The drain which is laid beneath a house for this purpose should consist of suitable earthenware pipes with the joints left open, and laid to a proper outfall, preferably in the open air, but in many instances it must necessarily discharge into a drain connected with the sewer. This connection should never be direct. The subsoil drain should always discharge into a trap, and should be ventilated at or near the trap by a shaft or upright pipe carried above the surface.

The soil drain must be laid with a sufficient fall for the purpose of enabling the drain to clear itself of its solid and fluid contents, and it is generally accepted that this should be one in forty, giving a velocity of flow in a 4-inch drain of about 3 feet per second.* Further, in discharging into a sewer, the drain should be connected with the upper half diameter of the sewer, so as to prevent any possible flooding of the basement at times of heavy rainfall when the sewer

* Maguire's "decimal" rule is convenient; 1 in 40 is a proper fall for a 4-inch pipe, 1 in 60 for a 6-inch pipe, 1 in 90 for a 9-inch pipe.

is charged. To enable this arrangement to be carried out, it is necessary that the original construction of the house should permit of the drain having the necessary fall from the lowest storey of the building.

The soil drain should be constructed of glazed stoneware pipes with cemented watertight joints, or preferably, if the drain be beneath a building, of iron pipes (of which the interior has been coated with Angus Smith's solution) jointed with lead. In all circumstances the drain should be laid on a bed of concrete, and if it be made of any other material than iron the whole drain should be embedded in concrete. It is customary to use drains having a diameter of 6 inches, but a four-inch diameter is sufficient for houses of moderate size. It should never be less than this.

As a general rule, the drain should not be laid beneath a building, but in the case of terrace houses it is often impossible to adopt any other plan. In this situation the drain must be laid in a direct line beneath the building and be embedded and covered in concrete not less than 6 inches thick; the top of the drain at its highest point must not be less than a distance equal to the full diameter of the drain below the surface of the ground under the building. Means of access should be provided at each end of this portion.

An important point in connection with drain construction is the prevention of air from the sewer passing into the drain, or from the drain into the house. The former of these risks is guarded against by the insertion of a trap in the drain as near as possible to the point of its connection with the sewer. The drain should be ventilated immediately on the house side of the trap, by a shaft carried up above the ground level; this will serve a double purpose, by admitting fresh air into the drain, and also affording a free outlet in case the trap is forced by pressure of sewer air.

A more complete and necessarily a more costly arrangement is to provide an inspection chamber at this point (Fig. 9). The drain is continued through this chamber in earthenware channels, and the arm in the trap, which is intended to allow the drain to be cleared between the trap and the sewer, is extended into the chamber. Branch drains are connected with

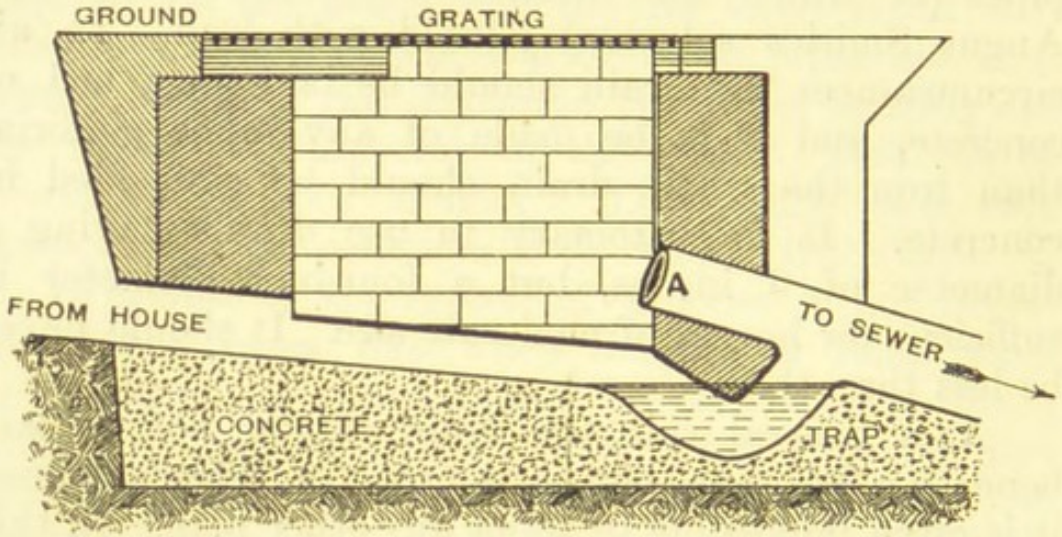

Fig. 9.—Disconnection (Inspection) Chamber.
A, "raking-arm" closed.

the main channel by branch channels in the floor of the inspection chamber.

In connecting branch drains with the main drain of the house, or with one another, no right-angle joints must be formed either vertical or horizontal. They must join obliquely in the direction of the flow.

The second risk, that of air from the drain entering the house, is guarded against in a number of ways :—

1. By the thorough ventilation of the drain.

2. By the efficient trapping of all inlets to the drain, except those required for its ventilation.

3. By the exclusion from the interior of the house of all inlets into the drain, except such as may be necessary from the apparatus of a water-closet.

The proper ventilation of the drain is secured by continuing the soil pipe in its full diameter above the

level of the roof. By this means air entering by the opening near the trap in the main drain is enabled to pass along the whole drain, and issues from the soil-pipe. It is, of course, immaterial whether the position of the two openings is as described or reversed.

The openings referred to must be covered with suitable gratings to keep out leaves and dirt, and to prevent birds from building nests in them, the open spaces in each grating being at least equal to the section of the pipe thus covered.

The sectional area of the ventilating pipe is important. For the purposes of efficient ventilation it is necessary that it should not be less than the sectional area of the drain which it ventilates.

The drain thus constructed should have no openings within the building, except that it may be necessary to connect a water-closet with it. Soil pipes should be situated on the outer walls of the house, and their junction with the drain, often a weak point in construction, will then be outside the house. If through any accident the junction of the soil pipe with the drain should be opened, the escape of drain emanations will then take place into the open air.

Whether the soil pipe is used for the purposes of ventilation or not, the rule to avoid, as far as possible, any bends in its course should be observed. As a general rule, a diameter of 4 inches is enough. The soil pipe should never be smaller than this, and if larger there is often difficulty in ensuring reasonable cleanliness of the internal surface. Iron and lead are both used in its construction; lead is more expensive, but is more durable, and is free from joints that might become loose. Rolled lead should be insisted on when the soil pipe is situated inside the house.

Formerly the provision of a trap at the foot of the soil pipe was customary, but this has now come to be

regarded as objectionable, the principle being accepted that the soil should be removed as quickly as possible from the whole drainage system of the house.

Waste-pipes.—The best method of treating the wastes of cisterns is simply to carry them through external walls, and leave them open in that situation, so that, on the one hand, no unwholesome emanations can enter the cistern, and, on the other, the waste of water resulting from a faulty ball valve is at once seen, and can be remedied. But the wastes of sinks, lavatories, and baths must be differently dealt with. Unless the sink is of the kind known as a slop-sink, and used for disposal of urine, a circumstance that requires it to be treated as a water-closet, all wastes should be made to discharge over trapped gullies in the open air. Such *disconnection* renders it impossible for the air from the drain to enter the house.

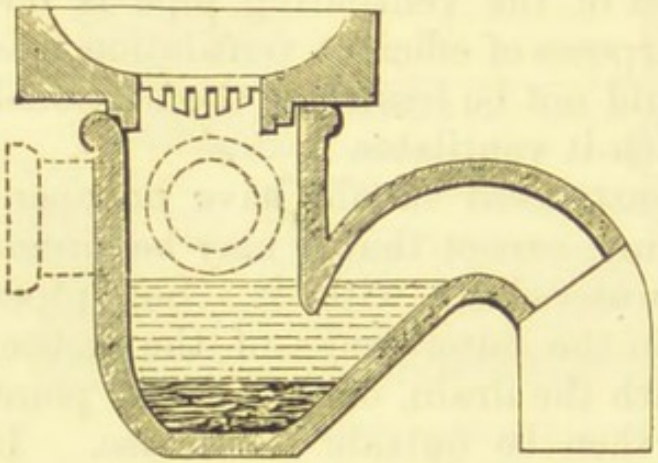

Fig. 10.—Yard Gully.

A suitable form of gully-trap of these wastes is shown in Fig. 10. It will be seen that in this apparatus provision is made for the waste to discharge through a side opening beneath the grating, and above the water in the trap. The grating must be large, with free opening kept constantly clear of obstruction by solid matter, or else the primary object of disconnection is lost. More commonly the waste-pipe pours *over* the grating. Neither of these methods complies with the requirements of the Model Byelaws that the waste-pipe shall discharge over a channel leading to a trapped gully grating at least 18 inches

distant; where, however, the waste-pipe is itself trapped, there can be little objection to the use of the apparatus shown.

But whichever of these methods is adopted, waste-pipes should always be trapped, and the trap situated as near as possible to the sink or bath. This is necessary for the reason that in the course of use the interior of the pipe becomes coated with decomposing soap or fat, which is itself offensive; the higher temperature of the interior of the house leads to an in-current through the untrapped pipe, often giving rise to an exceedingly unpleasant odour.

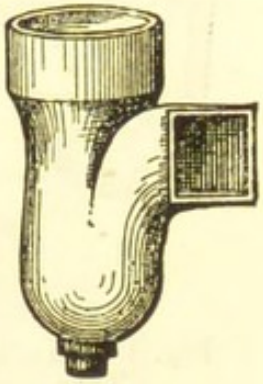

Fig. 11.—"Anti-D" Trap.

A convenient form of trap is one shaped like an S (Fig. 8), and fitted with a screw at its lowest point, by the removal of which it is possible to cleanse the trap. Where the momentum of the water-discharge is great, a useful modification of the trap is that shown in Fig. 11, by which the unsealing of the trap is prevented.

From the trap the waste should be carried as rapidly as possible through the wall, and then made to descend to the gully already described. The ventilation of the trap, which is needed to prevent siphonage when the waste-pipe is long, or when two or more waste-pipes are connected, is effected by the insertion of an air-pipe into the top of the trap, beyond the seal, the other end being carried through an external wall into the open air. Traps of other kinds are not infrequently used, the most common being the bell trap shown in Fig. 12. It is open to more than one objection; the depth

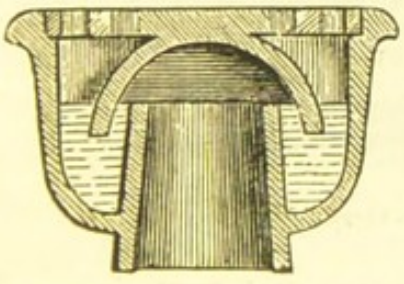

Fig. 12.—Bell Trap.

of the seal is in the first instance only about $\frac{3}{8}$ths of an inch, and thus the least pressure is able to render it abortive; again, it readily becomes choked with grease, and as a result the grating is commonly removed to give opportunity for water to pass away, and on each such occasion the waste-pipe is untrapped.

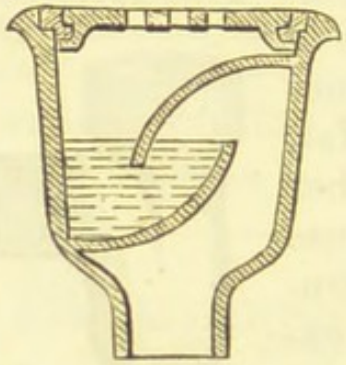

Fig. 13.—Antill's Trap.

Another trap of an objectionable kind is the D-trap shown in Fig. 20. This perhaps is the worst of any apparatus used, inasmuch as it readily becomes filthy, and always leads to the retention of a large amount of offensive matter.

In very large households the gully into which the scullery sink waste discharges is liable to become choked by sand and grease. In such cases the arrangement shown in Fig. 14 is sometimes adopted, the trap being cleaned out at short and regular intervals.

Before leaving the subject of waste-pipes, reference must be made to the custom of discharging the water from sinks and baths in upper storeys into the heads of rain-water pipes. This method undoubtedly fulfils all the requirements as to aërial disconnection, but is liable to cause nuisance, owing to the fouling of the large rain-water pipe with soapsuds and grease. A more perfect, though perhaps a somewhat more expensive, arrangement is to carry the waste directly to the gully, due precautions being taken

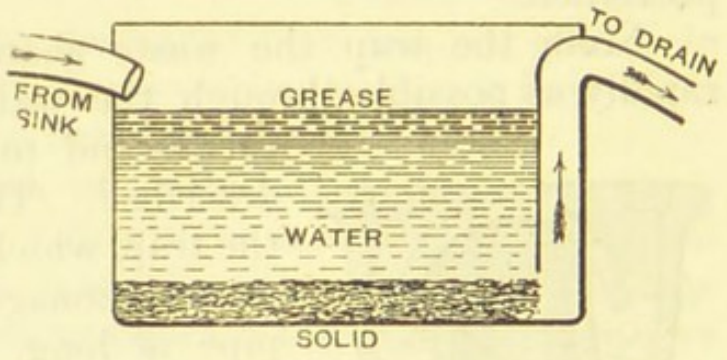

Fig. 14.—Grease Trap.

against siphonage. If the waste-pipe have a diameter of $1\frac{1}{2}$ inch, this will be sufficient even for baths, and if two or more be joined, they may discharge into a somewhat larger pipe; a good arrangement is then to carry a ventilating pipe from the upper end of the common pipe to some convenient position above the level of the windows.

The rain-water pipe should not be used as a soil pipe, or as a ventilating pipe to the drain. Thorough ventilation of the drain is most needed at times of heavy rain, when the rain-water pipe is least able to act in this way; and as the rain-pipe cannot be carried above the eaves of the roof, it often discharges its air contents too near to a window. For the latter reason this pipe should not be connected with the drainage system, but should be made to discharge its contents over a properly trapped gully. But in dry weather there is risk that the gully may become unsealed owing to the evaporation of water in the trap, and therefore, when it is possible, the waste-pipe of a sink, lavatory, or bath which is in frequent use, should be made to discharge into the same trap, and thus ensure that it shall always be charged with water.

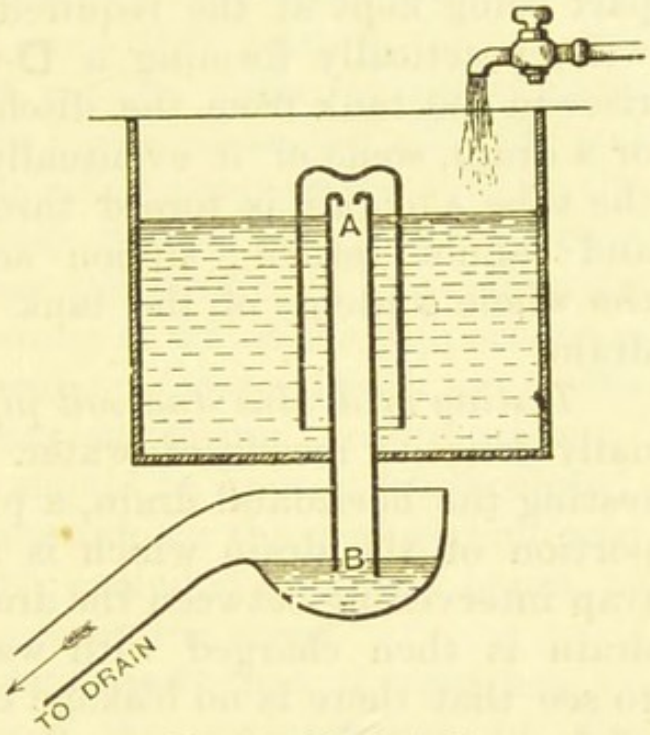

Fig. 15.—Flush-tank.

In small houses the water that is discharged into the soil drain is sufficient to remove its contents, but otherwise this can be accomplished by a

flush-tank that periodically discharges the whole of its contents into the drain (Fig. 15). This tank consists of a cistern that contains a large outer tube closed at the upper end and inverted over a small inner tube A B, thus forming a siphon. A B is open at the top, and passes vertically down through the tank, to dip slightly under the surface of water in a chamber below the tank, the water in this lower part being kept at the required level by means of a weir, practically forming a D-trap. As the water rises in the tank from the discharge into it of a tap or a drain, some of it eventually runs over the top of the tube A B; air is forced through the water at B, and cannot return; siphon action is started, and the whole contents of the tank are emptied into the drain.

Testing of drains and soil pipes can be most effectually done by means of water. For the purpose of testing the horizontal drain, a plug is inserted at that portion of the drain which is near the intercepting trap intervening between the drain and the sewer; the drain is then charged with water, care being taken to see that there is no leakage through or at the side of the plug, and the water is allowed to fill the drain to the top of one of the surface traps connected with it. At the end of from half an hour to an hour the maintenance or subsidence of the water level in this trap will show whether there is any leakage. In testing a large system of drainage it is necessary to take each section separately. In testing soil pipes with water, the plug must be inserted at the bottom, and if several water-closets are connected with the same soil pipe the trap of each must be plugged.

Smoke pumped into the drains previously plugged in the same way serves also as a useful test. The process must be continued until the smoke is seen issuing from the soil pipe or ventilating pipe, and if

several of these are connected with the same drainage system it is necessary that each must be plugged at the top as smoke issues from it until the whole system is charged, care being taken to prevent the smoke from being forced through the traps ; smoke in these circumstances, when there is leakage, soon finds its way into the interior of the house.

Peppermint may be used in the same way ; two or more ounces of the oil are either poured down a soil pipe with a pailful of boiling water, or down some trap situated outside the house connected with the soil drain ; the scent of the oil of peppermint will, in the course of an hour or more, find its way into the house if there be leakage near the surface. In performing this experiment the opening at which the peppermint is inserted should be immediately covered with wet cloths to prevent the smell from saturating the atmosphere ; all windows and doors should be kept carefully closed, and the person who pours down the peppermint and the hot water should be excluded from the house, as his clothes are liable to carry the scent.

The kind of **water-closet** that is used has an important bearing upon the maintenance of the house in a wholesome condition. The material of which it is constructed must necessarily be non-absorbent, and in its shape and capacity the basin must be able to receive the water that is discharged into it, and to allow all filth it receives to fall directly into water without soiling the sides. In both the *valve closet* (Fig. 16) and the *wash-out* pattern (Fig. 17), water is held in the basin independently of that in the trap below. In the one case it is held by a movable valve, in the other by a fixed dam, over which the contents are carried by the flush. In the *plug closet* the valve or dam is replaced by a solid plug, which works vertically in a side-chamber similar to that shown in Fig. 17. *Hopper closets* are of two

kinds; the basin of the old or "long" hopper (Fig. 18) is from its shape and construction liable to become filthy, and it has usually a bad flush; the *improved hopper* (Fig. 19) is free from objection, like the types

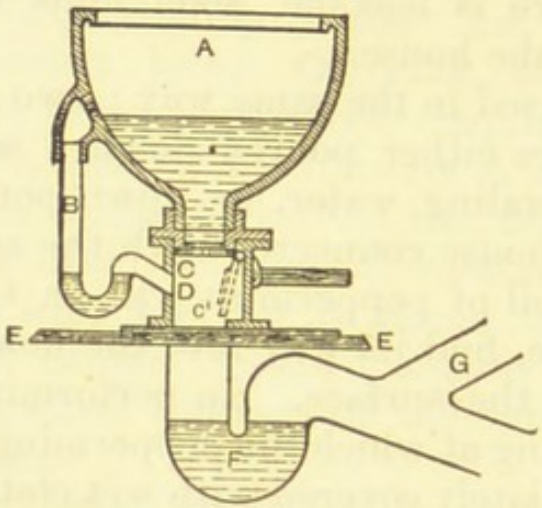

Fig. 16.—Valve Closet.

A, basin: flushing-rim above; B, trapped overflow; C C', valve, closed and open; D, valve-box; E E, safe; F, S-trap, ventilated at G.

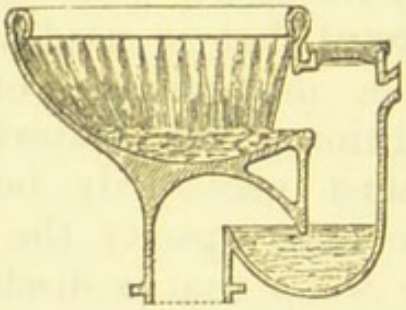

Fig. 17.—Wash-out Closet.

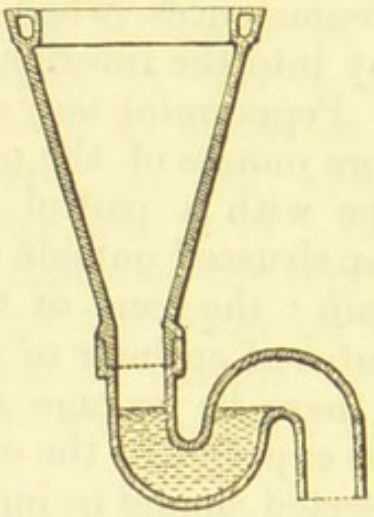

Fig. 18.—Long Hopper Closet.

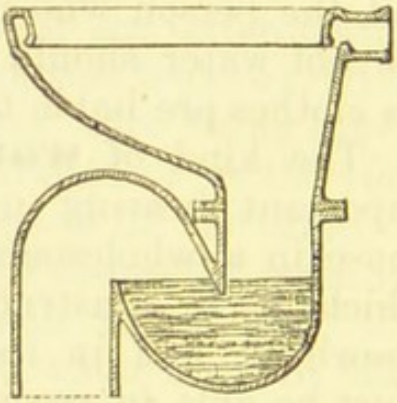

Fig. 19.—Wash-down or Short Hopper Closet.

previously mentioned. There is at present a wholesome tendency to dispense with all unnecessary woodwork and fittings, and to reduce the closet to its simplest form, as in the well-known "Unitas."

The form which is especially objectionable, and which is prohibited by the Model Byelaws, is the old *container closet*, or *pan-closet*, Fig. 20, the basin of which discharges into a large receptacle. This

very soon becomes foul and, every time the valve is opened, allows polluted air to escape.

The apparatus, of whatever kind, should be provided with a flushing rim which directs the water over the whole surface, and maintains it in a state of cleanliness. It is essential that the flush should be of sufficient volume (not less than two gallons), delivered with sufficient force (and for this purpose the pipe must not be less than $1\frac{1}{4}$ inch in diameter), and properly directed so as to wash the basin effectually. The flush must on no account be taken from a service pipe or a cistern that supplies water for household purposes, but from a special cistern. Gases and even filth have been found to make their way from the closet basin up the (usually empty) delivery-pipe.

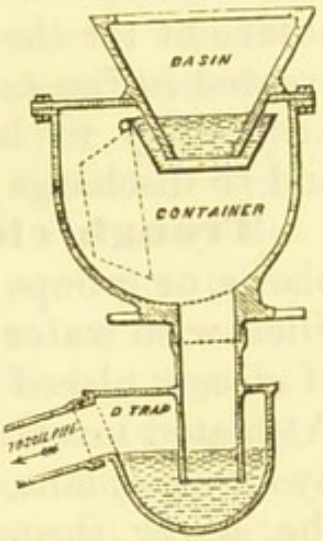

Fig. 20.—Pan Closet, with D-trap.

It is unnecessary to discuss at any length the traps used in connection with water-closets. The S-trap is here again found to be a useful form, but liable occasionally to become unsealed when the momentum of the water-discharge is great; for this reason, therefore, the form of trap (Fig. 11) recommended in connection with waste-pipes to obviate this difficulty is preferable. Whatever condemnation the D-trap has received already should be emphasised here, but unless specially prohibited by the byelaws of the Sanitary Authority, it is not uncommon to find it employed in connection with water-closets, and in this position it is more than ever offensive.

Water-closet traps are liable to become unsealed in the same manner as those of waste-pipes (page 172). Wherever two or more discharge into the same soil pipe, ventilation of the traps is therefore necessary. It is

sufficient if the ventilating pipe from the traps of the lowest water-closet of a series discharging into the same soil pipe receive the ventilating pipe of each above, and be finally connected with the soil pipe above the highest water-closet.

When water-closets or baths are placed on upper floors, they are usually provided with *safes* to receive any overflow or splashings that may result from their use ; such occasions are so exceptional that it is sufficient for the waste-pipe in these receptacles to be treated in the same way as the overflow from cisterns, *i.e.* simply to be carried through an external wall, and to discharge a few inches from the brickwork.

Trough closets are adapted for schools, work-places, or groups of artisans' dwellings. A long trough filled with water passes beneath the seats of a number of closets placed side by side, and receives the excreta. At stated intervals they are flushed, automatically or by an attendant, and the contents are carried away to the sewer through a trap at the outlet end of the trough. The automatic flush may be effected by a tilting receiver placed at the upper end of the trough, and so arranged as to capsize and discharge its contents as soon as it becomes filled by a regulated stream of water ; or still better by a flush tank fed by a stream of water and discharging itself into the trough by siphon action as soon as it becomes full. In either case the frequency of the flush can be regulated by the supply of water.

At Birmingham closets are constructed upon a similar principle, but the flush is effected by the house-hold waste water. The drainage from a row of houses is conducted to a flush tank placed at the end of the row farthest from the sewer. From the tank a large pipe drain passes to the sewer, and separate closets are placed upon its course, the excreta simply falling through large vertical drain pipes into the drain below,

and remaining there until the next flush sweeps them away into the sewer. The drain has a siphon trap after passing the lowest closet, and a manhole or access chamber at the same point for use in the event of obstruction.

In like manner the waste water of single houses has been utilised for flushing single out-door closets, the object being of course to avoid the expense of a separate water supply. During the last few years great improvements have been made in closets of this type, which are now commonly known as **slop closets,** and are being introduced on a large scale in many manufacturing towns, with apparent success. The household waste-water, supplemented if necessary by the rainfall, is collected in a "revolver" or "tumbler," an earthenware vessel working on pivots, and so constructed as to overbalance when full, discharging its contents forcibly along the drain, and then swinging back to its former position. On the drain, beyond the tumbler, is a large siphon trap, and the closet consists of a wide vertical shaft over this, so that the excreta fall into the water of the trap, and are carried away by the next flush.

Intermediate between the water-carriage and dry systems come certain Continental and other systems which may be described briefly. The *fosse permanente* is a large water-tight underground pit, to which pipes from the closets conduct the excreta; the pit is emptied at long intervals by suction through hose into an air-tight cart.

The *fosse mobile* is a closed movable tub placed outside the house, and connected with a fixed pipe that communicates with all the closets, etc., in the house; the tub is simply removed and replaced by another when full.

In *Liernur's system* a number of closets are connected by means of iron pipes with an air-tight tank

which is at intervals exhausted of air, so that the excreta are drawn into it.

In Bristol the privies are connected to the sewer by means of a trapped "eject," but have no water supply beyond that thrown in by hand.

"Dry" or "conservancy" systems of excreta removal include *middens*, *pail-closets* (with or without ashes), *ash-closets*, and *earth-closets*.

The **privy and ashpit**, or **midden** system, which is still largely employed in certain towns, and in almost all rural districts, aims at the deodorisation and drying of the excreta by admixture with ashes. The best construction is that of a small watertight pit, not drained but roofed over to exclude rain, and so arranged that the excreta and ashes become thoroughly mixed. For this purpose either the ashes must be thrown in through the closet seat, which may be hinged so as to be lifted *en masse*, or else a "shoot" or sloping slab must conduct one or the other to a common point. The floor should be smooth, and raised a few inches above the level of the adjoining ground Very few middens fulfil these conditions, however.

The contents ought to be removed at fixed short intervals by the Sanitary Authority, and the work should be done at night or early in the morning so as to minimise the nuisance. Unfortunately it is still common to leave the emptying of ashpits to contractors, or even to the owners and occupiers, and the interval is frequently several months instead of a week as prescribed by the Model Byelaws.

Privies alone, without admixture of ashes or other deodorants, are also met with. The receptacle should be small, and its contents frequently removed, but at best the system is more offensive than when ashes or earth are added.

Pail- or **tub-closets** are simply miniature privies, in which the ashpit is represented by a movable

pail placed beneath the closet seat. The full pails are removed and replaced by clean empty ones at regular intervals not exceeding a week. Close-fitting covers are often used during removal of the full pails. Various modifications of this system are in use. On the "Rochdale system" the pails contain excreta alone, while at Nottingham the ashes and other dry household refuse are added. In Manchester the ashes are thrown upon a sifter, and only the fine ash falls into the pails. At Halifax (Yorkshire) the Goux system is in use, the cleansed pails being lined with a dry, absorbent packing of compressed peat or like substance, which renders the contents drier and less offensive.

In Morell's cinder-sifting **ash-closet** the ashes are thrown in by a separate opening, and by a simple automatic arrangement are sifted, so that only the fine ash falls upon the excreta, the cinders finding their way to a separate chamber for further use as fuel. The receptacle is permanent and in this respect resembles a privy rather than a pail-closet, but it is small and so arranged as to be readily emptied by a special opening. Taylor's closet is somewhat similar in principle, but the urine is collected separately.

Earth-closets have a small receptacle, fixed or movable, beneath the closet seat. Clean dry earth (about 1½ lb.) is thrown upon the excreta, either by hand or by automatic delivery from a hopper, every time the closet is used. A constant supply of fine dry earth is needed, ordinary mould being the best. Sand is less efficacious. In Stanford's closet charcoal made from seaweed is used in place of earth, and only one-third of the quantity is said to be required.

Destination.—Water-carried excreta pass into the ordinary sewers, and their ultimate disposal will be considered in another section.

Pails are emptied and cleansed at a central depôt,

and are then ready for further use. Their contents are sent into rural districts as manure, either in the crude state or after conversion into "poudrette" by drying and other treatment.*

Contents of ashpits, being necessarily removed by carts, are commonly sent away at once into the country. The refuse of ash-closets or pail-closets of the Nottingham type is also available as manure.

The earth from earth-closets can be dried and used again and again, and finally restored to the garden or field, having gained surprisingly little in organic matter at the end of the time.

So, too, with the charcoal-closets; the charcoal can be used several times if re-carbonised in retorts. Both the charcoal and the tarry and ammoniacal products of distillation become valuable as manure.

Comparative advantages of water-carriage and dry systems:—

1. *Hygienic.*—Water-carriage is by general consent the most satisfactory in houses of the better class, where cleanliness and freedom from effluvia are the main considerations, and due care in use can be relied upon. The excreta are at once carried right away from the premises. Water-closets may safely be constructed practically within the house, a matter of great convenience. The objection that the sewers receive the specific poison of enteric and other fevers may be met by the use of disinfectants, and has not yet been proved to be weighty. It has been urged that indoor water-closets afford facilities for the entrance of sewer air, especially in case of obstruction of the sewers by floods or other causes. Indeed, it has been observed in more than one enteric outbreak that the inmates of large water-closet houses upon high ground

* For the manufacture of poudrette the excreta (free from ashes) are heated in revolving cylinders, so as to drive off the moisture. Sulphuric acid is often added to fix the ammonia.

suffered more than the poorer inhabitants of lower districts with outdoor closets. This danger, however, can scarcely occur unless there is grave defect in construction or management, and it extends equally to indoor sinks. As applied to poorer dwellings water-closets often fail. Owing to carelessness or misuse, the mechanism becomes deranged, or flushing is neglected, and the drains become choked by bulky objects improperly introduced into them. The Birmingham flush closets, trough closets, and even slop-closets, if kept under supervision, are to a great extent free from this objection, since they are not liable to become deranged by carelessness on the part of those using them. It must also be remembered that in Liverpool and other towns water-closets of ordinary construction are made serviceable even in houses of the poorest class, by careful supervision on the part of the Sanitary Authorities. Neglect of hand flushing may be met by automatic mechanism connected with the door or the seat. Water-closets placed outside houses are liable to have their water supply frozen up in winter, but this will very rarely happen if the cistern is properly cased with wood. For schools and factories trough-closets are best.

Privies and ashpits are being abandoned in most towns, although still almost inevitable in country districts where there is neither efficient drainage nor organised scavenging system. The retention of large quantities of excreta and other organic matter near dwellings is in itself objectionable, and the nuisance becomes great at the time of clearing out. It is highly probable that such an arrangement favours the spread of enteric fever and other diseases that have relation to filth, and especially those in which the poison is contained in the excreta. The case becomes worse when, as almost invariably happens, the pit leaks and allows its contents to pollute the soil and the subsoil water.

Pail-closets have the advantage of extreme simplicity, and cannot be deranged by carelessness or anything short of wilful destruction. Although not removed instantly, as in water-closets, the excreta remain near the dwelling for a few days only, instead of putrefying for weeks or months as in middens. The weekly or semi-weekly visits of the scavengers ensure a certain degree of cleanliness, apart from the mere substitution of cleansed pails. It is claimed that in the event of such diseases as enteric fever occurring, the pails and their contents can be disinfected; unfortunately not all the infective matter is thrown into the closet, and at best its disinfection in any true sense would be difficult, but it is quite possible to adopt the simple precaution of supplying specially marked pails to infected households, and cremating the contents of such pails when collected. Pail-closets that receive excreta only are inevitably offensive, however frequently changed. The addition of ashes removes the effluvia almost entirely, and the average amount of ash produced by an artisan household is found to be sufficient for the purpose. The Goux system also renders the excreta comparatively inodorous.

Earth-closets are convenient and free from effluvia. The difficulty of ensuring a constant supply of suitable dry earth, and of removing the products, has hitherto prevented their adoption in towns. In rural districts, where these difficulties do not exist, they offer great advantages, but can only succeed when used with care and kept under supervision.

2. *Economic.*—Water-carriage involves some cost, either to the individual or to the public, in the extra consumption of water, but this objection does not apply to those systems in which the flushing is effected by the household waste water. Drains and sewers have to be provided in any case, so their cost cannot

be charged to the account of water-carriage systems. The increased volume of sewage in water-closet towns or districts is far less material than is generally assumed, and forms at most only a small fraction of the enormous volume derived from rainfall, soil drainage, household waste water, trade effluents, and other sources. It has been found that the addition of water-closet sewage scarcely alters the chemical composition of the average sewage of a town. Hence the necessity of treating the sewage by irrigation or other means is quite independent of the admission of water-borne excreta to the sewers.

Water-carriage obviates some part of the expense of the scavenging required by the pail-closet system, but there must still be a costly organisation for collecting the dry household refuse, which, without the addition of excreta, is an unsaleable commodity, and further expense is therefore incurred in disposing of it after collection.

A similar objection is often urged from the theoretical side, namely, that the enormous dilution of excreta by water renders it difficult or impossible to recover them again for manurial purposes, and hence the soil is steadily impoverished by depriving it of what should naturally be returned to it in exchange for the crops that it yields. This argument has some weight as bearing upon the still common practice of pouring the sewage of towns into rivers or into the sea.

From the purely financial point of view the objectionable midden system probably costs less than any other.

The pail system involves a heavy initial outlay in buildings and plant, and an expensive staff to manage it efficiently. On the other hand, some part of the expense is recouped by the sale of manure, and a scavenging staff must in any circumstances be maintained for the removal of dry refuse. The market

value of the excreta is greater if unmixed with ashes, but it is questionable if the gain is sufficient to compensate for the cost of a separate collection of dry refuse, which, as already explained, is unsaleable. The dry systems ensure the return of most of the solid excreta to the soil, but a great part of the liquid excreta, which are more important as fertilisers, goes with the household drainage in any case.

Reviewing the whole question, the privy system must be regarded as contrary to sound principles of hygiene wherever facilities exist for any other arrangement. Water-closets are most suitable for upper- and middle-class households in town, and water-closets or earth-closets in the country. For factories, schools, and other places where closets used by large numbers of persons can be kept under control, trough-closets are best. In houses of the poorest class, where we have to count upon neglect and even misuse, pail-closets have great advantages, the only alternative being trough closets or water-closets of simple type kept under strict supervision by the sanitary staff.

Removal of ashes.—Where water-closets, or pail-closets for excreta alone, are in use, the ashes and kitchen refuse have to be removed separately. The best arrangement for this purpose is the provision of small covered tubs or boxes, standing in a yard or outhouse, and emptied at short and regular intervals by the scavengers. Frequently, however, large "bins," or "dry ashpits" are employed, the contents of which are allowed to accumulate for long periods.

Properly speaking, household refuse ought to consist of little more than ashes, the animal and vegetable refuse from the kitchen being easily burnt, but it is scarcely possible to enforce this in practice.

Trade refuse, from slaughter-houses, markets, fish and fruit shops, and many other sources, requires prompt removal. This duty is often left to the

proprietors, who make private arrangements with farmers, etc., to remove the refuse for use as manure, or convey it at their own cost to some suitable place. It is difficult to ensure proper system and regularity unless the Sanitary Authority itself undertakes the task, and the same difficulty occurs in urban districts in regard to manure from stables and cowsheds.

Road sweepings and the contents of street gulleys have also to be dealt with

Destructors.—Any kind of refuse which contains organic matter, but which cannot be at once disposed of as manure, should be cremated. For this purpose one or more large furnaces are used. The refuse is thrown in at the top, and becomes dry as it sinks down ; all organic matter is burnt off, and at intervals the mineral matter, or "clinker," is raked out below, to be used for road-making, filling up hollows, etc. After the furnace is started, the organic matter in the refuse is usually sufficient to maintain the fire without the addition of other fuel. The smoke from a destructor is offensive, and should be passed through a second furnace. At Bradford the contents of ashpits are burnt with the other refuse, but the smoke is rendered inoffensive by forcing a jet of steam, under pressure, beneath the fire-bars (Horsfall's process), and, secondly, by passing the fumes through a Jones's "Fume Cremator," which consists of a coke furnace provided with several projections or "bafflers."

Sewers may be required to convey

Household effluents, including waste water from baths, lavatories, sinks, and all liquid refuse and urine. Where there are water-closets, the volume of sewage is somewhat increased, but its composition is little altered. Latrines, etc., attached to works, schools, or public resorts may be included under this head.

Trade effluents of all degrees of impurity, from the comparatively pure water from condensers to the foul effluents from dyeworks.

Water used for public purposes, e.g. watering streets, fountains, public urinals, baths, etc.

Rainfall, of which the first portions (especially road-washings) are extremely impure.

Subsoil water, and even small natural streams.

Modern sewers, like house drains, are impervious tubes, oval or round in section. Their size varies according to requirements, say from 9 inches to 12 feet in diameter. If the diameter is not greater than $1\frac{1}{2}$ or 2 feet, glazed earthenware pipes set in cement are usually employed, laid in the manner described in speaking of house drains. Sewers of larger diameter than 18 inches are generally constructed of brick set in cement upon a bed of concrete, and are oval or ovate in section, so as to secure a better scour and less friction when little sewage is passing than if the section were circular. Sewers should be laid as far as possible in straight lines, with means of inspection and access at every change of direction. All junctions should be obliquely in the direction of flow, and the tributary sewer or drain should have a fall into the sewer at least equal to the difference in their respective diameters. It is desirable that the rate of flow should be not less than 2 feet per second, and 3 feet is better. Hence the minimum gradient should range from 1 in 250 to 1 in 750, according to the size of the sewer. The gradient should preferably be uniform, except at angles and junctions, where it is desirable to allow extra fall.

Manholes should be provided at short distances, and at all important angles, junctions, and changes of gradient, to allow of access for inspection and flushing. Flush-tanks may with advantage be placed at the head of each sewer. Flushing is chiefly required

in sewers with insufficient gradients, at "dead ends," and in hot dry seasons, when the flow of sewage is smallest and decomposition most rapid. It may be effected more or less automatically by means of flush-tanks, or by temporarily damming back the stream and then allowing it to escape with a rush, or by suddenly discharging a large volume of water into the sewer through a manhole. It must be confessed that little benefit is likely to result from the perfunctory "flushing" of sewers that is commonly practised, consisting as it does of simply pouring a small and inadequate volume of water into the sewer through a hose, at intervals of several weeks. There is little to be gained by the addition of "disinfectants," that is, deodorants, to the water used for flushing.

Ventilation of sewers.—Foul gases are given off by sewage, more especially if, from insufficient gradient or obstructed outfall, they become stagnant or "sewers of deposit." Hence it becomes necessary to provide means of vent or ventilation in order to avoid the risk of the pent-up gases forcing their way into houses through traps.* For this purpose openings are provided at intervals which should not exceed 100 yards. Some of these openings act as inlets, others as outlets, and the latter only are, of course, liable to be offensive. The conditions that determine the direction of the currents of air are highly complex, including force and direction of wind, internal and external temperature, volume and velocity of sewage, etc., and the result cannot be predicted, and is not even constant in the same sewer. Speaking generally, the tendency is for the air current to pass in the reverse direction to the sewage, that is from a lower to a higher level, so that the highest openings are most liable to be outlets, and the lowest to be inlets. Nevertheless, every opening may at different times act both parts.

* In Bristol the sewers are not ventilated.

The plan usually adopted is to provide grated openings in the roadway, leading directly to the sewer beneath, a cage being suspended immediately beneath the opening, to catch any solid débris that may fall through. It was formerly customary to place trays of charcoal in the openings so as to deodorise the sewer gases, but the charcoal obstructed the opening and soon became inert. To obviate annoyance from effluvia at outlets, it is becoming common in many towns to construct ventilating shafts (in substitution for these openings) attached to houses or even to trees ; these shafts should be, but rarely are, of sufficient calibre to efficiently ventilate the sewer. Sometimes factory chimneys are utilised for this purpose by carrying the vent into the stokehole or chimney. A recent device (Keeling's) is to ventilate the sewers through hollow lamp posts with gas jets inside serving to create a strong upward current and (it is claimed) to destroy all effluvia and organisms.

Considering the enormous number required in a whole town, most of these special arrangements are costly, especially those which require a continuous consumption of gas, and it remains to be shown that they are necessary. It is contended by the advocates of simple openings at the street level that the true remedy for offensive outlets lies in proper construction and flushing of sewers, and increasing the number of openings—that is, in approximating to the condition of an open sewer.

Rain and subsoil water.—If the sewers are water-tight, as they should be, the subsoil water cannot gain access to them, and separate provision must be made for draining the soil, although a certain quantity of water flows away along the comparatively easy track outside the sewer. Sometimes provision is made for this by leaving a space beneath the sewer for the ground-water to pass along.

It is becoming customary to exclude also the rainfall from the sewers, and thus avoid dilution of the sewage and sudden changes in volume, which add to the difficulty of treating it by precipitation or filtration. The first washings of the streets are very foul, and should be admitted to the sewers. When the "separate" system is adopted, the rain water is taken away by another system of drains, which may with advantage be permeable, and so available for draining the subsoil.

Capacity of sewers.—In towns only a comparatively small surface of ground is pervious, and almost all the rainfall rapidly makes its way to the sewers. Hence in planning the size and gradients of sewers it is necessary to provide for the immediate removal of the maximum hourly rainfall, say 1 inch per hour *plus* the maximum volume of sewage from other sources.

Parkes gives the following formula for calculating the discharge from a sewer :—

$$V = 55\,A \times \sqrt{2DF}.$$

V being the velocity, in cubic feet discharged per minute,
A, the section area of the current,
F, the fall, in feet per mile,
D, the *hydraulic mean depth*, in feet. This is $\frac{1}{4}$ of the diameter of the pipe, if running full or half-full; in all cases it is equal to the section area of the current divided by the "wetted perimeter"—that is, by the length of the arc formed by that part of the section of the circumference which is in contact with the stream.

When a sufficient fall cannot be obtained, *Shone's pneumatic system* offers great advantages. The sewage is conducted to one or many central collecting tanks by gravitation through drains and sewers of ordinary construction, and is forced through pipes leading from the tanks to the outfall, by means of compressed air. Thus difficulties arising from inequalities or from low level of districts to be drained can be overcome.

The Composition of Sewage varies from day to day,

and from hour to hour, since both the filth and the diluting water are inconstant in amount. There are variations according to season and weather, and trade effluents may be important factors. The admission or exclusion of rain water makes a very great difference, but the presence or absence of water-closets does not seem to affect the composition of sewage very materially. The Rivers Pollution Commissioners gave an average composition of sewage somewhat as follows :—

	Parts per Million.	
	Water-closet Towns.	Midden Towns.
Total Solid Residue . . .	1369	1215
Suspended Solids { Organic .	205	213
Suspended Solids { Mineral .	242	178
Suspended Solids { Total . .	447	391
Dissolved Solids . . .	722	824
Organic Carbon	47	42
Organic Nitrogen . . .	22	20
Ammonia	67	54
Total combined Nitrogen . .	77	65
Chlorine	107	115

and from other sources it appears that the phosphoric acid amounts to about 25 and the potash about 15 parts per million. These proportions are, of course, liable to very wide variation.

It is calculated that in an ordinary population $2\frac{1}{2}$ ounces of solid excreta and 40 ounces of urine, together containing 150 * grains of nitrogen, are yielded per head per day, taking an average of all ages. This corresponds to about 10 pounds of ammonia per annum, and a theoretical manurial value of 6s. 8d., to which the constituents of the urine

* This is Parkes' estimate. Frankland's estimate, for adult males, is 250 to 300 grains.

contribute six-sevenths, and the fæces one-seventh only. The manurial value of sewage is dependent upon the combined nitrogen, potash, and phosphoric acid. The annual amount of sewage per head of population may be taken as 100 tons, the theoretical money value as manure being about 17s., to which the dissolved matters contribute 15s., and the suspended matters only 2s.

Disposal of sewage.—In rural districts the household and other drainage, if not turned into some convenient ditch or watercourse, is usually conducted to a cesspool or collecting tank, from which it is periodically removed and used as manure. The former plan is bad in every respect. The latter is permissible only if the cesspool is made water-tight and properly covered and ventilated, regularly emptied at suitable intervals, and situated at a sufficient distance from any house, road, or water supply. The Annotated Model Byelaws require a minimum distance of fifty feet from any dwelling, and eighty feet from any water supply. Sometimes the sewage is led to a pit, or "dumb-well," in porous soil, the solids being removed at intervals and the liquids escaping into the ground. This practice is dangerous if the pit is near to dwellings or water supplies, and is not free from risk of polluting water in any case. Simple irrigation is free from objection if well managed, even on the small scale. "Subsoil irrigation" may work well when the conditions as to soil and fall are suitable; the drainage is conveyed into a branching system of loosely laid agricultural pipes, which allow it to escape into the subsoil. The pipes are laid about a foot or more beneath the surface. It is often necessary to relay them at intervals, owing to deposit of grease and other obstructive matter, but this may to some extent be prevented by the use of flush-tanks and grease-traps at the house-end of the drain.

The chief point is to expose the sewage to the influence of growing vegetation, not so much for the sake of utilising it as of rendering it innocuous. Sewage applied to the surface is partly absorbed by vegetation, partly oxidised (nitrified) in the superficial layers of earth. The sewage passed into leaking cesspools or dumb-wells escapes both forms of purification, and simply pollutes the soil and the subsoil water.

The disposal of town sewage may be effected in a variety of ways. The oldest and simplest is to pass it without purification into natural watercourses, or into the sea, a plan that is still practised in many large towns and most villages. So far as marine towns are concerned, the sea affords a ready means of disposing of the sewage. It is allowed to escape only with the ebb tide, and reflux is prevented by valves. If it is conducted by pipes sufficiently far out to sea, it may not be washed back by currents or by the returning tide and foul the shore. Such a degree of success is far from being the rule, and there are the further objections that the removal of sewage by this means is only intermittent, and that the sewage is (at best) wasted. Although this plan is advocated for coast towns by many eminent engineers, there is practically nothing to be said in defence of the still prevalent custom of polluting rivers by the sewage of inland communities. To a certain extent organic impurities in streams are got rid of by oxidation and by the growth of plants and other organisms, but this possibility of subsequent partial purification cannot justify the gross pollution of a stream at any given point. In few cases is the purification complete, and in no case can there be any certainty of the destruction of specific pollution, a consideration that is especially important when the stream furnishes the water supply of districts nearer

to its mouth. Most of the rivers in manufacturing districts are converted into mere sewers by this misuse, which the Rivers Pollution Act has been powerless to prevent.

The alternative plan is to purify the sewage with the object of oxidising or retaining its dissolved and suspended impurities, and allowing only the water (with, at most, harmless dissolved matter) to pass into watercourses or into the sea. This may be done by *precipitation*, *filtration*, or *irrigation*.

Precipitation processes aim at throwing down the organic matter chemically or mechanically, by the addition of a reagent to the sewage. For the most part their success in this respect is only partial, and they leave the ammonia and chlorides in the effluent. The reagents, dissolved or suspended in water,* are added to the raw sewage either in the sewers (Scott's and Conder's processes) or more usually in a conduit at the works. In either case the flow of the reagent is regulated as required, and it becomes thoroughly mixed with the sewage before entering the tanks. The settling tanks are large and are usually worked in series, the overflow from each into the next being over a broad shallow sill so that only the comparatively pure upper water may escape. The current being very slight in the tanks, suspended matters are gradually deposited, accumulating at the bottom in the form of sludge, which is periodically cleared out, dried, and sold as manure, or dug into the ground, or (in Scott's process) burnt into cement. A similar subsidence takes place if no precipitant is used, but the dissolved organic matter remains in solution, and the settlement of the suspended matter is much slower and less complete. A good precipitation process will rapidly clarify the sewage by removing all, or nearly all, the suspended impurities, and will

* In the alumino-ferric process, cakes of the reagent are laid in the sewage current, and dissolve slowly.

moreover carry down a greater or less part of the dissolved organic matter. The effluent will be fairly clear, but will contain the chlorides and certain other salts, ammonia, and more or less of the dissolved organic matter. It is therefore necessary to subject the effluent to further treatment, that is, to filtration, in order to oxidise the remaining organic matter.

Precipitation affords no guarantee of the removal of microbes, pathogenic or otherwise.

Many of the precipitation processes described in text-books have been abandoned on account of cost or want of efficiency, and have now only a historic interest. Lime is by far the most generally employed, either alone or in conjunction with other reagents. It has been used together with clay (Scott), calcic phosphate (Whitthread), magnesic chloride and tar (Hillé). The "Amines" process consists in adding lime together with a little herring brine. The latter, by virtue of the trimethylamine and other ingredients (aminol), acts as an antiseptic. The effluent does not decompose, and yields no microbes on cultivation. The precipitation is rapid. Lime with ferric chloride or aluminic sulphate gives a bulky precipitate of the respective hydrate, which entangles and carries down organic matter with it. Crude aluminic sulphate, made by acting upon clay or shale with sulphuric acid, is Anderson's (and also Bird's) precipitant; and sulphuric acid with mineral phosphate of alumina is the basis of Forbes and Price's process. Spence's "alumino-ferric" contains a very small proportion of iron salts. Sillar's A B C process, used at Aylesbury, consists in adding alum, blood, clay, and charcoal.

At Acton, Huddersfield, and elsewhere the precipitant is a material termed "ferozone," made by acting with sulphuric acid upon "polarite"—a specially prepared ore of iron. The effluent is filtered

through a bed of polarite. Another iron process, differing from the rest in being applied at the *head* of the sewer or house drain, is Conder's, in which a regulated quantity of ferrous sulphate is added constantly and automatically by means of a stream (of water or sewage) passing through a vessel ("ferrometer") containing crystals of $FeSO^4$. It seems to be successful in preventing decomposition and effluvia, and in keeping the drains free from deposit. A saturated oxy-chloride of iron is used as a precipitant, in the ordinary way, in the "Clarine" process.

Webster's electrolytic process adds iron indirectly. The sewage is made to flow through a series of tanks in which it is exposed to a powerful electric current passing between electrodes consisting of iron plates. Ferrous hydrate is continuously formed, and reacts at once in the nascent condition upon the sewage, causing a rapid and fairly complete precipitation of solids. A clear and slightly greenish affluent results, which is remarkably free from microbes and has little tendency to secondary putrefaction. In the Hermite process electrolysed sea-water is employed. In the Oxygen process, and also the Scott-Moncrieff system, the removal of organic matter is largely effected by the agency of microbes.

In the black-ash process, a waste product from alkali- and soap-works is used as a precipitant. This refuse contains calcic sulphide, which by exposure to air is partially oxidised into calcic sulphite and hyposulphite. The prepared black-ash is used together with lime, and is said to give satisfactory results as regards both precipitation and antiseptic effect, the effluent being comparatively pure and free from tendency to putrefaction.

Lime processes in general yield an alkaline effluent, which has a tendency to "secondary decomposition." A lime effluent that is bright and clear

on leaving the works will commonly be found to become turbid and offensive if its run can be traced for a few hundred yards without excessive dilution by other water.

Filtration of sewage may be adopted either alone or as a supplement to a precipitation process. The filtering media employed are land, certain ferruginous materials, and ashes or other matter containing carbon. By filtration it is sought to remove the suspended matters, and to oxidise the organic matters and ammonia. The effluent should contain only chlorides and other dissolved mineral salts and nitrates, but some free and albuminoid ammonia is always found upon analysis.

"Intermittent downward filtration" is the only form that gives satisfactory results, the flow of sewage being suspended from time to time in order to allow the filter to become charged afresh with oxygen from the air.

Land-filters require a porous soil, underdrained by porous pipes at a depth of about six feet.* The sewage is distributed over the surface by means of branching carriers or trenches, controlled by sluices, so that each portion of the ground in turn receives the sewage for a few hours, and each has intervals of rest. The soil is raised in ridges, upon which vegetables are grown, the sewage flowing along the furrows between the ridges. The utilisation of the sewage is a minor consideration; but vegetation is useful in absorbing and assimilating the organic matter. Land-filters planted with osiers (osier-beds)

* As the influence of vegetation and oxidising agencies is chiefly effective in the superficial layers of soil, a much less depth is now often recommended, and some engineers advocate "lateral filtration" without underdraining—that is, that the sewage should be allowed to flow down a gentle slope, finding its way through the upper portion of the soil to a trench at the foot of the slope.

are sometimes employed for the purification of village sewage, or for the occasional treatment of storm waters that cannot be dealt with otherwise. The osiers absorb water and sewage matter freely ; but constant care is needed to prevent choking of the surface-soil, or of the subdrainage.

The most important of the ferruginous filtering media applicable to sewage are "polarite," "magnetite," and "magnetic carbide." Filter-beds of these materials have a remarkable purifying effect upon sewage ; but they should be covered with a layer of sand, renewed at intervals ; and the sewage previously treated by precipitation should be passed through them not too rapidly, and with intermissions. Under these conditions the material does not require renewal, and the effluent loses most of its free and albuminoid ammonia, but contains abundance of nitrates.

Carbon filtration is only applicable with success to sewage previously treated by precipitation, although in Weare's process some purification was effected by passing sewage through ashes and vegetable charcoal. Recently it has been proposed to carbonise town refuse, including night-soil, and to utilise the material thus obtained for the purification of sewage, a plan that has obvious advantages if it can be carried out successfully.

According to present Local Government Board standards an acre of land may suffice for the sewage of a population of 2,000 persons, if preliminary treatment is adopted.

Broad irrigation "means 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. Filtration means the concentration of sewage at short intervals, on an area

of specially chosen ground, as *small* as will absorb and cleanse it, not excluding vegetation, but making the produce of secondary importance." For irrigation, as for filtration, the soil should be porous, and under-drained. (*See* page 204, and note.) As a rough average, one acre is stated to be sufficient for the treatment of the sewage of 100 persons, but this will vary greatly. The sewage is distributed over each portion of the ground intermittently, by means of branching carriers, which pass along ridges of soil twenty or thirty feet apart, or along contours of slopes, and are controlled by sluices. At stated intervals the sewage is turned into each carrier, and overflows down the slope on each side. The sewage is screened before distribution, unless it has been subjected to preliminary filtration or precipitation. The effluent is similar to that of simple intermittent downward filtration, of which, indeed, this is only a modification. The nitrates may, however, be reduced by vegetation. The crops grown upon "sewage-farms" are very heavy. Italian rye-grass is the best adapted for the purpose, since it grows rapidly and absorbs much sewage, but many other forms of vegetation can be substituted. If the land is limited in area, provision may be made for temporary excess of sewage after heavy rainfall by setting aside a portion of the ground as a land-filter.

Apart from the action of vegetation, the purifying effect of different soils shows considerable variation. The Rivers Pollution Commissioners found that a cubic yard of chalk or sand effectually purified 5·6 gallons of sewage per diem applied intermittently; while a sample of loam purified 9·9 gallons under the same conditions. Peat had slight purifying power at first, but improved with repeated use, owing, perhaps, to increase in the nitrifying organisms. Intermittent filtration through suitable soil removed 70 per cent.

of the organic nitrogen, and upwards of 80 per cent. of the organic carbon.

Experience has shown that with careful management a properly constructed sewage-farm can be carried on without nuisance or injury to the health of the surrounding population; but if the land becomes waterlogged from accident, defect, or inattention, grave nuisance may readily result. It was at first feared that parasitic and other diseases in animals and man would be promoted by the use of the produce of sewage-farms as food, but no such result has been observed.

The choice among the various methods of purification of sewage must be determined largely by local considerations. If the sewage is free from manufacturing effluents of injurious character, and if a sufficient area of suitable land can be obtained in a convenient position and at a reasonable cost, broad irrigation is entitled to preference as the most rational and economical method of treatment. If there is serious difficulty in obtaining land, simple intermittent downward filtration may be preferable; and precipitation processes can be efficiently carried out upon a still smaller area.

Proper construction in the first instance, and careful management afterwards, are essential in every process, and without them nuisance cannot fail to result. It is desirable, for the sake of economy and efficiency in management and supervision, that sewage should be dealt with at as few points as possible. The process of purification is greatly facilitated by the "separate" system of drainage, the volume of sewage being thereby reduced and rendered more constant.

In manufacturing districts the principal difficulty arises in connection with trade effluents. Many kinds of manufacturing refuse if admitted into the sewers interfere with the efficacy of land-filtration,

either by clogging the soil or chemically checking the process of oxidation. In such cases a preliminary purification by precipitation is necessary, and it is probable that the effluents of different trades will be found to require different chemical treatment. If they are poured into streams without purification, they cause pollution exceeding in intensity that caused by domestic sewage. For each manufacturer in such a district to deal with his own refuse would entail a very heavy aggregate expense; and the multiplication of such works is in itself undesirable, since it must increase the risks of mismanagement and failure. Still, where trade effluents cannot be received into the sewers, the responsibility for their purification rests with those who produce them. In some cases the difficulty may be overcome by combination among manufacturers, and in others by the provision of a special intercepting sewer. A satisfactory compromise has been reached in some towns by the manufacturers partially purifying the effluents before turning them into the sewers.

The legal aspect of the question will be dealt with in chapter xv. (upon Sanitary Law).

The Rivers Pollution Commissioners recommended that any of the following characters should be held to render an effluent inadmissible to a stream :—

(*a*) *Suspended matter.* More than 1 part dry organic matter, or more than 3 parts dry mineral matter in 100,000. Perfect rest in subsidence ponds for at least six hours is also required.

(*b*) *Dissolved matter.* More than 2 parts of organic carbon, or 0·3 of organic nitrogen in 100,000.

(*c*) *Colour.* Any distinct colour in depth of 1 inch, when examined by daylight in a white vessel.

(*d*) *Metals.* More than 2 parts of any metal (except calcium, magnesium, potassium or sodium) dissolved in 100,000 parts.

(*e*) *Arsenic.* More than 0·05 of arsenic in any form per 100,000.

(*f*) *Chlorine.* More than 1 part of free chlorine (after addition of sulphuric acid) per 100,000.

(*g*) *Sulphides.* More than 1 part of sulphur as sulphides, per 100,000.

(*h*) *Acidity.* More than that caused by 2 parts of hydrochloric acid per 100,000.

(*i*) *Alkalinity.* More than that caused by 1 part of caustic soda per 100,000.

(*j*) *Oily matter.* More than 0·05 part of petroleum or hydrocarbon oil suspended in 100,000 parts; or any film of oil upon the surface.

CHAPTER VIII.

DISPOSAL OF THE DEAD.

THE daily average of deaths among the population of England and Wales is about 1,500, the yearly total being considerably upwards of half a million. The disposal of this enormous number of dead (many of whom have died of infectious diseases) in such manner as to avoid danger to the living, is a sanitary problem which like many others has only received due attention within comparatively recent years. The horrible overcrowding of graveyards which prevailed in the early part of the present century is now rarely met with, and is only possible in the older grounds which are not subject to modern regulations, and which have not been formally closed by Order in Council. Still, many abuses of a kind opposed to all principles of hygiene are retained even now in connection with burial of the dead. Chief among them is the irrational attempt to frustrate the object of earth-burial by the use of metal or heavy wooden coffins. From the sanitary point of view, true earth-burial and cremation are the only admissible alternatives.

Burial-grounds.—The objects to be aimed at are rapid decomposition and complete oxidation or absorption of the products. Hence the soil should be light, finely porous, and either naturally or artificially drained to a depth of not less than eight feet, so that air and moisture may pass freely but in a finely divided state. Loam or sandy mould is about the best soil; clay is difficult to drain, retards decomposition by excluding air and moisture, and either retains the products of decomposition or allows them to escape through fissures. A loose stony

soil allows gases to escape too freely. In cases of difficulty, as regards soil or drainage, the level may be raised artificially. It is desirable that burial-grounds should not closely adjoin dwellings.* While convenient of access, they should, therefore, be placed outside the limits of present or probable future dense building, and a margin of twenty feet or more in width should be reserved for walks and planting. The surface should be grassed. Cemeteries should not be placed on elevated ground whence the natural drainage may find its way to dwellings below, or may contaminate any water supply. For obvious reasons, lands liable to floods or encroachment by streams or by the sea are unsuitable. The Home Office regulations and the Model Byelaws require that at least a foot of earth shall be left undisturbed above each coffin, and that every part of every coffin shall be at least four feet below the surface level; a grave is not to be reopened within fourteen years, except for the burial of further members of the same family subject to the above restrictions. The ordinary grave space being nine feet by four, it is usually estimated that an acre of ground is a minimum allowance for a population of 4,000 persons for fourteen years.

There can be no question of the injurious effects of overcrowded burial-grounds upon the health of the surrounding population, but there is no clear evidence of harm accruing under the conditions enforced in modern well-regulated cemeteries. The dangers to be apprehended are contamination of air and water, to which, perhaps, ought to be added the possible retention or even multiplication of the germs of specific disease, many varieties of which are

* 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.

known to be capable of flourishing in the soil. Effluvia may rise to the surface, or pass laterally for unknown distances, possibly to the basements of houses; but this is not likely to happen if the conditions already specified are observed. The drainage, artificial or natural, must be so arranged that it cannot find access to any supply of drinking-water, be it stream, well, or other source. Recent investigations by Buchanan Young show that organic matter and bacteria are increased in the deeper layers of soil, but not in the upper reaches.

Brick graves, vaults, catacombs, heavy oak coffins, and (worst of all) lead coffins, are all objectionable, and represent a futile attempt to prevent decomposition. They only retard the process, and render it far more likely to injure the living than if the pent-up gases and fluids were exposed to the deodorising and oxidising influence of aërated earth. Perishable coffins of wicker, light wood, or *papier mâché*, are most suitable of all. Quicklime or charcoal are sometimes employed with a vague idea of "disinfection," more properly deodorisation.

"The degree to which the purity of neighbouring wells is endangered by a cemetery, and the distance to which contamination may extend, obviously depend in each particular case upon the relative elevation of the respective sites of cemetery and well, and upon the nature and dip of the intervening strata, so that it would seem impossible to lay down a general rule for all cases. Fissured rocks might allow foul matters to traverse considerable distances, while the interposition of a bed of clay or a water-tight fault would shut them off, or the passage through an aërated stratum of finely divided earth would oxidise and destroy them on their way. A dangerous state of things is when graves and wells are sunk near together in a shallow superficial water-bearing stratum of loosely

porous nature resting on impervious clay. From experiments made at Dresden by Professor Fleck . . . it would seem that the degree to which wells so situated are liable to pollution is greater when the surface of the subsequent clay bed is horizontal than when it is sloping, even though the slope be towards the well. In the latter case the ground-water is on the move; in the former it is stagnant, and hence the foul matters are concentrated in a smaller volume of water; just as the water of a stagnant pool is more liable to become foul than that of a running stream. It does not appear, however, that the risk to which wells are exposed from the proximity of a properly managed cemetery is in ordinary cases great. A leaky cesspool is a far greater source of danger than a grave. The solid and liquid excretions voided by a human being in the course of a year amount to several times the weight of his body.

"The State Board of Health of Massachusetts . . . give a series of analyses of water from wells in the neighbourhood of cemeteries. Of seven wells in sandy and gravelly soil, varying in depth from 4 to 17 feet, situated at distances respectively of 60, 50, 10, 100, 200, 75, and 100 feet from the nearest grave, and having no other sources of contamination at hand, one only showed undoubted evidence of contamination; this was 10 feet from the nearest grave, the most recent interment, made five and a half months before, being 35 feet distant; the three purest wells were those at 60, 50, and 75 feet distance. The chemical characters by which it may be inferred that the contamination of a particular water is derived from decomposing bodies rather than from sewage, are a high proportion of nitrogenous organic matter and ammonia, or if oxidation have proceeded further, of nitrates and nitrites, relatively to the amount of chlorides present, and also the presence in notable

quantity of phosphates." (**L.G.B.** *Memorandum*, 1880.)

Duties of Sanitary Authorities in regard to Burial-grounds.—Both urban and rural authorities are enabled by the Public Health (Interments) Act of 1879 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. The Local Government Board point out, in a memorandum issued in August, 1879, that it is incumbent upon the Sanitary Authority to take action—

1. Where in any burial-ground that 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.

Interments underneath or within the walls of any church built after 1848 are forbidden by the Public Health Act of 1848 (section 83; re-enacted by the P. H. Act, 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).

Cremation is growing in favour in England, and there are no longer legal impediments to its adoption. In a crematorium of modern construction a body of average weight is reduced to about 3 lbs. of inorganic ash within two hours, and the destruction of organic matter is so complete that no offensive fumes are given off. There can be no question of the superiority of this method from a purely hygienic point of view. The chief objections to its adoption are that the soil is deprived of the organic matter that would otherwise be returned to it, that it involves an unnecessary waste of the world's limited stock of combined nitrogen, and that the impossibility of exhumation would increase the facilities for concealing homicide. The first objection has no great weight at present, since little attempt is made to utilise burial-grounds by cultivation, the principal aim being to promote "resolution" without causing annoyance or danger to the living. The last is, however, more serious, and cannot be regarded as satisfactorily disposed of by the proposition to require minute and detailed autopsy in every case. Half a million examinations annually, each sufficiently detailed to cover every known poison and every possible wound, would be impracticable, especially as the result must, in the vast majority of cases, be negative. The discovery of organic disease would not by any means necessarily exclude the possibility of foul play. Some few poisons, such as copper, might be detected in the ashes, but organic and volatile mineral poisons would be dissipated by cremation. The argument for cremation is strongest in regard to infectious diseases, the germs of which would be destroyed by fire; whereas some at least are known to be capable, under favourable conditions, of living in the soil, and of being transmitted by water.

CHAPTER IX.

ANIMAL PARASITES.

In addition to the pathogenic micro-organisms, belonging rather to the vegetable than the animal kingdom, which are now regarded as the ultimate cause of specific diseases, the human body is liable to invasion by a number of parasitic animal organisms, among which the following are, perhaps, the most important.

Tæniada, or **tapeworms.**— These parasites pass through two distinct phases, in two different hosts. In one, the head, or *scolex*, together with a cystic expansion, is embedded in muscle and other solid tissues. If the flesh containing these cysts (*cysticerci*) is eaten by another animal, the scolex reaches the alimentary canal of the new host, loses its cyst, and attaches itself to the wall of the intestine. It then develops from the caudal end joint after joint of *proglottides*, square or oblong flat segments, each of which is provided with double sexual organs. The chain of proglottides may attain a length of many feet. Ova are produced in the segments, and escape with the excreta of the host if the segments rupture or become detached, or if the whole of the tapeworm is expelled. Some of the ova are swallowed by a herbivorous host, and the embryo then bursts its shell, makes its way from the intestine to the solid tissues of the host, and after developing anew into a cysticercus, remains passive until it is devoured by a carnivorous animal, or perishes.

Man is subject to tapeworms, and more rarely to their cysticerci. *Tænia solium*, one of the commonest of human tapeworms, attains a length of seven to ten

feet or more. The head is about $\frac{1}{40}$ inch in diameter, and bears four suctorial discs, and a double circle of hooklets surrounding a prominence or *rostellum*. It attains its full development in three or four months, but may remain in the intestine for years. The ovum is spherical, $\frac{1}{700}$ inch in diameter, and has a thick brown shell; the embryo has six hooks. The cysticercus of the *Tænia solium* is termed *Cysticercus cellulosæ*. It affects the pig, and more rarely man; in the latter it lodges in the muscles, connective tissues, brain, eye, and serous membranes, and attains its full development in about $2\frac{1}{2}$ months. The cyst reaches the size of a pea, or even a marble; the head or scolex has a double crown of hooklets. In pigs it constitutes the affection known as "measles," and "measly" pork is the chief source of *Tænia solium* in man.

Tænia mediocanellata is equally common with *Tænia solium*, and somewhat resembles it, but its length is greater. The head is about $\frac{1}{15}$ inch in diameter, and has four suckers, but no rostellum or hooklets. The eggs are oval, the short diameter being about $\frac{1}{850}$ inch. The *Cysticercus tæniæ mediocanellatæ*, or *Cysticercus bovis*, is an oval vesicle smaller than the *Cysticercus cellulosæ*. It consists of a cyst, and a scolex identical with the head of the tænia itself. It occurs in the flesh of cattle.

Bothriocephalus latus.—This tænia attains a length of twenty-four feet or more. The head is ovoid, $\frac{1}{10}$ inch long, and has two longitudinal grooves or suckers, but no hooklets. The eggs are oval, about $\frac{1}{370}$ inch shorter diameter, and open by a lid at one end. The cysticercus is found in pike, turbot, perch, and other fish. The tænia is met with principally in the Baltic countries (Russia, Poland, Sweden) and in Switzerland. It may, perhaps, gain access to the alimentary canal by means of drinking-water, as the embryo is ciliated, and is found in river water.

Tænia echinococcus affects the dog and wolf only. The head resembles that of *Tænia solium* in presenting a rostellum surrounded with a double row of hooklets and four suckers, but it is only $\frac{1}{100}$ inch in width. There are four segments only, and the whole tapeworm is about $\frac{1}{4}$ inch long. Only the last segment has reproductive organs. The eggs are spherical. Its cysticercus is a dangerous human parasite affecting the liver and various other parts of the body under the name of *hydatid.* Unlike other cysticerci it increases indefinitely in size, and also forms within itself secondary cysts, some of which ("brood-capsules") contain one or more scolices (*echinococci*) and remain minute, while others, containing no scolex, enlarge and form "daughter cysts," which may in turn produce new cysts by gemmation. After death the scolex or echinococcus resembles the head of the tænia, but during life it is retracted into a depression, and thereby turned inside out. Hydatids may continue to grow for an indefinite number of years.

There are other tæniæ of rarer occurrence, which need not be enumerated here. *Tænia nana* is occasionally met with in England.

Nematoda.—The common round worm, or *Ascaris lumbricoides*, affects man and other animals. Its habitat in man is chiefly the small intestine. It is pinkish in colour, and tapers to each end. The male is about 6 inches long, the female 12. The ova, enormous numbers of which are discharged, are oval and nodulated, and measure about $\frac{1}{450}$ inch in least diameter. It is believed that the ova develop only in an intermediary host. The threadworm, *Oxyuris vermicularis*, is much smaller, the female measuring about half an inch in length, and the male about a quarter of an inch. They occur in enormous numbers, chiefly in the rectum. The ova are unsymmetrical but oval, their short diameter being $\frac{1}{1100}$ and long

diameter $\frac{1}{500}$ inch. The origin of threadworms is uncertain, but it is probable that they are occasionally disseminated by means of drinking-water.

Sclerostoma duodenale,* a nematode about half an inch long, is common in Egypt and other warm countries. It causes an intractable form of anæmia (Egyptian chlorosis) by attaching itself in large numbers to the villi of the upper part of the small intestine, abstracting blood and producing hæmorrhages. It may be conveyed by water.

Trichina spiralis attacks rodents, pigs, and many other animals besides man, causing the disease known as trichinosis. It is found in the tissues, and especially in the muscles, in the form of ovoid cysts about $\frac{1}{70}$ inch in length, just visible to the naked eye. Within each cyst is coiled an immature trichina, about $\frac{1}{35}$ inch long. The encapsuled trichinæ may retain their vitality for many years, or may perish and become calcified. If the tissues in which they lodge are eaten, the capsule is dissolved by the gastric juice, and the liberated trichinæ rapidly develop, the male attaining in one or two days a length of $\frac{1}{18}$ inch, the female $\frac{1}{8}$ inch. Ova are formed and impregnated, and are hatched within the uterus in about a week. The embryos escape, burrow into the walls of the intestine and find their way into the tissues of all parts of the body, where they become encapsuled and form the cysts already described, within a month from the ingestion of the trichinous food.

Trichinosis in man is generally due to the consumption of the imperfectly cooked flesh of a pig suffering from the disease. In Germany, where ham, pork, and sausage are often eaten almost or quite raw, trichinosis is far more common than it is in England. The symptoms commence within a week, with nausea,

* Also known as *Dochmius duodenalis*, *Strongylus duodenalis*, or *Anchylostomum duodenale*.

abdominal pain, irregularity of the bowels, prostration, rapid pulse, and elevation of temperature. The malady usually increases in severity for one or two weeks, and then gradually subsides, but fatal enteritis, peritonitis, or pneumonia may supervene, or the patient may die of exhaustion at any time from the end of the first to the end of the sixth week. Characteristic symptoms attend the invasion of the tissues by the parasites. The muscles become painful, tender, swollen, and stiff, so that the limbs are flexed and motionless. The voice is often hoarse or aphonic, from implication of the larynx. The pain in the limbs differs from that of rheumatism in not affecting the joints, but only the muscles. Œdema occurs early, first in the eyelids and face, next in the hands and feet, and may become general and involve the serous cavities. The other symptoms include increasing prostration and copious perspirations; the temperature may be little above the normal, and if high is irregular and subject to morning remissions. The mortality is sometimes very slight, sometimes 20 or 25 per cent.

Filaria sanguinis hominis, rarely seen in the adult form, is a hair-like parasite, and may attain a length of three or four inches. An immature form, met with in cases of chyluria, is about $\frac{1}{75}$ inch long. The ova are about $\frac{1}{1000}$ inch long, and having no distinct shell, their shape is somewhat irregular. The parasite is found chiefly in the East and West Indies, but occasionally in England, even among persons who have never left the country. It abounds in the blood of affected persons during the night, but disappears from the circulation by day; by changing the habits of the patient this periodicity can be reversed. Its presence is commonly associated with one of two diseases—chyluria and elephantiasis. The former is characterised by periodic attacks, in which the urine

becomes milky and upon standing coagulates, but the coagulum soon breaks down and decomposition sets in rapidly. These phenomena have been traced to admixture of lymph with urine, and immature *filariæ* are visible under the microscope. Elephantiasis is attended with enormous enlargement of the greater or smaller part of the trunk or limbs, and especially the legs and generative organs (*E. Arabum*).

Filaria medinensis, or Guinea worm, is about $\frac{1}{10}$ inch in diameter, and usually one to three feet long. It is endemic in certain tropical regions. The embryos affect minute aquatic crustacea (*Cyclops*), entering through the skin. Later they gain access to the human tissues, but whether by means of drinking-water or infection during bathing is not clear.

Bilharzia hæmatobia is believed to be the cause of a form of intermittent hæmaturia endemic in Egypt, South Africa, and elsewhere. The parasite is about $\frac{1}{4}$ inch long, and infests the veins of the large intestine, bladder, ureter, and pelvis of the kidney. It causes small patches of inflammation along these tracts, and the urine frequently contains blood and the ova of Bilharzia. The ureter may be obstructed. Dysenteric symptoms occasionally occur owing to the presence of the parasite in the veins of the intestine. The ova are about $\frac{1}{180}$ inch long, and have a sharp projecting spine at one end, not quite in the longitudinal axis.

The parasite probably gains access to the human body through water, either by drinking* or by direct infection of the urinary and alimentary tract during bathing.

Leeches have occasionally been known to be swallowed with water and to fix upon the pharynx, larynx, and posterior nares, causing serious loss of blood, and anæmia.

* This view has been confirmed by Sonsino. The *larva* becomes encysted in the body of a minute aquatic crustacean.

CHAPTER X.

INFECTION.

CERTAIN diseases, the number of which is steadily increasing owing to improved methods of observation, are termed specific or zymotic,* and are regarded as due to the invasion of the system from without by a definite "ferment" or poison, which grows and multiplies in the body. In some of them the poison is given off again, and these diseases are therefore infectious, or transmissible from person to person. It cannot be said that the possible means by which infection is given off have been exhaustively determined in regard to any disease, but certain well-established modes may be mentioned, namely :—

(1) By the *breath*, in small-pox, measles, whooping cough, pneumonia, mumps, typhus, scarlet-fever, and probably the great majority of infectious fevers. How far the breath derives its infectious quality from the throat and fauces is not always clear. Little is known of the distance to which infection can be carried through the air ; long ranges are known to be possible in small-pox, and may be suspected in measles and whooping cough ; typhus can only infect at short distances, and this is probably true of scarlet-fever.

(2) By *exhalations*, from the skin in typhus, and possibly many other diseases, from wounds in pyæmia, erysipelas, and other septic diseases.

(3) By *desquamated particles* of epidermis in scarlet-fever, and pustules in small-pox. These may be carried by currents of air.

(4) By *secretions* and *excretions*. Mucus from the

* The term *zymotic* is often limited to the more acute specific diseases.

mouth, throat, etc., is infective in diphtheria and scarlet-fever; sputa in tubercular phthisis; saliva in rabies in dogs if not in man. Milk is liable to carry infection (chapter iv.). The bowel excreta are infective in enteric fever and cholera, and many authorities believe that they are so in other diseases, including scarlet-fever. The urine is sometimes regarded as a vehicle of infection in acute specific fevers. Syphilis and gonorrhœa are transmitted by means of the specific discharges.

As regards the recipient the mode of infection is also varied. Many diseases are conveyed through the air, and the virus is doubtless inhaled, lodging either on the fauces or in the lungs. Water is known to be able to convey the poison of enteric fever and cholera, and milk that of scarlet fever, enteric fever, diphtheria, and cholera, the poison in such cases being swallowed. It is probable that the specific organisms multiply in these media. Experiments seem to show that the acid gastric juice kills microbes that are not in the spore stage, but since the reaction is not acid in the absence of solid food, this safeguard is incomplete, especially as regards water-borne virus. Infective particles carried in *fomites*, *i.e.* in clothing, etc., or conveyed by the hand to the mouth, may be inhaled or swallowed. Certain other diseases are usually imparted by more direct contact, for example syphilis and parasitic skin diseases; an unwise attempt is often made to distinguish these as "contagious" diseases, but it must be remembered that it is possible to convey the so-called "contagious" diseases without direct personal contact, and that all infectious diseases are most readily transmitted when contact is close. Puerperal fever may be regarded as an example of infection by contact or inoculation. A few diseases, of which rabies and vaccinia are typical examples, can only be conveyed by inoculation, that is, by lodgment

of the virus in an abrasion of the skin ; this is the ordinary mode of infection by anthrax and glanders, although inhalation is also possible. Small-pox, tuberculosis, and certain other diseases are also inoculable ; the evidence regarding scarlet-fever and measles is doubtful. Inoculation may occasionally take place through unbroken skin. This has recently been shown to be possible as regards virulent cultures of the glanders *bacillus* if rubbed in.

Malarial diseases are due to organisms that have their normal habitat in the soil. They appear to be acquired by man from this source only, whether by inhalation or swallowing, and although they multiply in the system they are not transmitted to other persons.

Leprosy is an instance of a specific disease in which the mode of infection is still unknown, although the microbe is now familiar. Even less has been made out in regard to rheumatic fever, the specific nature of which, though probable, still remains open to doubt.

Many authorities believe that certain specific diseases that are undoubtedly transmissible from person to person may yet occasionally arise *de novo*, independently of infection from any previous case. This has been alleged more especially as regards relapsing fever, typhus, enteric fever, diphtheria, erysipelas, puerperal fever, hospital gangrene, and septicæmia. Instances are of common occurrence in which the closest examination fails to reveal any possible exposure to infection, and occasionally, under favourable conditions, these diseases spring up without apparent specific cause in localities that have for years been entirely free from them ; but the tendency of modern research is to find an adequate explanation in infection conveyed by *fomites*, by food, by air-borne micro-organisms, or by lower animals suffering from the same disease, possibly with widely different

manifestations. The supposed logical necessity of a "previous case," that is, of an immediately antecedent *human* case, has lost some of its significance since we have learned to recognise the actual living *materies morbi*, to detect it in air, water, and soil, to cultivate it in dead media for indefinite periods, to transmit it to lower animals, and to increase or lessen its virulence at will. It is noteworthy that most of the infective diseases suspected of origin *de novo* are filth-diseases, and due to microbes that can be cultivated outside the living body. Quite recently it has been found that there are non-pathogenic microbes of wide distribution, which in every point except virulence closely resemble the specific microbes of enteric fever and diphtheria; and non-pathogenic bacilli, morphologically similar to anthrax bacilli, have been found to be protective against anthrax. Some authorities regard these harmless microbes as being probably generically identical with the virulent microbes that they resemble, and therefore capable of assuming a virulent character if cultivated under suitable conditions, a view that reintroduces the *de novo* hypothesis in a new form.

Many of the specific diseases, and especially those that have relation to telluric conditions, attach themselves more or less permanently to certain localities, and are termed *endemic;* thus cholera is endemic in the delta of the Ganges, leprosy in parts of Norway, small-pox in the Soudan and elsewhere, and in a less marked degree diphtheria, enteric, and scarlet-fever may be said to be endemic in certain districts in England. From time to time most diseases of the specific class become widely prevalent over a larger or smaller area, and are said to be *epidemic.* Thus cholera in an epidemic form occasionally spreads westward over Europe, disappearing almost entirely in the intervals. Small-pox, scarlet-fever, measles, and all the ordinary zymotic diseases, which are always

present in England, assume an epidemic form every few years, locally or in widespread outbreaks. Occasionally a disease diffuses itself so generally over a great part of the globe as to constitute a "pandemic."

The causes of such outbursts are still imperfectly known. They have been attributed vaguely to "epidemic constitution" of the air, to "pandemic waves" of unknown nature, and, more intelligibly, to climatic and meteorological conditions, accumulation of susceptible persons, facilities for convection, and (as regards cholera and other "filth-diseases") imperfect sanitation. Scarlet-fever, in temperate climates where it has established itself permanently, tends to become epidemic at intervals of about five years; measles at intervals of about two years. Whooping cough is more irregular than either, but on an average becomes prevalent every second year. Diphtheria shows no very marked periodicity, apart from its dependence upon season, and enteric fever none.

It will be seen presently that the liability to each kind of infection varies in man according to age and sex, as well as locality, climate, season, and surroundings. Similar variation occurs among the different races of men, and still more conspicuously among the different genera and species constituting the animal kingdom. Thus rodents and ruminants are susceptible to anthrax, but cats, dogs, and swine are almost exempt from it; inoculation of birds is only possible if their temperature is artificially lowered, and inoculation of frogs and lizards if their temperature is artificially raised.

The more important specific diseases that are common to man and certain lower animals are vaccinia, tuberculosis, anthrax, rabies, tetanus, diphtheria, glanders, actinomycosis, and septicæmia. Influenza ought probably to be added to the list. There is reason to believe that scarlet-fever affects cows, and the same

may be said of enteric fever. Variolous diseases attack sheep and other animals, but are probably not identical with small-pox.

A latent or incubative period intervenes between infection and the appearance of the first symptoms of the disease. Its duration is fairly constant for each disease; it seems to be shortest and most uniform when infection is due to inoculation or ingestion. The incubative period is less than a week in scarlet-fever, diphtheria, plague, cholera, yellow-fever, diarrhœa, influenza, and erysipelas * (Squire); more than a week in small-pox, varicella, measles, rötheln, mumps, enteric fever, and typhus.

Little is accurately known of the changes that occur during incubation, beyond the fact that the poison is multiplying in some part of the system.† The onset of symptoms is very gradual in enteric fever and a few others, but sudden in the majority. The temperature invariably rises, and the characteristic phenomena of each malady follow with more or less intensity. A rash makes its appearance upon the skin in certain of the infectious diseases, hence termed *exanthemata;* the date of its appearance is constant for each disease within narrow limits, and its distribution and other characteristics are also

* Squire believes the true incubation of whooping cough also to be less than a week. He points out that diseases with long incubation have usually a very definite course ending by crisis, without very prolonged or very definite sequelæ, and that infection ceases early. Those with short incubation, on the other hand, are liable to relapses and long definite sequelæ, and infection lasts far into convalescence.

† Concurrence of two distinct zymotic diseases is occasionally observed. Vaccinia and small-pox, measles and whooping cough, measles and scarlet-fever, measles and mumps, whooping cough and chicken-pox, are among the least rare examples. According to Squire, diseases with similar incubation (*i.e.* both long or both short) may run their course independently without interfering with each other, but if two diseases with dissimilar incubation are acquired at the same time, one or the other is delayed.

more or less uniform. The chief exanthemata affecting man are small-pox, varicella, scarlet-fever, measles, rötheln, enteric fever, and typhus; but syphilis may also be included in this group. In exceptional cases, however, the rash, like any other given symptom, may be wanting.

As a rule, the specific diseases have a short and definite course, ending in death, or in recovery with or without permanent changes in tissues and organs. Some, however, like syphilis and leprosy, run a life-long course, while malarial diseases tend to recur at regular intervals, or after years of apparently complete recovery. Rabies and a few more are almost invariably rapidly fatal, while rötheln, mumps, and varicella are attended with such slight constitutional disturbance that deaths are very rare. The tendency to death may be dependent upon constitutional symptoms such as hyperpyrexia, on local lesions as in enteric fever and diphtheria, on complications in the course of the disease (often really part of the disease itself), or, lastly, on sequelæ affecting important organs.

The intensity of any given disease is subject to wide variations. Thus small-pox may be so virulent as to kill the patient before any rash appears, or so mild that only one or two spots, sometimes none, may appear. Scarlet-fever similarly occurs sometimes in a malignant and rapidly fatal form, while in other cases its manifestations are so slight as to escape recognition. As a rule, the type, whether severe or the reverse, holds good for the great majority of cases occurring in a given outbreak, or at all events in the same period of the outbreak; but it is commonly more intense in the earlier than in the later part of an epidemic. As regards seasonal variations, however, there is some reason to believe that in scarlet-fever, and probably in other diseases also, increased prevalence is associated with diminished average severity, as measured

by the proportion of deaths to attacks. Age and sex have an important influence upon severity of attack as well as upon susceptibility, varying with different diseases ; thus scarlet-fever, whooping cough, and many others become less and less dangerous to life from infancy upwards, while in enteric fever the reverse is the case. Both scarlet-fever and small-pox are less liable to terminate fatally in females than in males, and the same seems to be true also of influenza.

An important general characteristic of specific diseases is their tendency in the event of recovery to protect the patient against a subsequent attack of the same disease. This statement must be taken in a modified sense as regards syphilis, leprosy, and the malarial diseases. The protection is perhaps most complete in small-pox, but in this, as in all others of the class, second and even third attacks are occasionally met with. In enteric fever, diphtheria, and influenza the protection is much less marked, and in erysipelas, phthisis, and septicæmia it can scarcely be said to exist. In all cases it diminishes with the lapse of time, its duration being dependent upon the nature of the disease, upon the amount of lesion (in vaccination at all events), and probably upon idiosyncrasy. Klein has shown that protection against anthrax, though real, is very brief in guineapigs, and much more lasting in cattle. Fatigue greatly increases the susceptibility of rats to anthrax. The presence of sugar in the tissues (due either to direct injection of sugar, or administration of phloridzin) lessens the resistance to glanders and to suppuration (*streptococcus pyogenes aureus*), but not to anthrax or tubercle. There are also examples of the virulence of a pathogenic microbe being intensified by the presence of an otherwise harmless germ : thus attenuated cultures of the specific microbes of pneumonia or erysipelas, too feeble to give rise to any symptoms, can be made to cause an intense

attack if along with them is injected a culture (sterilised or not) of a harmless saprophyte known as *proteus vulgaris*. It has been thought that an attack of enteric fever lessens or annuls the protective influence of vaccination. Little is known as to any protective power of one specific disease against another, unless vaccinia be regarded as absolutely distinct from small-pox. Erysipelas has been found experimentally to be protective against anthrax. Animals are inoculated with the "attenuated virus" of anthrax, fowl cholera, and other diseases, the object being to obtain protection by means of a mild form of the disease. Inoculation for small-pox, and the Pasteurian prophylaxis against rabies, are examples of similar procedure applied to man.

The Germ theory, broadly stated, affirms that certain specific diseases are invariably associated with the growth and multiplication in the system of corresponding specific microbes, and that these microbes are the actual contagia or causes of the disease. The evidence is partly direct, partly indirect.

1. In regard to a few diseases the proof is complete, since—(*a*) a certain microbe is invariably discovered in the blood or tissues of animals suffering from the disease in question; (*b*) this microbe can be cultivated in artificial media, for any required number of successive generations; (*c*) the same disease is reproduced by inoculation of a susceptible animal with the last cultivation; (*d*) in every such inoculated animal the specific microbe is found, with the same distribution as in animals infected in the ordinary way.*

The third stage being as a rule inadmissible as regards man, the complete proof is practically limited

* To these four points, formulated by Koch, Martin has added a fifth, namely, that the secondary infective agent (ptomaine, or albumose) separable from the tissues in the natural disease should have similar chemical and physiological action to the products obtained from a pure cultivation of the microbe.

to diseases that attack some lower animal. Of those affecting man (as well as lower animals) anthrax, erysipelas, and tuberculosis have been fully proved to be associated with specific microbes, and similar complete evidence is forthcoming in respect to many diseases attacking lower animals only.

2. A characteristic microbe is constantly found in the blood or tissues of persons suffering from certain other diseases—*e.g.* relapsing fevers, enteric fever, diphtheria, leprosy, pneumonia, cholera, scarlet-fever, etc., although the proof of causative relation is incomplete. In several diseases, however, which from analogy are nevertheless believed to be microbial, no specific or characteristic organism has been isolated with certainty. Measles and whooping cough may serve as examples.

3. There is a close analogy between the natural history of infection and that of organised living ferments such as yeast, in respect of the almost infinite multiplication of an almost infinitesimal charge planted in a suitable soil under suitable conditions, and also in respect of the effect of reagents in checking or permanently arresting their increase.

The germ theory is now generally accepted, even in respect of those specific diseases, such as hydrophobia, in which no characteristic microbe has yet been isolated. The chief alternative view which has been advocated is that infection is due to a non-organised chemical ferment, comparable to diastase, the microbes being regarded as (at most) effects or collateral phenomena, without causative influence as regards disease.

What the precise relation between the germs and the production of the varied phenomena of disease may be is less clear. Under certain conditions the enormous multiplication of the microbes may lead to obstruction of vessels—a "mechanical mycosis"—but the ordinary course of symptoms cannot be accounted

for by any physical properties of such minute particles. It is probable that they act mainly by modifying the physiological processes of the tissues—*e.g.* by depriving the red corpuscles of oxygen, or by secreting or excreting some chemical product, whether "ferment," "albumose," or "ptomaine," as a result of their growth and multiplication, which in its turn diffuses and acts as a poison.

Three principal hypotheses have been advanced to account for the protection conferred by an attack of such a disease.

1. The *exhaustion* or *pabulum* theory is that the microbes during the first attack remove some chemical substance necessary for their growth, the loss of this substance rendering further attack impossible. This view involves the improbable assumption that the human body contains a special and separate pabulum suited to each specific disease to which it is liable, since one disease is only protective against itself.

2. The *antidote* or *retention* theory assumes that the first attack leaves in the system some direct or indirect product of the growth of the microbes which inhibits any further multiplication. There is experimental evidence in support of this view,* as will be seen presently, and sterilised or filtered cultivations of certain pathogenic microbes have been found (if injected into the system) to have a protective action, which, curiously enough, does not necessarily include any power of checking the growth of the specific microbes outside the living body, in cultivating media. The effect therefore is not due to direct action on the microbes, but to increase of resistance.

3. According to the *acclimatisation* theory, the cells

* Carbolic acid is found in small quantity among the products of putrefaction of albuminous substances. Lactic fermentation of sugar is soon arrested by the accumulation of lactic acid, but recommences if the acid is neutralised by chalk.

and tissues are in some way modified during an attack so as to be able to resist future invasions of the same microbe. Metschnikoff found that when virulent anthrax bacilli are inoculated into an insusceptible animal (such as a frog), the white (amœboid) blood corpuscles absorb the bacilli bodily, and presumably destroy them (Fig. 21). The same happens when attenuated virus is inoculated, even into susceptible animals; the bacilli may be seen partially or wholly embedded in the amœboid corpuscles. When a susceptible animal is inoculated with virulent anthrax, however, few if any bacilli can be seen inside the corpuscles. The inference to be drawn from Metschnikoff's observations is that the amœboid corpuscles act as "phagocytes," or destroyers of pathogenic microbes: and that "protection" is largely, if not entirely, dependent upon this action.

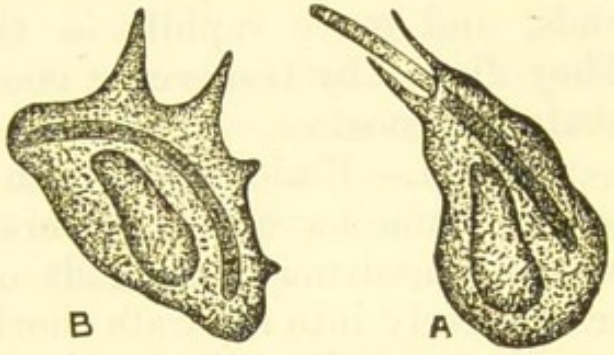

Fig. 21.—A, Amœboid Blood-corpuscle of Frog absorbing *Bacillus anthracis*. B, Same, a few minutes later. (*Metschnikoff.*)

The same hypotheses may serve to account for the termination of an attack. It may be assumed that all the pathogenic microbes perish or are eliminated at the end of an attack of most of the infectious diseases, but pass into a quiescent stage in the intervals of malarial and relapsing fever. In tuberculosis, leprosy, and syphilis, their development may be progressive.

Microbes.—"Microbe," "micro-organism," "microzyme," "bacterium," "germ," are terms applied almost indifferently to a vast and increasing number of microscopic organisms, which are destitute of chlorophyll and consist of protoplasm enclosed in a cellulose membrane. They multiply by fission, and

are therefore termed *Schizomycetes*, or *fission fungi*. They may be classified, according to their form, as—

Micrococci.—Minute spherical microbes, without cilia. They multiply by elongating and then dividing transversely, forming *diplococci* (*i.e.* pairs), *streptococci* (chains), *staphylococci* (clusters), *sarcinæ* (square groups of four cocci, or multiples of these), or *zooglœa* (irregular masses embedded in a gelatinous matrix).

Bacteria.—Oval or short cylindrical microbes with rounded ends. They have a cilium at one or both ends, and move rapidly in the presence of oxygen. They divide by transverse constriction and may form chains or zooglœa.

Bacilli.—Rod-shaped, with rounded or square-cut ends. Some have cilia, others are motionless. They elongate, and may form rods of any length, or divide transversely into separate short rods, or chains of rods or zooglœa. Bacilli also form spores under certain conditions, among which may be mentioned moisture, suitable temperature (12° C. to 40° C. in the case of *Bacillus anthracis*, according to Pasteur), and presence of oxygen. The spores are round or oval glistening spots, which appear in the substance of the bacillus, and grow at the expense of the protoplasm until the sheath bursts and liberates them. They are extremely resistant to heat and cold, but in cultivating media the spores readily germinate, a projection appearing at one point and growing into a bacillus.

Vibriones.—Long, wavy, and motile (ciliated) filaments.

Spirilla.—Motile spiral filaments. Sometimes they form long chains (*spirochæta*) and may produce spores.

Micrococci have been proved to be of constant occurrence, and pathogenic, in septic processes, acute suppuration, acute infective osteo-myelitis, and erysipelas. There is strong but not absolutely complete evidence to the same effect in respect of

pneumonia, gonorrhœa, ulcerative endocarditis, scarlet-fever, and puerperal fever; micrococci are always present in active lymph of vaccine and small-pox, and the virulence is lost when they are removed by filtration, but beyond this the proof of their being the actual *materies morbi* is incomplete. Ammoniacal fermentation of urine is determined by *M. ureæ*, which converts urea into ammonic carbonate. Many diseases of animals, including cattle-plague, are believed to be due to specific micrococci. Micrococci are also concerned in putrefactive processes.

Bacteria are pathogenic in fowl-cholera and certain forms of septicæmia in rabbits. *Bacterium termo* is the most important of the putrefactive organisms. *B. lactis* converts milk sugar into lactic acid,* and is the cause of milk turning sour. *Mycoderma aceti* changes alcohol into acetic acid.

Bacilli are known to be pathogenic in anthrax, tuberculosis, tetanus, and glanders, and are believed to be so in enteric fever, diphtheria, septicæmia, leprosy, influenza, syphilis, malaria, and the Welbeck disease. Many diseases affecting lower animals are due to specific bacilli, and among them *Rauschbrand* ("symptomatic anthrax" or "black leg"). The fermentation of cheese, producing butyric acid, is due to the growth of *Bacillus butyricus* (*Bacillus amylobacter*).

Spirillum obermeyeri is found in the blood during the acute stages of relapsing fever. The *Vibrio choleræ asiaticæ*, or "comma bacillus," is now generally regarded as the cause of cholera.

It should be mentioned that other micro-organisms, not classed with bacteria, have relation to disease and fermentative processes. Thus thrush is due to the

* Several microbes have the power of converting sugars into lactic acid. Among them are *micrococci*, met with in dental caries, the lactic acid they produce being the active agent in dissolving out the lime salts.

growth of *Oidium albicans*, a mycelial form of a *torula* (*Saccharomyces mycoderma*). Mycelial growths, with spores or *conidia*, are associated with ringworm (*Trichophyton tonsurans*), favus (*Achorion schönleinii*) and pityriasis versicolor (*Microsporon furfur*).

Actinomycosis is characterised by the presence of a mycelial growth, with peculiar masses of club-shaped corpuscles radiating from a centre. Minute amœboid bodies termed *plasmodia* are pathogenic in malaria, according to the researches of Marchiafava and Celli. Parasitic amœbæ, twelve times the size of white blood corpuscles, have been found in the intestines and fæces in cases of dysentery, and in pus from tropical abscesses of the liver associated with dysentery.

Organisms destitute of chlorophyll, having their habitat in living hosts, animal or vegetable, are termed *parasites*, while those living upon dead organic material are known as *saprophytes*. Many microbes are capable of playing both parts, though not necessarily with equal facility. Parasites that have not been found to grow under any known conditions as saprophytes are distinguished as "obligate," the rest as "facultative." Bacillus anthracis is an example of a facultative parasite, and the unknown microbes of vaccinia and many other infectious or inoculable diseases may be provisionally classed as obligate. Cultivation in non-living media, that is, a form of saprophytism, is essential for the complete proof of the pathogenic nature of a given microbe.

Some parasites are quite harmless to their hosts, so far as is known. The mouth, nose, and respiratory and alimentary passages generally, abound with microbes, even in health. Organisms apparently indistinguishable from the supposed pathogenic microbes of cholera and pneumonia have been found in normal saliva.

The action of microbes is essentially one of oxidation.

As a rule carbonic acid is given off, but there are innumerable known and unknown bodies formed coincidently, which vary greatly with the pabulum as well as with the microbe. Among other products of the vital processes of microbes highly poisonous alkaloids (*ptomaines* or *leucomaines*) are formed, which, so far as pathogenic microbes are concerned, are usually to be regarded as the immediate agents in the production of disease-symptoms. They are soluble, and even when freed from their respective microbes have in certain cases (*e.g.* in fowl-cholera) been found to be capable of producing a slight and transient appearance of characteristic symptoms. They may also be protective against disease, and it has been shown, for example, that the injection of filtered fluid in which anthrax bacilli have been cultivated protects against subsequent or even coincident inoculation with virulent anthrax. Hankin isolated from cultures of the anthrax bacillus an *albumose*, the injection of which into mice renders them insusceptible to anthrax. Brieger and Fränkel have isolated pathogenic albumoses from cultures of the specific microbes of diphtheria, enteric fever, cholera, and tetanus. Roux and Yersin believe the soluble poison to be a ferment, and Martin has shown that in anthrax and diphtheria the microbe produces such a ferment or *enzyme*, which reacts on the tissues to form *albumoses*, and that these break up into simpler bodies, including *ptomaines*. Both albumoses and ptomaines possess the specific toxic virulence and protective power; in diphtheria the albumose is most virulent, in anthrax the ptomaine.

Cultivation.—Microbes derive oxygen either from the air or from compounds containing oxygen; in the former case they are termed *aërobic*, in the latter *anaërobic*. Yeast (*Torula cerevisiæ*) is anaërobic, and acquires oxygen at the expense of the sugar, which is reduced to alcohol; the "vinegar plant," *Mycoderma*

aceti, is aërobic, and oxidises alcohol into acetic acid. Aërobic microbes grow best at the surface of a liquid, anaërobic organisms deeper down away from contact with air or aërated layers of fluid. The distinction is not absolute, and many microbes are able to exist under either condition.

Besides oxygen, microbes need nitrogen, which some are able to take from salts, such as ammonic tartrate, while others can only assimilate it from albumen or gelatin. Carbon is necessary, and also inorganic salts, including sodium, potassium, and phosphoric acid. Cultivating media should be neutral or faintly alkaline.

Both liquid and solid media are used. Among fluid media are broths made from various kinds of flesh, peptones, meat extracts, blood serum, hydrocele fluid, sugar, Pasteur's solution (water containing cane sugar, ammonic tartrate, and yeast-ash), and Cohn's solution (water with ammonic tartrate, potassic phosphate, tricalcic phosphate, and magnesic sulphate). Some of the more common solid media are boiled potato, solid egg-albumen, solid hydrocele fluid, agar-agar, gelatin, nutrient gelatin (gelatin with admixture of meat extract), and paste.

The medium must be adapted to the organism. Pathogenic organisms will not grow in Pasteur's or Cohn's solution.

After careful sterilisation by heat, gelatin media are kept in sterilised test-tubes, guarded, by means of sterilised plugs of cotton wool, against infection by air-borne germs. Each tube may then be "inoculated" by means of a (previously sterilised) platinum wire charged with the microbes to be cultivated; the wool plug is removed momentarily for this purpose, and then replaced. Potato cultures are made by inoculating the freshly cut surface of a boiled potato, and guarding it by a glass bell-cover, the edge of

which may dip under a solution of mercuric chloride. For plate-cultivation, a small portion of the liquid under examination is diffused through melted nutrient gelatin or other suitable medium, and then poured upon a flat surface and allowed to solidify by cooling; protection from aërial germs is afforded by a glass cover.

The temperature must be kept constantly at the point which experiment has shown to be most favourable for the microbe in question. For this purpose an "incubator" is used, in which the temperature is regulated automatically.

Solid media offer great advantages. If more than one variety of microbe is present, the resulting colonies tend to remain distinct, and it is possible to establish a pure cultivation of each by inoculating afresh from it. Plate-cultivations are especially useful in this way, since by regulating the proportions the distribution of the colonies may be made as sparse as is necessary. Accidental contamination by aërial organisms is readily detected. Another important advantage is that pure cultivations upon solid media frequently exhibit characteristic naked-eye peculiarities of outline and direction of growth that are important as means of identification. Another method of obtaining a pure cultivation is adopted in isolating Eberth's typhoid bacillus from fæces. A cultivation is made under conditions inhibitory to other microbes, but not to this bacillus: this is effected by adding iodine trichloride or carbolic acid, or by maintaining the temperature at 45° C.

Among the points that serve for the differentiation of the large and increasing number of varieties of microbes are the following:—Microscopic appearances, as to form, size, structure, movement; effect of certain staining and decolorising agents; media in which growth occurs, and temperature required; rate

of growth; microscopic appearance of cultivation in solid media, including form, colour, distribution (superficial or deep), liquefaction of gelatin, etc.; results of inoculation upon animals.

Attenuation of virus has been effected in several ways.

1. *Cultivation with free exposure to oxygen.*—Pasteur found that the microbe of fowl-cholera retains its virulence unimpaired if kept in sealed tubes, or if cultivated with a minimum interval between the successive cultures. If, however, the cultivation is allowed to remain exposed to air for weeks or months the virus is attenuated, and when inoculated causes a mild but protective form of the disease.

2. *Cultivation at high temperatures.*—Pasteur prepared a "vaccine" (*i.e.* an attenuated virus) of anthrax by cultivating the bacilli for three weeks in air at 42° to 43° C. There is no visible change in the mode of growth during this period except that spores are rarely if ever formed, but spore formation is immediately resumed if the bacilli are transferred to a fresh culture at ordinary temperatures. The virus becomes more and more attenuated if the temperature is maintained, but in about a month the bacilli all perish. The attenuation is brought about more rapidly at higher temperatures; a few days suffice at 45° C., a few hours at 47° C., a few minutes at 50° to 53° C. The original virulence is regained speedily upon transferring the attenuated bacilli to fresh cultivation at ordinary temperatures, if the attenuation has been rapid. If, however, it has been slow, it is difficult to restore the virulence.

3. *Cultivation in presence of inhibitory reagents.*—Klein cultivated anthrax bacilli in gelatin containing 0·0025 per cent. of mercuric chloride, and obtained an attenuated virus which for a time protected guinea-pigs. Cultivations from the attenuated virus were

virulent. Other reagents, including potassic bichromate and terchloride of iodine, have been employed in like manner.

4. *Transmission from one animal to another.*—Anthrax bacilli from sheep or cattle cause fatal anthrax if again inoculated upon susceptible sheep or cattle, or upon white mice; but bacilli taken from white mice produce only a transient illness in sheep, which, however, is protective. Assuming Jenner's view to be correct, vaccinia is an example of attenuation of virus, that of small-pox being so modified by transmission through the cow as to produce a mild but protective form of the disease.

These changes brought about in the laboratory by artificial means find a close parallel in the varying virulence of epidemic diseases. Sometimes the type, whether of small pox, scarlet fever, diphtheria, or measles, will be malignant and fatal, and at other times the same disease will be so mild as to cause scarcely any deaths.

It would seem that immunity from specific diseases may be acquired in many different ways, quite apart from protection due to a previous attack, or avoidance of exposure to infection. For some maladies, at all events, increasing age in itself brings lessened susceptibility. Many instances will be given presently of marked differences in susceptibility to infectious disease between the two sexes, and between different races. Some degree of immunity from yellow fever and malaria seems to be acquired by residence in countries where these diseases are prevalent, and it may be suspected that these are really instances of protection by repeated minimal or attenuated infection. Protective inoculation by attenuated virus has just been considered. A broad line of distinction may be drawn between the use for protective purposes of an attenuated virus containing living organisms,

and the injection of non-living products such as ptomaines and albumoses. Examples of both have already been given. Pasteur's anti-rabic inoculations are believed to belong to the latter category, so far at all events as the earlier operations are concerned. Recently it has been discovered that the blood or blood serum has a remarkable power of destroying pathogenic microbes, and that the serum of an animal naturally or artificially immune to certain diseases, confers immunity upon a susceptible animal if injected into its system. It seems that tetanus in animals can be arrested, even during the acute stage, by this means. Another variety of protective inoculation is the "minimal" method, in which a very small quantity of virulent material is used, with the result that only slight symptoms follow, but the animal becomes thereby insusceptible to further inoculation of the same diseases. This has been established as regards *Rauschbrand* (symptomatic anthrax) by Arloing and others. How far it is true of other diseases remains to be seen, but it is in harmony with what we now know of vaccination, and also with many observations that have been made tending to show (1) that a certain "dose" of virus is necessary to produce an attack of certain diseases, and (2) that the severity of the attack varies with the "dose" of virus.

CHAPTER XI.

DISINFECTION.

Disinfection is the destruction of the specific virus upon which infection depends, and as regards the germ diseases the term *disinfectant* is equivalent to *bactericide*. It is, however, often loosely applied also to *antiseptics*, that is, to substances that arrest or impede the growth of microbes without destroying their vitality, and even to *deodorants* or reagents that destroy or mask the effluvia which are the frequent by-products of bacterial growth.

It is probable that protracted exposure to air and light will ultimately destroy most, if not all, pathogenic microbes, although under favourable conditions the virus of scarlet fever and other transmissible diseases has been known to retain its vitality for many years. It would seem also that mere diffusion in the atmosphere may render a virus inert. Typhus attacks a very large proportion of those who come into close contact with typhus patients, but rarely spreads under other conditions even if the isolation is imperfect. Small-pox, on the other hand, is believed upon strong evidence to be carried by air currents for long distances under favourable meteorological conditions. Spores of pathogenic bacilli would doubtless be among the most resistant, but mechanical portability (influenced by the form of the microbe and the size and weight of the epithelial scales or other particles to which it may be attached), the dryness (or the reverse) of the air, and the chemical effect of the atmospheric oxygen, must be regarded as important possible factors, and it is at all events conceivable that a certain minimum "dose" of the virus is

necessary for infection, so that mere dilution beyond a given point would render the virus harmless, even without destroying its vitality. According to Koch, mere drying kills the cholera bacillus.

The complete disappearance, often for long periods, of measles and other infectious diseases from a district after a widespread epidemic, is in itself a sufficient proof that an enormous amount of *contagium* does in some way or other speedily become inert, apart from all attempts at disinfection.

Mechanical removal of infection from rooms or garments is often an important adjunct to disinfection proper. Walls are stripped of paper, or scraped, or rubbed with bread crumb, or washed; floors are washed or swept; a strong current of air is sent through the room; garments are washed or brushed, or beaten, and hung out in the open air. As a rule, such measures are in themselves incomplete safeguards, since some portion of the virus may escape dislodgment, and there is no certainty as to the future harmlessness of the rest.

True disinfection, that is destruction of germs, may be effected by heat or by chemical methods.

Disinfection by heat is the simplest and most thorough of all methods. With articles of small value, the safest plan is of course to burn them, but when this radical remedy is inapplicable, true disinfection may usually be effected by exposure to moist or dry heat.

The experiments of Koch, Parsons, and others, have shown that even spores of bacilli are destroyed by exposure to steam at a temperature of 212° F. for five minutes, or to hot air at a temperature of 220° F. for four hours. Less resistant organisms, for example micrococci or bacilli free from spores, are destroyed by hot air at 220° F. in an hour. Water at a temperature of 212° F.—that is, boiling water—is at least as efficacious as steam.

The mode of experiment was to steep threads in cultivations of the respective organisms, and after exposing them to known temperatures for measured periods, to test their vitality by inoculation or further cultivation; "control experiments" were, of course, made in each instance, to prove that threads treated in exactly the same way except as regards exposure to heat, gave positive results in cultivation or inoculation. Anthrax spores and anthrax bacilli serve admirably as test objects, since they are themselves pathogenic, and can be readily cultivated or inoculated, with characteristic and unmistakable results. Little is known with certainty as to the specific microbes of the ordinary infectious diseases attacking man, and in regard to them inoculation experiments are inadmissible, so that for the present we can only place reliance upon such processes as are found experimentally to destroy the most resistant of other organisms, namely, the spores of bacilli.

In practice the problem of disinfection is almost always complicated by the fact that the virus is not exposed freely, but enclosed in garments, pillows, or even beds; that is, in more or less bulky articles made of materials that have been selected for use as being the worst conductors of heat.* It is found

* Wool and silk are the warmest materials used for clothing. Not only are they bad conductors of heat, but they absorb a considerable amount of moisture without becoming damp. The watery vapour of perspiration is condensed, and its latent heat rendered sensible, while the tenacity with which the moisture is held prevents re-evaporation and chill. Linen and cotton are much better conductors of heat, and absorb little water. Perspiration readily makes them damp, and they are then chilly owing to evaporation.

A brief note may be introduced here respecting the microscopic and chemical characters of these materials. *Under the microscope*, wool fibres, like hair, are straight, unbranched, and exhibit faint cross-markings and marginal indentations, due to the imbrication of the scales. Silk filaments have no such markings, and are structureless except for occasional nodes. Linen fibres have many

that steam rapidly penetrates into the interior of such objects. The first portions condense, parting with their latent heat in so doing, and create a partial vacuum,* so that successive supplies of steam follow continuously until a temperature of at least 212° Fahr. is attained at the centre. Dry hot air, on the contrary, being dependent upon conduction, very slightly aided by convection, has no such power, and it is practically impossible to raise the temperature at the centre of a bed or similar bulky object to 212° Fahr. by dry heat within any reasonable number of hours. Hot air moistened by steam is superior to dry hot air in penetration, but not in germicidal power, and is far inferior to steam in both respects.

Another important consideration is the effect upon the colour and texture of fabrics exposed to heat. Articles composed in part of fusible substances, such as glue or sealing-wax, are, of course, ruined by heat in any form. Steam is inadmissible for leather objects, since it shrivels them up and renders them worthless; hot air merely makes them temporarily dry and brittle.

nodes, with ragged branching filaments. Cotton fibres are flat and twisted, without nodes or branches. The chemical reactions are shown in the following table :—

Reagent.	Wool.	Silk.	Cotton.	Linen.
Potash or Soda (hot strong solution) .	Dissolves.	Dissolves.	Nil.	Nil.
Sulphuric Acid . .	Nil.	Dissolves slowly.	Gelatinises.	Gelatinises.
Nitric (or Picric) Acid	Turns yellow.	Turns yellow.	Nil.	Nil.
Zinc Chloride (hot strong solution) .	Nil.	Dissolves.	—	—
Ammonic Cuprate (solution of CuO in NH_3)	Swells.	Dissolves.	Dissolves.	Dissolves slowly.

* Steam, in condensing to water, shrinks to $\frac{1}{1200}$ of its bulk, and gives off latent heat sufficient to raise its temperature 300° F.

With these exceptions, steam is less injurious than hot air in almost all respects. New woollen goods, such as blankets and flannels, lose some of their whiteness and fleeciness by either process, but not more than in one or two ordinary washings. Silk and cotton are not injured by steam, nor by hot air if the temperature is carefully regulated. Dyes are surprisingly little affected by either steam or hot air.

The chief difficulty in steam apparatus is to prevent loss of heat, and condensation. This is overcome by surrounding the steam chamber by a "steam-jacket," that is, by making the wall of the apparatus double, and admitting steam into the space between the inner and outer casings. A door is provided at each end, one for the reception of infected goods, and the other for removal of the goods after disinfection. The doors are steam-tight, and are fastened by strong screw-clamps. The articles to be disinfected are placed in trays, or suspended from sliding racks.

Washington Lyon's apparatus is oval in section, and is usually worked with a pressure of 10 lbs. per square inch in the jacket and 5 lbs. in the chamber, so that the steam in the latter is superheated,* a further precaution against condensation. The articles having been introduced, and the doors closed and secured, steam is first sent into the jacket so as to heat the contents of the chamber. Steam is next admitted into the chamber itself, and soon reaches the full pressure required. It is found that penetration is more rapid if the pressure

* The boiling-point of liquids is regulated by the pressure. Water under ordinary atmospheric pressure, 14·7 lbs. per sq. inch, boils at 212° F., and cannot be heated above this; consequently steam cooled to 212° condenses. If the steam is "superheated" above 212° at the same pressure, which cannot be done in contact with water, it behaves as a permanent gas until the temperature falls to 212° again, or until the pressure is increased. If the pressure is doubled, the boiling-point is raised to 249°; if trebled, to 273°.

is intermitted once or twice, which is readily effected by turning a cock. Ten to twenty minutes suffice for the penetration of even bulky objects, and at the end of that time the steam is allowed to escape from the chamber, the door is opened, and the articles are removed. Further drying may be effected if necessary by leaving the door ajar for a few minutes, and exposing the articles to heat from the jacket.

Goddard, Massey, and Warner's apparatus differs from Lyon's in several points. It is rectangular, not oval; the doors are hollow, and form part of the steam-jacket, their interior being connected with the rest of the jacket by a jointed pipe; the pressure in the chamber and jacket is the same—usually about 20 lbs., so that the steam in the chamber is not superheated; the preliminary heating and the final drying are effected not by radiation from the jacket, but by a current of hot air, which is drawn through the chamber by means of a steam jet at the outlet. The steam-jacket and boiler are one, the lower portion of the jacket being filled with water, and serving as a boiler; in Lyon's apparatus the boiler is detached. When the steam in the jacket-boiler has reached the working pressure, the articles are placed in the chamber, and the doors are shut and secured. Hot air is drawn through the chamber for two or three minutes, then steam from the jacket-boiler is turned on, and in a minute or two reaches its full pressure. After ten to twenty minutes, according to the nature of the objects to be disinfected, the steam is allowed to escape from the chamber, hot air is again drawn through for a few minutes, and then the door is opened and the goods are removed.

Both of these forms of apparatus are designed for steam at high pressure, although they can be used for low-pressure steam. Van Overbeek de Meyer, of Leyden, has introduced an apparatus of somewhat similar, but simpler, construction in which steam at

atmospheric pressure is used. The steam, generated in a jacket-boiler that surrounds the chamber, passes thence into the interior through an opening at the top. As it is not under pressure, the temperature does not exceed 212° Fahr., but the penetration appears to be little less rapid than at the higher temperature and pressure. Drying is provided for by means of a current of hot air, which can be passed through the chamber when the steam is shut off, but is found to be rarely necessary.

Reck's is a still simpler low pressure apparatus, in which the jacket is dispensed with altogether. Illingworth's, again, has no jacket. Others might be mentioned. Each kind has been conclusively shown by experiment to fulfil the essential conditions, namely, rapidity of penetration. destruction of all organic life in the interior of articles of moderate bulk without injury to fabrics, and, lastly, convenience in working. High pressure, intermitted, is perhaps preferable for exceptionally bulky goods, but for ordinary purposes the question of high *versus* low pressure must be regarded as still undecided. Low-pressure apparatus is, for obvious reasons, simpler and less costly, and it is contended by Koch and others that high pressure gives little or no advantage either in rapidity or certainty of disinfection, while Esmarch has cast doubt upon the germicidal efficiency of superheated steam.

Hot air disinfection apparatus labours under a threefold disadvantage as compared with steam. The available temperature and duration of exposure are limited by the tendency to scorch the articles exposed ; the penetration of heat is so slow that it is practically impossible to thoroughly disinfect objects of moderate thickness, such as pillows ; and lastly the germicidal effect of a given temperature is far less with hot air than with steam. The only advantage that can be claimed for hot air is that leather

and bound books are not spoiled by it as they are by steam.

The best apparatus of this kind is that devised many years ago by Ransom. It consists of a rectangular chamber of wood and iron, lined with non-conducting material. Hot air mixed with the products of combustion passes into the chamber after being heated by a number of gas jets; the temperature of the hot blast is kept constant by an automatic mercurial regulator, which controls the gas supply and can be set for any required temperature. An outlet with a chimney is provided at the top of the chamber. The best working temperature is about 255° F., this being the highest that can be used for long periods without danger of singeing cotton goods. Thermometers are placed at the inlet and outlet. If the contents of the stove should take fire owing to overheating or to lucifer matches being left in pockets, the gas is automatically turned off and the entrance of air arrested, by the falling of a weighted lever, which, until such accident occurs, is held suspended by a chain attached to a fusible metal bar in the interior of the chamber. It is customary to expose articles to hot air at about 255° F. for two, four, or eight hours or more, according to their bulk, but for reasons already stated the penetration of heat is very limited. The outlet thermometer should be watched and the interval reckoned from the time at which it reaches its maximum, which, however, is almost always 5° or more below the temperature at the inlet. The direction of the hot air current being upwards, the lower surface of objects is heated much more rapidly than the upper.

The following figures, which give the mean values obtained in a series of 120 experiments, serve to show how slowly the temperature rises in the interior of woollen objects exposed to hot air. The inlet

temperature was about 255° F. throughout the series, and the final outlet temperature 245° to 250° F. :—

Registering Maximum Thermometers placed beneath Layers of Blanket.

Duration of Exposure.	2 layers.	4 layers.	6 layers.	12 layers.	18 layers.
4 hours . .	220° F.	206° F.	190° F.	162° F.	139° F.
6 ,, . .	226° ,,	214° ,,	208° ,,	174° ,,	153° ,,
8 ,, . .	230° ,,	221° ,,	215° ,,	196° ,,	182° ,,

In striking contrast to the above were the results of another series of experiments* with steam apparatus, the same blankets being employed. An electric thermometer, set so as to ring at 212° F., was placed beneath sixteen or more layers of blanket, and served to indicate the exact interval between the first exposure to steam and the attainment of the required temperature—namely, 212° F. All the three forms of steam apparatus previously referred to were tested, with low pressure as well as high, and the maximum interval noted was 17 minutes.

It is essential that any apparatus for disinfection by heat, whether by hot air or steam, should have doors at opposite ends, opening into entirely separate rooms provided with separate entrances. One of these rooms should be strictly reserved for infected and the other for disinfected goods, and no articles should on any account be allowed to enter the latter room except through the stove, the object being of course to guard against the danger of re-infection of the purified articles.

Chemical disinfection has been shown by the accurate experiments of Koch and others to be a matter

* By Dr. Ashby of Reading and myself.

of far greater difficulty than it was generally held to be a few years since. Most of the so-called disinfectants that are still almost universally employed are mere deodorants, or at best antiseptics, and have little or no germicidal power.

The next table gives the results of Koch's experiments upon anthrax spores with solutions of certain common "disinfectants." Threads were soaked in cultivations of the spores, dried, then placed in the disinfectant solutions for measured periods, and finally tested by cultivation or inoculation experiments.

The following solutions only, out of a long series, destroyed the spores within a day :—

Chlorine Water.	Potassic Permanganate (5 per cent.).
Bromine Water (2 per cent.).	Osmic Acid (1 per cent.).
Iodine Water.	Carbolic Acid (5 per cent.).
Mercuric Chloride (1 per cent.).	

A 4 per cent. solution of carbolic acid took three days, and a 1 per cent. solution of permanganate had not acted at the end of two days.

Many other common disinfectants, including those mentioned below, either took several days to kill anthrax spores or entirely failed to do so :—

Chloride of Lime	5 per cent.*	Boracic Acid	5 per cent.*
Zinc Sulphate	5 ,,	Borax	5 ,,
Zinc Chloride	5 ,,	Hydrochloric Acid	2 ,,
Cupric Sulphate	5 ,,	Carbolic Oil	5 ,,
Ferrous Sulphate	5 ,,	Sulphurous Acid	5 ,,

For practical disinfection the time required should never exceed twenty-four hours, and in many cases only a few minutes are available. The second series may, therefore, be dismissed from consideration as disinfectants, however useful as antiseptics or deodorants.

A most important consideration in regard to the more potent reagents forming the first series is their

* By weight in aqueous solution.

"working strength." If, for example, it is proposed to disinfect a putrescent liquid by means of permanganate of potash, it is absolutely useless to add a little of a five per cent. solution of the salt. We must add either the solid permanganate or a highly concentrated solution, until the permanganate is present as such to the extent of five per cent. of the whole weight of liquid, this five per cent. being of course in addition to the amount required to oxidise the organic matter. It is scarcely necessary to say that these essential conditions are rarely if ever observed in practice, and therefore "disinfection" by permanganate consists really of deodorisation with partial oxidation of organic matter. A similar consideration applies to mercuric chloride, which, if added to liquids containing organic matter, forms a precipitate that carries down part of the mercury in an inert form, and if sulphuretted hydrogen is present, the equally inert sulphide of mercury is thrown down. So, too, with carbolic acid, which must form not less than five per cent. of the whole weight of liquid—not merely of the stock solution—if it is to destroy anthrax spores.

It would seem, therefore, that mercuric chloride is the only reagent that can be conveniently employed in solution under such conditions as to destroy the most resistant microbes. Whether the contagia of human diseases are amenable to less potent reagents is still an open question,* but for the present it is not safe to assume this. One part of mercuric chloride in 1,000 of water destroys anthrax spores, according to Koch, but other observers have found this strength inadequate, and Wynter Blyth considers one per cent. necessary. The great drawback to this reagent is its extremely poisonous nature, but it may be kept in

* There is reason to believe that the virus of septicæmic diseases, including puerperal fever, is difficult to destroy, while vaccine lymph yields even to sulphurous acid.

fluted poison bottles properly labelled, and the solution may be artificially coloured with indigo, and "odorised" with thymol, as further safeguards. The following proportions are suggested in a memorandum of the Local Government Board:—½ oz. mercuric chloride, 1 oz. hydrochloric acid, and 5 grains of commercial aniline blue, in three gallons of water. It ought not to cost more than 3d. the bucketful (three gallons), and should not be further diluted. Non-metallic vessels (wooden or earthenware) should be used. Articles soaked in the mercurial solution should be steeped in water for some hours before washing.

Fumigation.—For the disinfection of rooms and other closed spaces the principal reagents in use are sulphurous acid, chlorine, bromine, nitrous acid, and hydrochloric acid. Sulphurous acid is usually generated by setting fire to fragments of roll sulphur in an iron vessel, with the addition of a little alcohol to facilitate lighting. Sulphur candles are convenient substitutes, or bisulphide of carbon may be burnt. The prescribed proportions are 1 lb. of sulphur to every 1,000 cubic feet of air space, yielding theoretically 1·1 per cent. of sulphurous acid in the air of the room.

Chlorine is most conveniently produced by adding crude hydrochloric acid to chloride of lime. The strength of the latter varies, but as a rule 1½ to 2 pints of the acid should be allowed for each pound of chloride of lime. No heat is required, indeed the reaction is so rapid that it is necessary to secure time for the operator to escape, by letting the acid drip through a small hole upon a little cup which, when full, overflows into the dish containing the lime. The quantities required, according to German experiments, are very large—about 15 lbs. of chloride of lime and 22 lbs. of hydrochloric acid * for every 1,000

* Strong sulphuric acid may be substituted for crude hydrochloric acid. About a third of the quantity would suffice.

cubic feet. These quantities, being somewhat prohibitive, are commonly reduced to one-tenth or less in practice. The reagents should be divided into a convenient number of portions and placed in several parts of the room in positions as near the ceiling as practicable.

Nitrous fumes are generated by adding copper filings or other reducing agents to nitric acid.

In any case the room must be rendered as nearly air-tight as possible before fumigation. Paper should be pasted over the fireplaces and ventilators, and around the window-sashes and doors, leaving, of course, one door to be pasted up on the outside after the operator quits the room. It is desirable to render the air of the room moist by means of steam before fumigating by sulphurous acid or chlorine, to an extent sufficient to moisten the walls and other surfaces.

Koch's experiments in an almost air-tight box showed that sulphurous acid, in the proportion of 1·0 per cent. of the cubic space, killed anthrax bacilli and other sensitive organisms in half an hour, but that anthrax spores and other spores of bacilli resisted 6·0 per cent. for days. The addition of moisture greatly accelerated the action upon bacilli, and so far increased the effect upon spores of bacilli that some of them were killed by exposure to 50 per cent. sulphurous acid for twenty-four hours.

From further experiments in ordinary rooms it appeared that the unavoidable leakage was enormous, so that the theoretical proportion of the gas was only present for a very short time, if at all. The same occurred in fumigation by chlorine. Another difficulty was that the slightest protection was found to shield even sensitive microbes from the action of the fumigant; very few were killed that lay in crevices, or in the pocket of a coat, or were wrapped in filter paper.

It would seem, therefore, that if precautions are taken to reduce the leakage to a minimum, fumigation by sulphurous acid or chlorine may be able to destroy most, if not all, of those microbes that are not very resistant, and that happen to be freely exposed upon the surface. More than this cannot be expected. Exact experiments as regards nitrous acid are wanting, but probably the result would not be widely different.

Klein found experimentally that the infection of swine-plague, which diffuses readily through air, does not spread in that way if chlorine is present even in such small proportion as to be still respirable; and that an infected place was effectually disinfected by fumigation.

From what has been said, it will be seen that the reputed disinfectants and processes of disinfection may be classified somewhat as follows :—

1. Those that are capable of destroying the most resistant microbes, and are therefore beyond reasonable doubt true disinfectants. Such are fire, boiling-water, steam, protracted and direct exposure to hot air at or above 220° Fahr., mercuric chloride, carbolic acid solution of strength exceeding 5 per cent., and a few others.

2. Those that are capable of destroying sensitive microbes, but not the more resistant. Until we learn to which class the germs of the respective human diseases belong, we cannot regard such reagents as trustworthy disinfectants. In this group come chloride of lime, sulphurous acid, 3 or 4 per cent. solution of carbolic acid, and other weak solutions of potent reagents, brief exposure to heat, and many others.

3. Those that have been shown by experiment to be unable to destroy even sensitive microbes under the conditions occurring in practice. Such are solutions of ferrous sulphate, chloride of zinc, 1 or 2 per

cent. solutions of carbolic acid, and other disinfectants in undue dilution, boracic acid, hot air or fumigation applied to bulky objects, or for an inadequate time. It would be easy to add to the list, which, however, includes many reagents that have a real value as antiseptics or deodorants.

In few departments of hygiene have absurd generalisations been so prevalent as in reference to disinfection. "Disinfectants," or substances labelled as such, are still widely employed under conditions which a moment's reflection would show to be utterly incompatible with any real efficacy. Passing over such trivialities as "fumigation" by burning brown paper or green sticks, we have the wholesale employment of deodorants and antiseptics under the name of disinfection, unsupported by any scientific evidence of their utility. The few true disinfectants in general use are commonly employed under such conditions as to quantity, concentration, and duration of exposure, that little benefit can result from them. Earth is popularly believed to be a universal disinfectant, and yet earth abounds in microbes, some of which are pathogenic. Indeed, the very nitrification upon which the purifying action of earth is so largely dependent is in great part due to the life and growth of microbes. It is often asserted that the danger of infection by diseased meat is exaggerated, because the process of cooking must destroy any microbes that may be present. Even as regards microbes, the temperature in the interior of joints obviously may fall far short of that required for disinfection, and the ptomaines and unorganised ferments should not be forgotten. The gastric juice also is credited with a disinfecting power much greater than the evidence warrants. The "comma" bacilli and many others are destroyed by it, but spores may escape. Sarcinæ and other microbes may be found in abundance in the

stomach itself, fully exposed to the alleged germicidal gastric juice; and in the intestine millions of microbes are always present. Moreover, it is now established beyond dispute that tuberculosis and other diseases are communicable to animals by means of the alimentary canal.

Attempts are often made to "disinfect" sewers and drains, by flushing them with solutions of chloride of lime, carbolic acid, or ferrous sulphate. A little consideration will render it clear that any real disinfection of this kind is scarcely practicable, even if true disinfectants such as strong solutions of mercuric chloride are used. The reagent is quickly diluted by the contents of the drain, and rapidly passes away without coming even momentarily into effectual contact with the whole of the material and surfaces it is supposed to disinfect. If the drain or sewer is properly constructed, thorough flushing by water will be as effectual as the use of disinfectants.

Antiseptics are reagents which prevent, arrest, or impede the growth and multiplication of microbes, without necessarily destroying them. All true chemical disinfectants are still antiseptic when diluted, provided that the dilution is not carried too far, but the great majority of antiseptics are incapable of killing resistant microbes. Among the more important antiseptics are :—

1. True disinfectants, *e.g.* mercuric chloride (which has some trace of antiseptic power even at the enormous dilution of 1 in 300,000), carbolic acid, creasote, permanganate of potash, chlorine, etc.

2. Certain inorganic reagents, notably boracic acid, borax, and mineral acids including sulphurous acid.

3. Most, if not all, essential oils, including those of mustard, thyme, turpentine, peppermint, cloves, and eucalyptus.

4. Quinine and other alkaloids.

5. Many other organic substances, including allyl alcohol, aniline, salicylic acid, and hydrocyanic acid.

The following table shows the degree of dilution at which certain reagents still retain their antiseptic action, as determined by Koch's experiments with anthrax. The proportions stated are the least that are found to arrest the growth of anthrax bacilli in suitable media. Sodic chloride impeded their growth at 1·5 per cent., but did not arrest it at 4 per cent.

	Parts per million in aqueous solution.		Parts per million in aqueous solution.
Mercuric Chloride	3	Oil of Mustard	30
Carbolic Acid	1,200	Quinine	1,600
Potassic Permanganate	700	Allyl Alcohol	12
Boracic Acid	1,200	Salicylic Acid	700
Borax	1,400	Hydrocyanic Acid	125
Hydrochloric Acid	600	Alcohol	80,000
Chromic Acid	200		

Antiseptics are employed mainly to prevent or arrest decomposition of organic substances. Apart from surgical purposes, they are used for the preservation of food, to prevent or restrain decomposition in organic refuse, as a precaution against rotting of timber, and in many other ways.

Deodorants serve to remove or mask effluvia. Among aërial deodorants, nitrous acid is one of the most powerful. Chlorine and the fumes given off by moist chloride of lime are also potent, and act by oxidation of organic matter; they decompose sulphuretted hydrogen, which is an important constituent of the gases of putrefaction. Hydrochloric acid fumes, like chlorine, neutralise the free ammonia and ammonic carbonate. Sulphurous acid may, perhaps, act in some degree as a reducing agent, and also as an antiseptic, but its chief effect is to overpower the effluvia and necessitate free ventilation. Fumes

of wood, tar, or paper are quite useless except for the same reason.

Of the solid or liquid deodorants, ferrous sulphate and cupric sulphate act mainly by removing the sulphuretted hydrogen as a precipitate; potassic permanganate simply oxidises; carbolic acid and the essential oils exert an antiseptic effect and so check further decomposition, while at the same time their powerful odour masks all others. The ozone or peroxide of hydrogen which is believed to be associated with the essential oils may effect some small amount of oxidation.

CHAPTER XII.

SPECIFIC DISEASES.

Small-pox has been described more or less clearly in Eastern countries for nearly two thousand years, and more definitely in Europe since the sixth century. No part of the world is exempt from epidemic visitation; but in India and the Soudan it is so constantly prevalent that these may be regarded as endemic foci. Pandemic extension occurs from time to time, characterised by the enormous areas attacked, and by the malignant type of the disease. The last of these was that of 1871-2, which overran Europe and America, and caused in England alone 42,000 deaths during the two years.

The whole epidemic character of small-pox has completely changed since the introduction of vaccination. The "bills of mortality" show that upon the average 7 to 9 per cent. of the persons buried in London during the seventeenth and eighteenth centuries had died of small-pox, and in epidemic years the proportion often rose to 13, 15, or even 18 per cent. The only approach to this state of things since the introduction of vaccination was in the pandemic year 1871, when 9·8 per cent. of the deaths in London were due to small-pox. The general mortality upon which this percentage is calculated is, of course, far smaller in proportion to population than in the last century. A further change has come about during the last few years, whether permanent or, as is more probable, temporary remains to be seen. During the greater part of the present century small-pox became somewhat prevalent in London every four or five years, but since 1885 it has, for the first time in

recent history, become almost extinct, causing a death-rate for four consecutive years of 0·002 or less. The same remarks apply more or less to the other English towns, all of which suffered heavily in 1871-2, and have with few exceptions been unprecedentedly free from

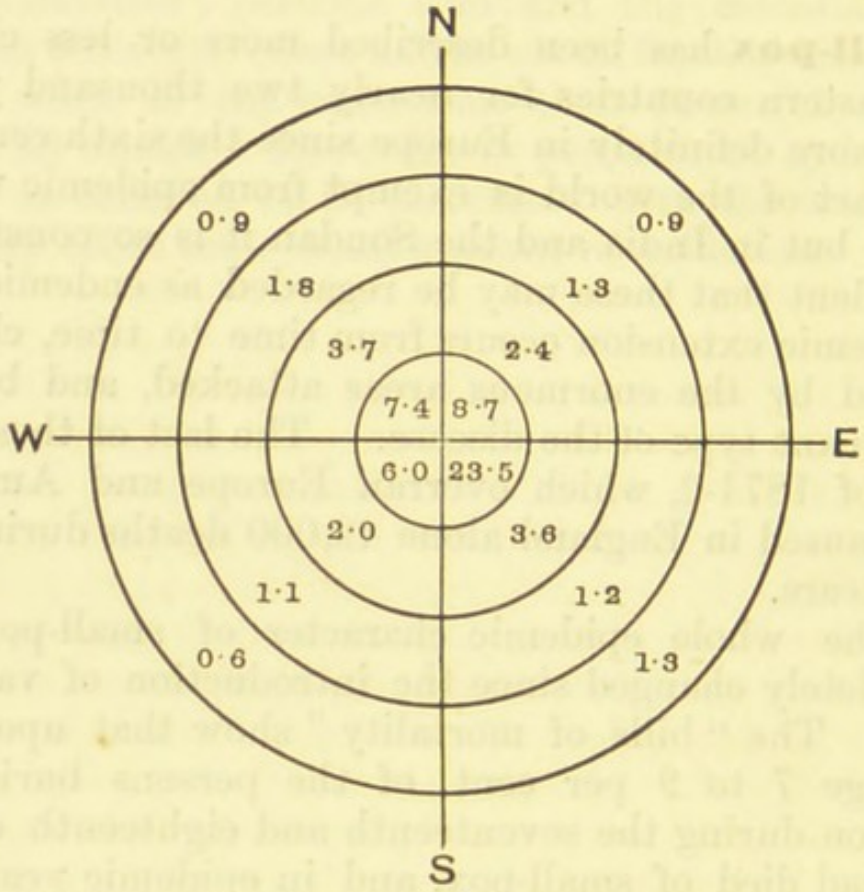

Fig. 22.—Incidence of Small-pox upon District around Fulham Hospital, May 25th, 1884, to September 26th, 1885.
The figures show the percentage of houses invaded in each quadrant and quarter mile zone.

the disease for the last few years. A severe epidemic occurred in Sheffield in 1887-8, however, and since 1891 there have been ominous indications of reviving activity, more especially in the manufacturing districts of Yorkshire and Lancashire and the Midlands.

Season.—The mortality curve for small-pox in England is a simple one (page 535), being above the mean from January to June, and below it from July to December. The New York curve does not differ essentially from this, but rises to a more definite maximum

in May. In India the maximum occurs in the cold season, namely, in March or April. The records of ninety-nine epidemics in Europe and North America show the same preponderance during winter and spring (*Hirsch*).

Soil is not found to have any influence upon the prevalence of small-pox.

Air.—In 1884-5 it was found by Power that cases of small-pox in the surrounding districts followed the admission of acute cases into Fulham Hospital. He 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 (Fig. 22). The position was such that direct communication by traffic could, practically, be disregarded, and, indeed, the incidence upon the S.W. 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 perhaps only under certain atmospheric conditions that cannot as yet be defined.

Barry found a similar radiation of infection from hospital upon a larger scale in the Sheffield epidemic of 1887-8, but the possibility of personal convection could not be entirely excluded. These and other careful investigations leave little room for doubt that under favourable conditions small-pox can be conveyed through the air, and for considerable distances. An observation in Nottingham, 1887-8, tends to show that the same radiation may occur upon a small scale from a single acute case. The town had been absolutely

free from small-pox for a year, when a case was imported and concealed in a crowded house in a dense quarter. On the south side this house was closely adjoined by courts and alleys that were only accessible (from the north) by a long and circuitous route; streets and houses on all the other sides of the house in question were freely accessible. Three houses situated in the isolated courts on the south were invaded, but none in the directions in which traffic could pass. The dates of attack in each case corresponded with the hypothesis of aërial convection from the concealed case during the acute stage, and the wind was northerly at the time of probable infection in each. Confirmatory evidence as to diffusion of small-pox from hospitals has since been met with at Bradford, Leicester, and elsewhere, and the L.G.B. have of late increased the stringency of their requirements as to the isolation of small-pox wards. (*See note*, page 568.)

Neither water nor milk has been shown to convey the infection of small-pox.

Age and sex.—The mortality from small-pox is greater among males, not only at all ages taken together, but also, with few exceptions, at each age period. The exceptions are the second and third year of life, and the tenth to the fifteenth year, at all of which, from some unexplained cause, the female mortality slightly exceeds the male.

The relation to age has to be considered with reference to vaccination. In pre-vaccination times, as McVail has shown from the Kilmarnock registers, 90 per cent. of the deaths were at ages below five years, the actual maximum being in the second year. Under present conditions, the deaths under five years, being practically limited to unvaccinated children, constitute only 30 per cent. of the total small-pox deaths, and in this age period the greatest mortality occurs in the first year, being, indeed, highest in the

first three months of life. It diminishes steadily from this point until about the fifteenth year, rises to a second maximum about the twenty-fifth year, and thenceforward diminishes again.

Race.—Coloured races, and especially negroes, have a peculiar susceptibility to small-pox. They take it more readily, and suffer a heavier case mortality, than white races, apart from all question of vaccination.

The incubation period is usually twelve days, or counting to the appearance of the rash, fourteen days, so that the rash is seen on the fifteenth day, on the same day of the week that the infection was acquired. There are, however, exceptions to this rule. Inoculation of small-pox is followed by constitutional symptoms on the seventh or eighth day, and the general rash appears on the tenth or eleventh. Even after infection by more ordinary means it is stated that the latent period may range from seven to eighteen days; and the rash is often delayed until the fourth day (*i.e.* the third *after* onset) instead of appearing on the third.

Infection is given off, presumably by the breath, from the earliest onset. The exhalations, the vesicles, pustules, and scabs are also highly infectious. The virus may be carried by air currents, as already mentioned. It readily lodges in clothing, and retains its vitality tenaciously; hence outbreaks are liable to occur in paper-works and other manufactures in which rags are employed. Isolation should be maintained for at least three weeks in the mildest case, and always until every scab has disappeared—a process which, in confluent cases, will take six weeks, and often considerably longer. After exposure to infection, a quarantine of seventeen days—to allow a margin over the fortnight—is sufficient. Second attacks are rare, except after several years' interval. Third attacks are not unknown.

The precautionary measures to be taken in case of an outbreak of small-pox include immediate and rigid

isolation, which can only be satisfactorily carried out in hospital, especially when the danger of aërial spread of infection is considered; *disinfection; vaccination*, or *re-vaccination* of all persons who have been exposed to risk of infection, however remotely, those only being excepted who have recently (say within four years) undergone successful vaccination, or who bear marks of recent small-pox. No reliance can be placed upon verbal assurances as to previous attacks, or even as to vaccination, and after a time the protection of previous small-pox, as well as of vaccination, may vanish.

The pathogenic microbe has not been identified with certainty. Micrococci abound in the lymph of the vesicles and in the adjacent lymphatics, as in vaccine lymph; and filtration through porcelain removes not only the micrococci, but also the virulence, as tested by inoculation.

Inoculation of small-pox, already referred to above, was generally practised in England in the last century, having been introduced from the East in 1721 by Lady Mary Wortley Montagu. It seems to have been customary to inoculate from the primary vesicle, not from the secondary rash. Mild cases were selected, and the lymph was taken before suppuration set in. The fatality (2 or 3 per cent.), though far lower than that of "natural" small-pox, was by no means trifling, and the readiness with which the risk was incurred is a strong illustration of the magnitude of the danger to which it was the only known alternative. It was superseded by vaccination, and was finally forbidden by law in 1840.

Vaccination, introduced by Jenner in 1796, gradually superseded inoculation during the earlier part of the present century. 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.

DEATH-RATES FROM SMALL-POX, PER 1,000 LIVING AT EACH AGE-PERIOD.*

	All Ages.	0–5.	5–10.	10–15.	15–25.	25–45.	Over 45.
1847–1853. Vaccination gratuitous but optional .	0·305	1·617	0·337	0·094	0·109	0·066	0·022
1854–1871. Vaccination compulsory but not efficiently enforced .	0·223	0·817	0·243	0·088	0·163	0·131	0·052
1872–1891. Vaccination enforced .	0·089	0·177	0·095	0·054	0·097	0·086	0·038

This table shows that each extension of vaccination has been attended with a reduction in the small-pox mortality, in which, however, the different ages have by no means shared equally. The reduction has been greatest at the ages of highest mortality—that is, among children under 10 years of age—while at ages over 15 the change has been comparatively slight. The latter no longer include, as in former generations, a large proportion who are protected by non-fatal attacks of small-pox undergone in early life, and on the other hand the protection due to infantile vaccination has had time to fade. Moreover, even unvaccinated persons have, under the new conditions, a better chance of escaping small-pox until adult life. The enormous

* Reg.-Gen. 43rd Ann. Rep.; and Foster, *British Medical Journal*, i., 1893, p. 1069. The ages were not abstracted before 1847.

reduction in mortality among young children whose vaccination is recent speaks for itself, and it must not be forgotten that the mortality at ages under 5 years occurs among the unvaccinated residuum, the vaccinated being practically exempt, as will be seen presently.

Another illustration of the great change in the age-incidence of small-pox has already been given. In Kilmarnock, from 1728 to 1764, there were 622 deaths from small-pox, of which 563, or 90 *per cent.*, were at ages below 5 years. The corresponding proportion in England from 1871 to 1880 was 30 per cent. Buchanan* gives other instances in the following table, and appends an analysis of the age-incidence of small-pox mortality in London in 1884 upon the vaccinated and unvaccinated, *separately*, from which it is manifest that the old conditions remain unchanged among the unvaccinated, except that the protection which the rest of the community has acquired lessens the probability of exposure to infection :—

Contribution of Various Ages to 100 Small-Pox Deaths at all Ages.

	Geneva, 1580–1760.	Kilmarnock, 1728–1764.	Paris, 1842–51.	London, 1848–51.	London, 1884.		
					Unvaccinated.	Vaccinated.	Whole Community.
0–10 years	96·1	98·8	39·7	81·5	61·2	8·6	34·3
10–20 ,,	2·6	0·5	13·3	5·9	14·6	17·3	17·0
20–30 ,,	1·0	0·7	32·9	8·3	10·8	31·9	21·3
30–40 ,,	0·3	—	11·0	3·2	7·2	22·1	14·2
Over 40 ,,		—	3·1	1·1	6·2	20·1	13·2
	100·0	100·0	100·0	100·0	100·0	100·0	100·0

* Report of the Medical Officer to the Local Government Board for 1884.

An analysis of the returns of the 5,683 small-pox deaths in London during the ten years 1879-88, as given by the Registrar-General, yields the following results :—

Ages.	Of 1,406 stated to be *Vaccinated.*	Of 2,265 stated to be *Unvaccinated.*	Of 2,012 Vaccination not stated.	Of the total 5,683, irrespective of Vaccination.
	Per cent.	Per cent.	Per cent.	Per cent.
0 to 10 years	8·4	56·0	35·0	36·8
10 to 20 years	16·0	17·2	14·7	16·0
Over 20 years	75·6	26·8	50·3	47·2

Confirmatory evidence, if any be needed, is afforded by Barry in reference to the Sheffield epidemic of 1887-8 :—

Sheffield, 1887–8.—Small-Pox Attacks and Deaths (per 1,000 Persons of each Class stated).

	Attack-rate.		Death-rate.	
	Vaccinated.	Unvaccinated.	Vaccinated.	Unvaccinated.
0–10 years . . .	5	101	0·1	44
Ditto, living in invaded houses . .	78	869	1	381
Over 10 years . .	19	94	1	51
Ditto, living in invaded houses . .	281	686	14	371
All ages . . .	15·5	97	0·7	48
Ditto, living in invaded houses . .	230	750	11	372

From these statistics it appears that the vaccinated part of the population had, as compared with the unvaccinated, *at ages below* 10 *years*, a 20-fold immunity from attack, and 480-fold security against death from

small-pox ; *at ages above* 10 *years*, a 5-fold immunity from attack, and 51-fold security against death from small-pox ; *at "all ages,"* a 6-fold immunity from attack, and a 64-fold security against death from small-pox.

Vaccination has long been widely adopted in all civilised countries, although not compulsory in all. As regards London, the proportion of small-pox deaths to deaths from all causes is available as a measure of the prevalence of the disease before and after the introduction of vaccination, which came gradually into operation at the beginning of the 19th century.

From the bills of mortality it appears that during the thirty-one years 1770-1800 small-pox caused 59,253 out of the 626,530 deaths in London, or 9·4 per cent. In the thirty-one years 1801-31 the proportion was 4·6 per cent. From 1832 to 1837 no returns are attainable ; but for the thirty-one years 1838 to 1868 the proportion was 1·4 per cent. Even in 1871, when the pandemic wave reached London, the deaths from small-pox were only 9·8 per cent. of the total deaths, a proportion very little in excess of the *average* which prevailed between 1770 and 1800.

The following figures are quoted from Seaton :—

Period before Vaccination.	Period after Vaccination.	Locality.	Mean Annual Small-Pox Mortality per 1000.	
			Before Vaccination.	After Vaccination.
1777–1806	1807–1850	Lower Austria	2·48	0·34
1777–1806	1807–1850	Upper Austria and Salzburg	1·42	0·50
1781–1805	1810–1850	Berlin	3·44	0·18
1774–1801	1810–1850	Sweden	2·05	0·16
1751–1800	1801–1850	Copenhagen	3·13	0·29

The greater susceptibility of the unvaccinated to the small-pox virus is manifested not only in a greater liability to attack, but in a higher case mortality.

The quality of vaccination also—that is, the number, area, and character of the cicatrices—has an important bearing upon the degree and permanence of the protection afforded. Both of these points come out clearly in all large hospital statistics, of which the following three examples will suffice :—

Case Mortality in relation to quality of vaccination and to age, based upon an analysis of 10,403 *cases in Metropolitan Small-Pox Hospitals.* (GAYTON.)

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	1,187	563	47·4
10–20	1,045	17	1·6	1,976	98	5·0	419	81	19·5	521	160	30·7
20–40	725	37	5·1	1,898	258	13·6	420	140	33·3	382	181	47·4
Over 40	48	6	12·5	266	51	19·2	131	44	33·8	79	34	43·0
All ages	2,085	62	3	4,854	455	9	1,295	352	27	2,169	938	43

Sheffield Hospitals, 1887-8. *Proportion of mild* ("*varioloid*" *and* "*discrete*") *and severe* ("*coherent*" *and* "*confluent*") *cases per* 100 *attacks among persons of each class stated.* (BARRY.)

	Vaccinated.		Unvaccinated.	
	Mild.	Severe.	Mild.	Severe.
0–10 years . . .	91·0	9·0	21·8	78·2
All ages	82·8	17·2	18·5	81·5

Case mortality in relation to number of vaccine cicatrices. (Marson.)

	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

Re-vaccination renews in all respects the immunity given by primary vaccination. As regards entire populations, the results of general, if not universal, re-vaccination are shown in the following figures, taken from the report of the German Vaccination Commission of 1884. After the pandemic of 1870-74, re-vaccination was made compulsory in Germany *only*, and small-pox has never become seriously epidemic during the years that have since elapsed; while in other countries the incidence has continued much the same as it was in the period before 1870:—

Small-Pox Death Rates.

	Austria.	Prussia.*	Berlin.*	Hamburg.*	London.	Paris.	Vienna.
1870	0·30	0·175	0·22	0·25	0·30	5 46	0·46
1871	0·39	2·432	6·32	10·75	2·42	?	0·74
1872	1·90	2·624	1·38	0·95	0·53	0·06	5·36
1873	3·23	0·337	0·11	0·008	0·04	0·01	2·28
1874	1·78	0·095	0·024	0·005	0·02	0·02	1·35
1875	0·58	*0·036*	*0·051*	*0·000*	0·01	0·13	1·13
1876	0·39	*0·031*	*0·018*	*0·018*	0·20	0·20	1·67
1877	0·53	*0·003*	*0·004*	*0·012*	0·70	0·07	0·84
1878	0·61	*0·007*	*0·007*	*0·002*	0·38	0·04	0·75
1879	0·51	*0·013*	*0·007*	*0·000*	0·12	0·45	0·46
1880	0·64	*0·026*	*0·008*	*0·000*	0·12	1·09	0·73
1881	0·83	*0·036*	*0·047*	*0·022*	0·61	0·49	1·23
1882		*0·036*	*0·004*	*0·004*	0·11	0·29	1·08
1883		*0·019*	*0·003*	*0·000*	0·03	0·20	0·10

* Italic figures are inserted for the years in which compulsory re-vaccination was in force.

Barry shows that in the Sheffield epidemic the re-vaccinated had a great advantage over the rest. Of 8,198 persons re-vaccinated prior to the epidemic, 25 were attacked and 1 died, the attack-rate being therefore 3·0 per 1,000, and the death-rate 0·1. Among 56,233 persons re-vaccinated during 1887-8, 2 were doubtfully attacked, and none died.

It may be convenient to summarise the evidence as follows:—

A. *As regards vaccinated and unvaccinated populations respectively.*—(1) In pre-vaccination times the heaviest incidence of small-pox was upon childhood. (2) In the unvaccinated part of the community it is so still. (3) Among vaccinated persons childhood is exempt, and small-pox is only fatal in later years, when the protective influence of vaccination has faded. (4) In a mixed community (vaccinated and unvaccinated) both these effects are apparent, the heavier incidence upon the unvaccinated compensating for their scanty numbers. (5) The immunity at early ages among the vaccinated may be extended indefinitely by re-vaccination. (6) In every epidemic, in every community, and in every year—if the numbers are sufficiently large to preclude fallacy—the unvaccinated suffer more attacks *in proportion to their numbers* than the vaccinated, and (7) a larger percentage of the attacks are fatal. (8) Among the vaccinated who suffer from small-pox in later years, the proportion of fatal to non-fatal attacks diminishes as the number or area of the cicatrices increases.

B. *As regards entire populations.*—(9) The introduction of vaccination has in all cases been followed by a lowered average incidence of small-pox. (10) Each extension of compulsory vaccination has led to a further reduction. (11) Compulsory re-vaccination has almost entirely suppressed small-pox.

The vaccine virus is that of cow-pox or vaccinia, a

disease formerly prevalent among cattle, but now rarely met with. It occurs in the form of vesicles upon the teats and udder in cows. The virus is inoculable upon human beings as well as cows, and this inoculation constitutes vaccination. Goats also are susceptible. No person is insusceptible except as the result of previous vaccination, or an attack of small-pox.

Primary vaccination in the human subject is followed on the third day by a papule, which on the fifth or sixth day is vesicular. On the eighth day the vesicle is mature; it is greyish, elevated, tense, loculated, and contains a clear viscid lymph which exudes when the vesicle is pricked. On the ninth day inflammatory changes set in; the lymph begins to contain pus, and a reddish "areola" surrounds the vesicle. Slight constitutional symptoms are common at this stage. The vesicle becomes a pustule, begins to dry up about the tenth day, and forms a dark scab about the fourteenth. The scab falls off in the fourth week, leaving a permanent scar which should be depressed and pitted.

Vaccination may be carried on from arm to arm for an indefinite and probably unlimited number of years without having recourse to the cow again. The lymph should always be taken on the eighth day (that is, exactly a week after the vaccination) from normal and unbroken vesicles. No lymph should be collected after a re-vaccination, or from an unhealthy subject, or from vesicles showing any sign of inflammatory action. By far the surest plan is to vaccinate directly from the vesicle, but the lymph may be sealed in capillary tubes or dried upon ivory points, and retains much of its efficacy for a considerable time.

Calf vaccination is now coming into use upon a large scale, owing partly to an unproved suspicion that the current arm-to-arm vaccination is losing its power, but chiefly to the fear of the virus of syphilis

or other malady being inoculated with the lymph from diseased human subjects. There appears to be no difference either in the course of the symptoms or in results between ordinary arm-to-arm and vaccination from the calf. If stored calf-lymph is used, two large "points" are needed for each child.

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 vesicles produced. Hence 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. Comparatively few persons are insusceptible to re-vaccination after the lapse of ten or twelve years; many "take" readily 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 the primary operation, 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.

Vaccine lymph contains, among other microbes, bacilli which Copeman regards as pathogenic. He finds, too, that it is possible to kill out the extraneous organisms by suitable admixture with glycerine, leaving the lymph still active. Filtration renders it inert. The virus is somewhat readily destroyed by chemical disinfectants, but the lymph can be kept in the dry state, or in sealed tubes, for months or even years, although it begins to lose some of its activity from the very first.

Jenner believed that vaccinia was small-pox modified by transmission through the cow, a form of attenuation very similar to that which we now know to be possible as regards many other diseases. Cow-pox, formerly common, has become rare among cattle coincidently with the reduction in human small-pox due to vaccination. The seat of the eruption was the teats and udders of cows, a limitation that suggests contact with the hands of milkers as a means of inoculation. It is difficult to inoculate cows with small-pox virus, but if effected, vaccinia seems to result. Hime has done so, in the calf. Ceely succeeded twice in a large number of experiments, Badcock in only seven per cent. of his attempts, and other experimenters have failed entirely. Voigt claims to have succeeded by the device of vaccinating a calf in one part of its body, and at the same time inoculating with small-pox in another, true vaccine vesicles appearing in both places. Chauveau failed to produce vaccinia by inoculating calves with small-pox, but papules appeared at the points of insertion, and the contents of these papules inoculated upon susceptible human subjects gave rise, not to vaccinia, but to small-pox. It is possible that Chauveau's results correspond to Ceely's and Badcock's failures, not to their few successes, since they, too, sometimes obtained slight local effects which they did not regard as vaccinia; and the reproduction of human small-pox by inoculation from the papules may have been due simply to the unaltered small-pox virus which he had inserted.

Bouley, and also Ceely, having produced such papules by inoculating small-pox matter, afterwards inoculated the same animals with vaccine matter, and with success.

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.

Successful vaccination within three days after exposure to infection will prevent the appearance of symptoms, and it is probable that the attack will either be arrested or modified by vaccination as late as the fifth or even sixth day. The proof of this 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 usual incubation of small-pox, it will be remembered, is twelve days.

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 certificate of postponement must specify a period not exceeding two months, which may be repeated by further certificates if necessary.

A certain number of children are lost sight of by the vaccination officers, owing chiefly to migration. In some districts wholesale evasions of the law are countenanced by the authorities responsible for the administration of the Vaccination Acts, but taking the whole of England and Wales the proportion "remaining unaccounted for" up to the end of

* Out of 38,000 primary vaccinations, Cory failed only in one case, and in that one he had no opportunity of making a third attempt.

January in the second year after their birth has, until the last few years, been only about 6·5 per cent.

Since 1885 the returns have been less satisfactory:—

Percentage of Births in 1889 accounted for up to January, 1891.

	Births.	Successfully vaccinated.	Insusceptible.	Died unvaccinated.	Vaccination postponed.	Remaining.	Not finally accounted for, including cases postponed.
England and Wales .	885,909	79·8	0·20	10·1	1·5	8·4	9·9
London . . .	132,273	78·6	0·32	9·5	1·5	10·1	11·6
Leicester Union .	4,786	2·7	0·08	17·4	—	79·8	79·8
Keighley Union .	1,902	4·7	0·16	14·0	—	81·1	81·1

The administration of the Vaccination Acts, subject to the control of the Local Government Board, is entrusted to the Poor Law Guardians, not to the Sanitary Authorities. Instructions and blank forms of certificate are issued by the sub-registrars to the parents at the time of registration of birth. The vaccination may be performed, and the certificate signed, by any qualified medical practitioner, but the Guardians are required to provide for the gratuitous vaccination of all children. For this purpose Public Vaccinators are appointed, and attend at convenient vaccination stations at fixed days and hours. In populous districts the stations are opened every week, but in the country it is not possible to secure a sufficient weekly attendance to carry on arm-to-arm vaccination, and in such cases the station is held at quarterly or half yearly intervals, for two, three, or four consecutive weeks. The child must be brought for inspection a week after the vaccination. It fortunately happens that the lymph is at its best on the eighth day, that is, exactly a week after insertion, so that if the station is

opened on one fixed day in every week, there is every facility for arm-to-arm vaccination. 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 immediate risk of infection by small-pox. Registers are kept by public vaccinators, from which the history of each strain of lymph can be traced through the successive vaccinifers.

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.

Varicella or chicken-pox was only clearly distinguished from small-pox in the last century, but beyond a certain superficial resemblance there is nothing in common between the two diseases. Varicella occurs as an epidemic, which not infrequently coincides with small-pox outbreaks, and adds to the difficulty of diagnosis of mild cases of the latter. Persons of all ages are liable to attack, but children more than adults. The mortality is practically *nil*, a fatal result being unknown except in cases almost moribund from other causes, or in cases of *varicella gangrenosa*. Nothing is known of the conditions that determine the appearance of this rare and malignant type of varicella in individual cases during an outbreak of ordinary character.

The latent interval is very commonly a fortnight. The characteristic vesicular eruption, which may be very profuse and widely distributed, is thickest upon the back and shoulders. The vesicles are not usually umbilicated, although this is not a reliable point for

diagnostic purposes, and among them are some that are aptly compared to drops of scalding water upon the skin, there being no induration around them. At other times varicella spots simulate small-pox more closely, but there is almost always a want of uniformity in size, appearance, and stage of development. The symptoms that accompany the onset of small-pox only, the distribution and appearance of the rash, the relation to vaccination, and the history of exposure to one or other kind of infection will seldom fail to make the diagnosis clear.

The infection of varicella is active from the first onset, and is readily imparted by contact or by means of fomites. The mode in which it is given off is unknown, but the breath is the most probable. Attempts have been made to inoculate from the vesicles, but without success. Second attacks are rare.

A quarantine of eighteen days is sufficient after exposure to infection; after an attack, isolation should be kept up until all scabs have disappeared.

Measles became clearly differentiated from small-pox and scarlet-fever in the seventeenth century. No country or race appears to be exempt from it, and it has no demonstrated relation to climate. Some dependence upon meteorological conditions may be inferred from the fact that the colder months, even in the tropics, are favourable to the rise and spread of measles epidemics. In London the seasonal curve of mortality shows two maxima, a principal one in December, and a lesser one in June, the minima occurring in February and September.* The influence of age as regards liability to attack has not been

* *See* Fig. 23, page 535. The winter maximum vanishes in many parts of Great Britain and the Continent, particularly where the measles mortality is low, leaving a simple curve with a maximum in June and a minimum in September or October. (*Reg. Gen. Ann. Rept. for* 1884. See also "Measles Epidemics, Major and Minor," *Transactions of the Epidemiological Society*, 1892-3.)

worked out, but the mortality from measles is greatest in the second year of life, and rapidly falls in every succeeding year. Sixty per cent. of the deaths occur during the first two years of age, 75 per cent. in the first three, and upwards of 90 per cent. under five years. The mortality is greater among females at all ages above five years, but greater among males up to that point, so that upon the whole the female mortality is lower than the male.

Measles epidemics are occasionally so malignant in type as to have a case mortality of 30 per cent. or more, but in such instances neglect, improper treatment, or insanitary conditions, have often been largely responsible for the result. The mortality has been excessive in several recorded epidemics among aboriginal races, notably in Fiji in 1874, and here the conditions above mentioned were operative, together with probably a maximum susceptibility. The disease was previously unknown, and not only was there absence of protection derived from previous attack, but it may reasonably be assumed that the whole race was more susceptible than it would have been had measles been able to kill off in previous generations those most liable to attack. The epidemics that are now met with in Great Britain, though variable in severity of type, cause a case mortality that rarely exceeds five per cent., and is often not more than one or two per cent. The fatal cases are as a rule due to pulmonary complications or diarrhœa rather than to the primary disease itself, the tendency to the one or the other complication being often fairly constant throughout an epidemic, but apparently independent of season (*Hirsch*). Unlike scarlet fever, measles often disappears almost entirely from a district in the interval between epidemics. These intervals, however, are usually short, and few towns in England escape an epidemic for much longer than two or at most three

years at a time. Insular communities such as Iceland and Faröe, with little communication with the outside world, remain free for an indefinite number of years after the subsidence of an epidemic, until infection is introduced afresh. Occasionally measles, like small-pox, becomes "pandemic" and diffuses itself for a brief period over a large part of the globe.

Measles is said to have been inoculated by nasal mucus (*Bristowe*) with an incubation of seven or eight days. It has no known relation to soil. It does not appear to be transmitted by drinking-water, milk, or other food, or to have any connection with diseases of lower animals. "Insanitary conditions"—notably overcrowding, exposure, and want of food—diminish greatly the chance of recovery, as was found in the outbreak among French troops in the siege of Paris, when 86 out of 215 died. Whether such conditions increase the liability to attack cannot be stated. The virus appears to be readily conveyed by the air, probably for considerable distances, but of this exact proof is wanting. Measles has not yet been isolated upon the large scale, so that the question of the possibility of aërial spread of infection from hospitals has not arisen.

From analogy it may be assumed that a specific measles microbe exists, but none has yet been satisfactorily demonstrated.

Infection is probably always acquired by inhalation. The incubation period is usually about twelve days, and is followed by the stage of invasion marked by pyrexia and catarrhal symptoms affecting chiefly the respiratory tract and the conjunctiva. The rash appears on the fourth day of illness, first on the forehead, then becoming general. It consists of dusky pink, slightly elevated spots, which increase for two or three days, and then slowly fade. Slight scurfy desquamation follows.

Infection is given off by the breath and mucus from the onset of the first symptoms, and very possibly even during the stage of incubation. It is not clear how long this liability continues, nor whether the desquamated cuticle is infectious, but the usual rule is to allow a quarantine of not less than three weeks.

An attack is usually protective throughout life, and this is probably the main reason for the comparative immunity of adults, but well-authenticated instances of repeated attacks in the same person are far from infrequent.

Comparing measles with scarlet-fever, it is at once apparent that preventive measures are less likely to be successful against the former. Infection begins at least three days before the characteristic rash appears, and hence isolation is not adopted at a sufficiently early date to prevent the spread of the disease, so far as the household is concerned. The long incubation adds to the difficulty, since a quarantine of a fortnight is necessary before those who have been exposed to infection can be regarded as safe, while in the event of one of the household succumbing at the end of this period, a fresh quarantine has to be begun as regards the rest.

Epidemics of measles are often so widespread that few susceptible children among the working class escape. How far this is due to the general disposition to regard the disease as trivial and childish and to dispense with medical attendance, it is impossible to say. The fact remains that measles is still allowed to run its epidemic course practically unchecked by any serious attempt at isolation or disinfection, and it is, therefore, not surprising to find that it shows no signs of sharing in the reduction of mortality which is so conspicuous in respect of scarlet-fever, enteric fever, and small-pox. It is

customary to close schools during measles epidemics, and there is, doubtless, great advantage in doing so in rural districts.

Whooping cough, or pertussis, has been recognised in Europe for 300 years, and has a practically world-wide distribution, although it appears to be on the whole less prevalent and less severe in hot countries. In London its average prevalence is greatest in March and April, least in September and October, but, according to Hirsch, the seasonal curve of mortality varies greatly in different parts of Europe. The New York curve presents a second and greater maximum in September.

By far the greatest mortality occurs in the first year of life. Of the whole number of deaths from pertussis, over 40 per cent. occur in the first year, nearly 75 per cent. under two years of age, and 96 per cent. under five years. At every age the mortality among females is greater than among males. There are no statistics sufficient to show the actual or relative incidence of attacks at different ages, but the vast majority of cases occur in children, although age confers no complete exemption. Concurrent epidemics of measles and whooping cough are of frequent occurrence. Like measles, whooping cough is a typically epidemic disease, and recurs at short but irregular intervals (usually two or three years) in outbreaks that affect a very large proportion of susceptible persons. The case mortality is usually small, and probably seldom exceeds 5 per cent. The deaths are almost always due to bronchitis, pneumonia, convulsions, or other complications.

Whooping cough has not been shown to be transmissible by water, milk, or other food, or to affect lower animals, or to have any relation with telluric conditions. It is readily conveyed by fomites. Faulty hygienic conditions — especially overcrowding and

exposure—increase the danger to life, but there is no proof that they increase susceptibility. The specific microbe has not been isolated, nor is the disease known to be inoculable.

Whooping cough is, in all probability, always acquired by inhalation of the virus. The incubation period appears to be about a fortnight, but can rarely be fixed definitely owing to the very gradual onset of characteristic symptoms. Squire believes it to be less than a week. After a week or more of apparently ordinary nasal and bronchial catarrh, the characteristic paroxysmal cough sets in, and continues for a very variable period which is rarely less than two weeks and may exceed two months.

Whooping cough is certainly infectious in the preliminary catarrhal stage, and possibly even earlier than this. Isolation ought to be maintained until at least a week after the spasmodic cough has entirely disappeared. The infection is given off in the breath and sputa. Second attacks are very rare.

What has been said as to the prevention of measles applies in all respects to whooping cough, and with even greater force. Owing to the absence of rash, and the insidious onset of symptoms, the disease is rarely detected until many days after it has reached the infectious stage.

Mumps occurs in all parts of the world in brief but often intense epidemics which cause little or no mortality. Cold and wet weather is the most favourable, and outbreaks usually occur in the winter and spring, often in concurrence with epidemics of measles, or sometimes scarlet-fever. Mumps usually disappears entirely from a district at the end of the outbreak, and there is no appearance of periodicity in its return, which may be delayed for many years.

Nothing is known of its etiology beyond its extreme infectiousness by means of the breath.

Second attacks are very rare. The characteristic symptoms, including swelling of the parotid and sub-maxillary glands, set in after an incubation of about three weeks (often 19 days), and the disease runs its course in about a fortnight more. Three weeks is a sufficient time for isolation, and four weeks for the quarantine of a person who has been exposed to infection.

Röthein, epidemic roseola, or German measles, is a disease that occasionally becomes epidemic among children, but causes very slight mortality. An outbreak in the New Forest in 1880 was, however, said to have been attended with a case mortality of 3 per cent. After a latent period, often about $2\frac{1}{2}$ weeks in length, slight general symptoms manifest themselves and are followed immediately, or in a day or two, by an eruption of red, slightly elevated spots, variable in size and often confluent. They appear first on the face and fore-arms, increase and become more or less general in one or two days, and disappear before the end of a week. The symptoms have some resemblance to those of scarlet-fever and measles, especially the latter. It is of course an entirely distinct and independent disease, and not a "hybrid," as is popularly supposed. The disease is infectious, but never very actively so, and isolation for a fortnight is sufficient. Infection is probably given off by the breath, and acquired by inhalation. Second attacks do not appear to be common. Quarantine should extend to 23 days.

Scarlet-fever, or scarlatina, has been recognised in Europe for at least 550 years, and in England upwards of 200 years. It was long confounded with measles, and only in the present century has it been definitely distinguished from 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 Asia Minor. Temperate and somewhat humid climates

seem to be most favourable to it, but the evidence upon this point is conflicting. In England it is more prevalent in urban than in rural areas, mining districts and several of the large manufacturing towns being most affected of all. It is probable that the explanation of this is to be found in the greater facilities for receiving and transmitting infection from person to person. Scarlet-fever has a well-marked relation to season. In England the mortality is at its minimum in March and April, and rises to a maximum in October, subject to irregularities if only small numbers or short periods are taken. In New York, however, the curve is almost reversed, the minimum being in September and the maximum in April. From the notification returns in England and Scotland it appears that—as was to be expected—the number of attacks varies according to season in the same way as the mortality, but the seasonal range of variation is greater in the attack curve; apparently the attacks in spring are, on the average, more severe, though fewer, than those in autumn.

As to the meteorological conditions that are most favourable to the spread of scarlet-fever, there is wide divergence of opinion among authorities. The rise and fall of scarlet-fever epidemics often cover a period of years, and the mortality in any particular week or month must not be regarded as determined solely, or even principally, by the meteorology of that brief season. Upon the whole it seems probable that the tendency to spread is increased by atmospheric humidity and absence of wind and rain.

*Age.**—Children under one year of age, and

* The number of *deaths* from scarlet-fever increases from birth to a maximum in the third year of life, and steadily declines afterwards: 90 per cent. of the deaths occur at ages under ten years, and 65 per cent. under five years. Further details will be found in a paper on "Age, Sex, and Season in relation to Scarlet Fever" in the *Transactions of the Epidemiological Society for* 1887-8.

especially under three months, are comparatively rarely attacked, but the incidence rapidly increases and reaches its maximum in the fifth year of life. After that period it declines steadily year by year. About 45 per cent. of the attacks occur at ages under five years, 40 per cent. between five and ten years, and 11 per cent. between ten and fifteen years. The average severity of attack, measured by the proportion of fatal cases, is greatest in infancy or in the second year, and diminishes as age increases, but there is an apparent increase in the severity of the (very few) cases that occur in adults after the 15th or 20th year. The lessened liability with increasing age is greater than can be accounted for either by protection afforded by previous attacks, or by diminished exposure to infection, and must be attributed to a real and increasing insusceptibility.

There is, therefore, a double gain in shielding a child from infection during the first few years of his life. Every year of escape after the fifth leaves him less and less susceptible until finally he becomes almost immune; and secondly, if he should be attacked, every year that the attack is delayed reduces the danger to life, and also the risk of formidable complications that may become chronic and disabling even if not immediately fatal.

Females are upon the whole more liable than males, but the attacks are somewhat less fatal, and hence up to ten years of age the mortality is higher among males than among females. At ages above ten the female deaths exceed the male, owing, no doubt, to the greater frequency of attack among women who have the charge of children.

Scarlet-fever is for the most part an epidemic disease. In many districts it rises and falls with almost rhythmic regularity for long series of years, the usual interval between the epidemic maxima being

five or six years. The seasonal curve of comparative prevalence already mentioned is superadded upon this larger epidemic wave. Such uniformity as regards epidemic recurrence is exceptional, and would appear to be liable to interruption or termination at any time. In most towns epidemics occur at more or less irregular intervals. Sometimes scarlet-fever will disappear entirely for years, or "sporadic" cases may occur without any serious general prevalence. In certain manufacturing towns in the North of England, on the contrary, scarlet-fever may be said to be endemic, although subject to frequent epidemic outbursts.

Graves noted that scarlet-fever was prevalent and malignant in Dublin from 1801 to 1804; during the next 27 years epidemics recurred at intervals, but the type was always mild and the mortality slight, until in 1834 the disease reverted once more to the old malignant form. A similar change appears to have occurred in most parts of England during the last few years. The mortality from scarlet-fever throughout England averaged 1·0 per thousand per annum from 1861 to 1870, 0·7 from 1871 to 1880, 0·4 from 1881 to 1885, and 0·24 from 1886 to 1890. Epidemic prevalence still occurs from time to time in different towns, but for the most part the type is mild, and, although modern preventive measures have undoubtedly produced some effect, the reduction in mortality is greater than can be accounted for by diminished prevalence alone. Several towns which for many years had exhibited a steady epidemic wave at fairly regular intervals have since 1880 ceased to do so. Several instances are on record in which the type has suddenly changed during an epidemic from mild to severe, or *vice versâ*. In some epidemics the case mortality is as low as 3 per cent., or even less, while in others it may reach 30 per cent. or more. As a rule the cases are more severe during the early part of an epidemic.

No adequate explanation has been offered of the

causes that determine the rise and fall of scarlet-fever epidemics, and still less of the causes of the variations in type. Seasonal changes, especially meteorological, doubtless have an influence, but, as already explained, this is superadded upon the true epidemic wave. During the inter-epidemic intervals the proportion of susceptible persons increases on the whole, but as regards ages above five years the delay lessens the susceptibility, and it does not appear that the intensity of the outbreak bears any relation to the length of the previous interval.

The pathogenic microbe of scarlet-fever, according to Klein, is a micrococcus, which he has isolated from the blood and tissues of persons suffering from this disease. He has cultivated the micrococcus, and by inoculation upon calves has produced a disease which he believes to be bovine scarlet-fever. It appears further that the same micrococcus was found in cows suffering from the Hendon disease, also in a sample of condensed milk that apparently caused an outbreak of scarlet-fever, and in the blood of a monkey that, during an epidemic of scarlet-fever at Wimbledon, presented symptoms of the disease. The crucial experiment of inoculation upon susceptible children being inadmissible, the proof is not absolute, but the evidence is very strong. Edington has also found a bacillus, which he regards as the true specific microbe of scarlet-fever, in the blood during the first two or three days of the fever and in the desquamation after the twenty-first day of the fever. Cultivations of this bacillus inoculated into rabbits and guineapigs caused an erythematous rash followed by desquamation ; calves thus inoculated presented similar symptoms, together with inflammation of the throat. Raskina believes that the malignant complications of scarlet-fever are due to secondary or superadded infection by a streptococcus.

The period of incubation is usually three or four days, but it would appear that in exceptional cases it may be less than twenty-four hours, or as long as seven days. Some authorities believe the usual incubation period to be much longer than four days, but Tonge-Smith's exact observations upon cases which, owing to error in diagnosis, were exposed to infection during transit to hospital in an ambulance, afford strong proof of the accuracy of the estimate given above.

The onset in well-marked cases is sudden, with vomiting, rigors, headache, pyrexia, and sore throat as prominent symptoms. The rash follows in about 24 hours. It is at first punctiform, but becomes diffuse. It is usually seen first about the neck and chest, but may spread over the whole body. It increases for one or two days and begins to decline in two or three days more. Desquamation begins as soon as the rash disappears, the chest being the first and the hands and feet the last parts to clear. True relapses occur in one or two per cent. of the cases, usually about a month after the onset.

Infection is given off from the first onset and until the end of desquamation, a period that is seldom less than five weeks, and not infrequently exceeds two months. Hospital experience has abundantly proved that no precautions as to disinfection, etc., render it safe to discharge a patient until every trace of desquamation has disappeared from the feet, and it seems that still longer isolation may be necessary if any symptoms remain, such as discharges from the nose or ears, or albuminuria.

The virus of scarlet-fever retains its vitality for long periods, possibly years, under favourable conditions, and can be lodged in crevices, or carried in garments, etc.

By far the commonest mode of infection is from a

previous case, either by contact, by proximity, or by means of infected articles. Whether the virus is usually inhaled or swallowed is less certain: probably both are possible. Aërial convection for short distances —across a room, for example—may be assumed to occur readily, but there is no proof of radiation of infection from scarlet-fever hospitals, although careful inquiries have been made, notably by Tripe in respect of the Homerton Fever Hospital.

Nothing is definitely known as to any relation between soil and scarlet-fever.*

There is at present no evidence to show that scarlet-fever is ever disseminated by drinking-water, but milk has been conclusively proved to act as a vehicle of infection. It was until recently believed that this was always brought about by infection of the milk by virus from a human case of scarlet-fever, but the Hendon outbreak seems to show that the cow itself may be the source of infection. Corfield has traced scarlet-fever infection to a tin of condensed milk. Squire states that scarlet-fever is inoculable.

Alfred Carpenter suggests that decomposing animal matter, and especially blood, may cause an outbreak of scarlet-fever, but this has not been confirmed. It is at least doubtful whether "insanitary conditions" as to drainage, etc., have even a predisposing influence as regards this disease, but it seems probable that they may seriously affect the chances of recovery. "Surgical scarlet-fever" is liable to follow upon operations, especially in children. How far the operation is to be regarded as an actual inoculation, or merely as a predisposing cause, is not clear.

It is generally believed that puerperal women are especially liable to acquire scarlet-fever in a dangerous form, and that under such conditions its course may

* Boobbyer has recorded a series of cases the incidence of which appeared to be determined by disturbance of the soil.

be modified and constitute a variety of puerperal fever. Recent observations show that the danger has been greatly exaggerated, and that even in the event of infection under such conditions scarlet-fever may run a normal, and even mild, course.

At first the infection is doubtless given off by the breath and secretions from the mouth and throat, and later by the desquamated cuticle also. The infection is less active about the end of the first week than it is either during the acute stage or after desquamation is well advanced.

The preventive measures available are isolation and disinfection. Considerable difficulty arises from the long duration of the infectious stage, covering, as it almost invariably does, a period of at least four or five weeks after the patient has ceased to be ill. Nothing short of hospital isolation can be relied upon. It is practically impossible, in a working-class household, to maintain the requisite seclusion, and the comparative freedom and better hygiene in hospital are conducive to the patient's welfare. Another source of difficulty is the occurrence of slight cases. There may be no noticeable symptoms whatever beyond sore throat, or slight desquamation, and yet any case, however slight, is capable of spreading infection. On the other hand, the short, and apparently non-infectious, incubation period, and the early appearance and distinctive characters of the rash and other symptoms, render this disease much more easy to deal with than measles or whooping cough, if proper facilities are afforded. Schools are often instrumental in spreading infection, and it may be necessary to close them when epidemic prevalence is threatened. Scholars from infected households should be excluded for at least six weeks, and only re-admitted upon a medical certificate, but a quarantine of a week is sufficient if the persons attacked have been removed to hospital and the

premises disinfected. Special care is needed in guarding milk supplies from risk of direct or indirect infection from a case of scarlet-fever, and there should be no hesitation in stopping the business if necessary. At the same time it seems that boiling the milk removes all danger.

Diphtheria.—Although the term "diphtheria" was only introduced by Bretonneau in 1826, epidemics of malignant sore throat destroying life by suffocation, attacking children rather than adults, and sometimes leaving paralytic sequelæ, have been described from the earliest times. According to Hirsch, there is a tendency to cyclical *epidemic*, or *pandemic* waves, lasting often for many years, and followed by long intervals of comparative quiescence. Although no climate gives immunity, the tropics suffer less than cold and temperate climates. During the present century France has been a principal centre for diphtheria. In England localised epidemics occurred in 1815-25, after which the country was almost free from the disease until 1857, when it appeared as part of a general prevalence affecting almost the whole of Europe. The mortality increased during the next two years, reaching its maximum, 0·52 per thousand living, in 1859. Since then the disease has held its ground in England, and at the present time shows indication of a tendency to increase.

Season.—The curve of seasonal prevalence of diphtheria shows a relation to cold, the maximum mortality being reached in November or December, and the minimum in the summer. In New York the curve is similar. Records of epidemic prevalence show the same preference for the cold months (winter and spring), and many are associated with cold and wet weather. There are, however, many exceptions, in some of which heat has been regarded by local observers as inducing, and cold as arresting, the epidemic.

In Great Britain atmospheric humidity is considered most favourable to the prevalence of diphtheria, but malignant epidemics have occurred in excessively dry weather in California. Both cold and humidity must therefore be regarded as having merely a relative influence.

Diphtheria occurs upon high and low levels, and upon dry and moist soils; but Kelly has observed in Surrey a greater average prevalence upon damp soils, and this relation seems to hold good in many other parts of the country. A special incidence of diphtheria upon damp houses has often been noted.

Locality.—Diphtheria is, upon the average, more prevalent in rural than in urban districts; but in recent years it has shown a tendency to establish itself in towns. During the last decade (1881–90) the mean diphtheria mortality in the 28 great towns of England was 0·19 per thousand per annum, the corresponding rate for the whole country being 0·16. Longstaff has compared the statistics of the various registration counties in respect of their average density of population and average mortality from diphtheria, with the following result:—

Mean Diphtheria Mortality.	*Dense districts* (less than 1 acre per person).	*Medium districts* (1 to 2 acres per person).	*Sparse districts* (over 2 acres per person).
1855–60	0·123 per 1000	0·182 per 1000	0·248 per 1000
1861–70	0·163 ,,	0·164 ,,	0·223 ,,
1871–80	0·114 ,,	0·125 ,,	0·132 ,,

The increasing incidence of diphtheria upon the more dense populations as compared with the less dense has, therefore, been in operation for many years past.

The peculiarity of the distribution of diphtheria in

regard of population suggests that its causes "should not be sought for primarily in any high development of civilisation, such as sewers, but rather in some condition associated with a more primitive form of life" (*Longstaff*). A disease closely resembling diphtheria in many respects has often been observed to attack cats, pigeons, fowls, and horses during the prevalence of human diphtheria. This coincidence points to the possibility that some part of the greater incidence upon rural districts may be due to infection from lower animals. Some of the symptoms of diphtheria have been produced in animals by inoculating them with diphtheritic material (page 300).

Diphtheria frequently occurs in a purely sporadic form, no clue to any source of infection being discoverable, but all cases, whatever their origin, are highly infectious. It may be regarded as endemic in certain localities, sporadic cases bridging over the intervals between more or less frequent epidemics.

Air.—Several otherwise inexplicable outbreaks in secluded positions have been attributed to transmission of infection by wind for a distance of some miles. There is no *à priori* improbability in this explanation, but it seems clear that no such wind-convection can occur in those outbreaks that remain limited to certain streets or even houses in urban districts.

Water has been suspected of conveying infection, but no complete demonstration has been made out.

Milk, on the contrary, has been abundantly proved to convey the diphtheria poison. Many extensive outbreaks have been traced to this agency, and careful inquiry has brought to light a close relation in such cases between the quantity of milk consumed and the danger of attack. The milk may become infected by some person suffering from a slight attack of diphtheria, but we have now to bear in mind the possible

occurrence of bovine diphtheria, and of infection from the cow itself.

Drainage effluvia.—Diphtheria is more severe and more prevalent among persons exposed to the foul gases from sewers or drains. In a large proportion of households invaded by diphtheria drainage defects are found to exist. The relation is, however, by no means so universal as the public has learnt to believe. Houses with the worst forms of drainage defects may remain free from diphtheria for indefinite periods, and many cases of diphtheria occur in premises in which no defect can be found. The same may be said of other insanitary conditions, notably accumulations of manure and other filth in proximity to houses. All these ought probably to be regarded as predisposing causes only.

Age and sex.—The mortality is greater among females than among males at all ages between three and forty-five years, and hence at all ages taken together.

In both sexes the mortality increases from infancy to a maximum in the fourth year of life, and declines steadily thereafter, but there is a somewhat greater mortality (in proportion to the comparatively scanty surviving population) after the fiftieth year.

Of the whole number of deaths ascribed to diphtheria 53 per cent. occur at ages under five years, and 82 per cent. under ten years.

"The most common period of incubation in diphtheria is from two to three days: less frequently the period is diminished to 24 hours or extended to four days; and the limit between an almost immediate operation of the infection and a delay of six or seven days practically covers the period of incubation for preventive purposes" (*Thorne Thorne*).

The early symptoms are often insidious, but as a rule the membrane is visible within a day or two of

the onset, if not at first. In non-fatal cases the disease usually runs its course in two or three weeks.

The case mortality varies greatly in different epidemics, and there is little constancy even in the same epidemic. It is usually high in well-marked cases, frequently 30 per cent., or more. The protection conferred by an attack of diphtheria does not appear to be very great. Gresswell has raised a very important question in regard to those persons who have suffered from diphtheria in former years, and in whom acute inflammation of the tonsils is set up by change of weather or trifling exposure. He has observed that among those associating with them at such times, diphtheria is apt to occur without discoverable cause; and suggests that the chronic morbid condition may really be a latent form of diphtheria, the occasional recrudescence of which becomes the starting-point for the spread of infection. Slight cases, in which the symptoms are scarcely recognisable, are extremely difficult of diagnosis. During prevalence of diphtheria any sore throat should be regarded with suspicion, even if no membranes are visible and the constitutional symptoms are wanting. There is no necessary relation between the severity of attack in two cases of which one is infected from the other; the slightest case may impart fatal infection. In doubtful cases, where no membranes can be found, some assistance may be given by the knowledge of the existence of other cases of diphtheria, and paralytic sequelæ may ultimately clear up an obscure diagnosis. The breath and sputa are infectious from the first and it is safer to act upon the assumption that the excreta are so too. Isolation should be maintained for at least a fortnight after the membranes disappear. After exposure to infection a quarantine of ten days is sufficient. Clothing, furniture, and even walls and floors may retain the virus tenaciously.

Schools afford a highly favourable ground for the spread of diphtheria. There children at the most susceptible ages are brought together for many hours daily in close contact, often in a moist and impure atmosphere, with scanty ventilation. Nor is the danger limited to the mere spread of infection, for, as Thorne Thorne has shown, there is good reason to believe that in diphtheria a progressive development of virulence and infectiousness is sometimes brought about by the aggregation of slight (possibly unrecognisable) cases among susceptible children at school. Many instances are on record of school-outbreaks, especially in districts where diphtheria, "croup," and sore throat are more or less endemic, commencing with the appearance of cases of sore throat, followed presently by cases of diphtheria, which increase in numbers and severity. The epidemic is usually arrested by closure of the school, but is not unlikely to break out again, with renewed virulence, as soon as the school is reopened.

Among preventive measures, the first are isolation and disinfection. Doubtful cases should be secluded and no children from infected households should be allowed to attend school. Closure of schools is advisable if many cases have occurred among the scholars, or if diphtheria is prevalent in the district, and especially if the school is the means of bringing children from infected villages into contact with others. Milk supplies that are found to be implicated in the spread of infection must be stopped at once, and most rigid precautions should be taken in regard to households connected with the milk trade. Lastly, insanitary conditions should be sought for and remedied.

Löffler has discovered a specific bacillus in the membranes in the great majority of cases of diphtheria; after cultivation it can be inoculated upon the trachea

of rabbits, fowls, and pigeons, and leads to the formation of false membranes. In a certain number of cases paralysis followed in about three weeks. He found the same bacillus occasionally in healthy saliva. Roux and Yersin obtained similar results by injecting the cultivation liquid after filtering off the microbes. According to Martin, the bacillus produces a powerful "enzyme" or ferment, which converts fibrin into virulent soluble "albumoses," and these in turn break down into less virulent and less complex bodies, one being comparable to a ptomaine, but acid. Cultures retain their virulence indefinitely if kept from access of light and air. Of late anti-toxic serum, from the horse or other animal, immunised after Behring's method by repeated small inoculations, has been largely used for the curative treatment of diphtheria.

Klein has shown that pure cultivations produce by inoculation a 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 udder, and the kidneys undergo fatty degeneration. The fluid from the vesicles, and also the milk taken from healthy teats with every precaution against contamination, contain the same bacilli, and cats fed upon the milk develop in a few days a severe and often fatal illness apparently identical with that which sometimes affects cats during the prevalence of human diphtheria. In the cat, as in the cow, the lung symptoms predominate.

Croup is credited with an annual death-rate of between 0·1 and 0·2 per 1,000 living. There can be no doubt that many deaths from diphtheria and laryngitis have been attributed to croup, and if, as many authorities still maintain, there is a true "croup"—that is, a non-infectious membranous laryngitis due mainly to wet and cold, and not followed by paralysis,—it is of less frequent occurrence than the death

returns would imply. The death-rate from croup is declining, and the decline is probably due to improved diagnosis. Outbreaks of diphtheria are commonly attended with cases of so-called "croup," which upon investigation prove to be diphtheritic.

The seasonal curve of deaths attributed rightly or wrongly to croup has its maximum in the cold months from December to March. It is much later than that of diphtheria, and approximates more closely to the laryngitis curve. In the distribution as regards age and sex a further difference from diphtheria is noticeable. Croup is more fatal to males than females upon the whole, the mortality among females being lower up to fifteen years of age. The highest mortality in both sexes occurs in the second year of life. In all these respects "croup" is allied to laryngitis rather than diphtheria.

Erysipelas occurs in all parts of the world, but more in temperate regions than elsewhere (*Hirsch*). In North America it has repeatedly taken the form of widespread and malignant epidemics, and in England and elsewhere virulent outbreaks often originated in former years in hospitals, especially in surgical wards where cleanliness, ventilation, air-space, drainage, and other sanitary essentials were neglected. At the present time outbreaks of this kind are rare, and erysipelas is chiefly met with in sporadic form. It adds about 0·8 to the English death-rate. In its seasonal curve, and also in its local attachments and periods of recurrence, it is closely allied with scarlet fever and diphtheria and still more closely with puerperal fever. It attacks males more than females, and kills more in early infancy than at any other period of life, although the mortality increases again after 25 years of age. After inoculation the incubation is usually from one to three days. It is not certain whether the disease is ever acquired except through some breach of continuity of

skin or mucous membrane, but the occurrence of so-called "idiopathic" (non-traumatic) erysipelas points to this. The pathogenic microbe is a micrococcus, readily cultivated, and reproducing the disease upon subsequent inoculation.

Relapsing fever, "famine fever," or "bilious typhoid," was first recognised clearly in Ireland in the last century, and still has its principal focus there, although epidemics are not infrequent in Scotland, and have occurred in England, Northern Europe, the Levant, India, and several eastern countries. It occurs remarkably often in conjunction with typhus and is apparently closely related to it in etiology. Epidemics of the two diseases frequently coincide, or one follows the other closely, or sporadic cases of the one are observed during prevalence of the other. Neither climate nor weather has been found to influence it in any marked degree, nor has it any apparent relation to soil. Overcrowding and want of food are powerful predisposing causes, especially the latter, which Murchison thought was capable of originating the disease, but many epidemics have occurred without noteworthy privation. The wealthier classes are almost exempt and females are less susceptible than males. Under favourable conditions it appears in districts that have long been free from it, and in many such cases no history of imported infection can be made out, but nevertheless the theory of spontaneous origin cannot now be accepted.

The disease is highly infectious, but appears to be capable of transport through the air for short distances only, though it readily attaches itself to fomites. A specific spirillum was discovered by Obermeier in the blood of patients during the febrile stage only, and inoculation with blood containing spirilla has been found to reproduce the disease in men and monkeys. The protection afforded by an attack is slight. Only

about 5 per cent. of the cases terminate fatally, but convalescence is slow.

Typhus has only comparatively recently been distinguished from enteric fever, but the two diseases are widely different in their etiology and epidemiology. Typhus epidemics have been recorded in considerable numbers for several centuries past, more especially in times of war and famine, and were common in the seventeenth century and up to 1815. The only great epidemic in Europe since that time was in 1846-7. Ireland has been from earliest times one of the chief centres of the disease, Russia being another. Although for the most part limited to cold and temperate climates, typhus is by no means unknown in many hot countries,* but usually at considerable elevation. The different habits of life, and especially the abundant ventilation, which prevail in warm countries may help to account for their comparative immunity, but as the effect of season remains marked, there is probably some further influence at work. In former times, epidemics of typhus frequently reached England, apparently by invasion from Ireland; but for many years past typhus has almost entirely disappeared from the southern and midland towns of England, although still occurring in the large towns of the north and of Scotland, especially those containing a large Irish population. The last general epidemic in Ireland was in 1862-4.

Cases of typhus are most numerous in winter and spring, and in warm countries epidemics seldom occur at any other season. In countries in which typhus is common, however, the origin and course of epidemics are not checked by either extreme of temperature.

Telluric conditions are not known to have any influence.

* Mexico, Peru, North Africa, Persia, North China.

The great predisposing causes of typhus are overcrowding, want of ventilation, filth, debility, and privation. Wars and famines in former centuries were frequently followed by outbreaks of fever, among which typhus was prominent. "Gaol fever" (typhus) was common in English prisons up to the last century, owing to their filthy and overcrowded state. Better ventilation of vessels has rendered "ship fever" almost unknown, but accidental repetition of the old conditions, even in recent years, has led to fresh outbreaks of typhus. Typhus broke out among the British troops in the Crimea in 1854-5, and among the besieged in Metz in 1870. In Ireland the years of famine and distress have been attended with typhus.

It is not clear that any race or class is especially susceptible, or the reverse, apart from the conditions under which they live; but for the reasons already stated, the poorest classes suffer by far the most from typhus.

Age and sex.—The mortality from typhus increases from childhood to about fifty years of age, and then declines somewhat. It is greater among males, except, perhaps, in childhood. Handford finds that the susceptibility is greatest in the ten to fifteen years age-period, but that the case mortality, *i.e.* the proportion of deaths to attacks, is at its minimum in this period, and rapidly increases at later ages. Spear has called attention to the mildness of the symptoms in children, owing to which the initial attacks in an outbreak are liable to escape diagnosis.

The incubation period seems to be very variable, and, according to Murchison, may be only a few hours or as long as three weeks or more. It has been observed to be short in certain cases after exposure to the poison in a concentrated form. Perhaps twelve days may be taken as the most usual duration. The rash appears within a week after the onset, and, as a

rule, on the fourth or fifth day. The disease generally terminates in death or convalescence about the end of the second week, and isolation may be terminated in ten days or a fortnight more. The mortality averages about 20 per cent., but varies with the age, condition, and surroundings of the patient, and with the epidemic.

Infection is given off by the breath, probably by the exhalations from the skin, and possibly by the excreta. According to Murchison, it is more active after the first week. The air immediately surrounding the patient is intensely infectious, but its virulence is rapidly lost by diffusion—a result that may be attributed to dilution, desiccation, or oxidation. The poison clings readily and strongly to clothing and other fomites, but has not been shown to be conveyed by water, or by milk or other food. Doctors and nurses in typhus wards rarely escape for long unless protected by a previous attack. Second attacks are rare.

Typhus is, no doubt, acquired by inhalation of the poison, whether from contact with the patient, breathing the air in his immediate vicinity, or by the intervention of fomites. The powerful predisposing influence of overcrowding and want of ventilation may be explained by the facilities which they give for infection and for concentration of the poison, as well as their effect in rendering the individual more susceptible.

No pathogenic microbe is yet known, but it may safely be inferred from analogy that, without the presence of a specific poison, no intensity of the favouring conditions can originate an outbreak of typhus. It is, nevertheless, true that the disease often makes its appearance suddenly among overcrowded and filthy communities—on shipboard, for example—in instances where no previous case can be traced.

Typhus is essentially a preventible disease. Isolation of the patient, disinfection, and quarantine of

persons exposed to infection will rarely fail to arrest a localised outbreak. Cleanliness and ventilation are auxiliaries of the first importance.

Enteric or typhoid fever was differentiated from typhus in 1850 by Jenner. It is a disease of practically world-wide distribution, but is less prevalent in tropical regions than elsewhere. In England it is decreasing in prevalence, and now contributes not more than 0·2 to the average general death-rate.

Season.—In England the greatest prevalence occurs in October, and the minimum in May or June. The autumnal maximum is very general, but the exact position of the summit of the curve varies in different countries; in New York it occurs in September.

Weather.—High or low temperature of the air has in itself no clear relation to enteric prevalence, nor has the rainfall, but instances are recorded in which hot and dry summers were followed by high mortality from the disease, upon the occurrence of rain, and the reverse after cold and wet summers. It is probable, in view of the frequent relations between telluric conditions and enteric fever, that meteorological conditions act mainly by modifying the temperature and moisture of the soil, and that rainfall may either increase or diminish the chances of an outbreak according to the previous condition of the ground.

Soil.—Pollution of the earth by animal matter, especially if excrementitious in origin, is conducive to the endemic or epidemic prevalence of enteric fever. Pettenkofer and Buhl have traced a connection between the movements of the ground water and the occurrence of enteric fever sickness and mortality in Munich, which has been confirmed by further observation in Berlin and other parts of Germany, and elsewhere. "The total of the cases of sickness and death from typhoid falls with the rise of the subsoil

water, and rises with the fall of it; . . . the level reached by the disease is not in proportion, however, to the then level of the subsoil water, but only to the variation in it on each occasion; or, in other words, it is not the high or low level of the subsoil water that is decisive, but only the range of fluctuation" (*Hirsch*). This relation is so constant as to leave no room for doubt as to its reality and significance in the localities in question, but it does not appear to hold good in England, and Fodor has found exactly the reverse in Pesth. In many places where enteric fever occurs, the subsoil water is so deep and its movement so trifling that there is little probability of its producing any material effect. In Munich the soil is porous, the ground-water high, and, until recently, leaking cesspools are said to have been universal. As Buchanan has pointed out, the purity of water in wells is liable to be affected by changes in the level of the ground-water, and the readiness with which enteric fever is spread by means of specifically polluted water must not be lost sight of.

Air does not appear to carry the poison of enteric fever under ordinary conditions; at all events the chances of infection by mere proximity to a patient are extremely slight. While this is true in general, it is necessary to bear in mind the suspicion that telluric miasmas, or drain emanations, may impart the disease.

Water is one of the most important agencies in the spread of enteric fever. While water polluted even with excremental filth has often been drunk for years by numbers of people with perfect impunity so far as the appearance of enteric fever is concerned, the slightest contamination with the excreta of a case of enteric fever has over and over again been found to result in widespread outbreaks of the disease, the incidence of which in such instances exactly follows the distribution of the water, and affects only those

persons who drink it. The virulence of the water-borne poison is not dependent upon the organic matter in the water, but upon the specific pollution. Thus an outbreak of enteric fever at Redhill and Caterham in 1879 was traced by Thorne Thorne to pollution of one of the adits at the Caterham Waterworks by the excreta of a workman suffering from a mild attack of enteric fever, the organic impurity of the water, as shown by analysis, being extremely small. A sudden outbreak at Guildford in 1867 was found by Buchanan to be limited to houses supplied by certain mains, which, upon one occasion only, ten days before the outbreak, had contained water from a well into which sewers were leaking. Here the analysis clearly showed pollution by sewage.

Innumerable other instances are on record in which direct and obvious excretal contamination of wells, springs, streams, cisterns, or reservoirs has been followed by enteric outbreaks upon a large or small scale, according to the number of persons drinking the water. Many confirmatory observations have been made of places in which enteric fever, once endemic, has become rare coincidently with the substitution of a pure for an impure water supply. Thus at Millbank prison artesian well water was substituted for Thames water in 1854, and the previous endemic prevalence of enteric fever disappeared.

In several of the cases mentioned above, the proof of specific pollution was incomplete, and many authorities have held that sewage-polluted water may acquire the property of causing enteric fever in those who drink it, without the access of enteric excreta. In country districts, where the movements and identity of every person coming into the locality are easily traced, it has often been found impossible to obtain evidence of specific pollution of water that was nevertheless instrumental in spreading enteric fever.

On the other hand, it is clear that something beyond simple excremental pollution is necessary to account for the sudden acquisition of morbific properties in a water that has long been polluted; and, moreover, attacks of enteric fever may be so mild as to escape recognition, nor is it safe to disregard the possibility that the specific poison may gain access in ways as yet unsuspected. Upon the whole it is perhaps most reasonable to withhold judgment upon this point, and to affirm only that sewage-polluted water may convey enteric fever without the addition of the excreta of *known* previous cases of the disease.*

Milk was first recognised as a medium for the dissemination of enteric fever by Ballard, in 1870, in investigating an outbreak in Islington. Many instances have since been recorded, in England and other countries, the infection being sometimes traced to the use of polluted water for washing the cans or diluting the milk, sometimes to the milk being infected more or less directly by a person suffering from enteric fever. There is reason to suspect that the milk itself may be capable of imparting the disease, or in other words that there is a bovine enteric fever just as there is believed to be a bovine diphtheria and scarlet-fever, the infection of which is contained in the milk yielded by the cows affected.

Drain effluvia, sewer gases, and emanations from manure heaps and other filth accumulations, are often regarded as directly causing enteric fever. That they are powerful predisposing causes is beyond doubt, and it may be supposed that persons exposed to their

* Latterly some doubt has arisen whether the non-pathogenic *bacillus coli communis*, a saprophyte found in fæces, may not be a transition form of Eberth's bacillus, which is believed to be the specific germ of enteric fever. This, if established, would lend support to Murchison's doctrine that fermentation of fæcal matter is capable of giving rise to enteric (hence called by him "pythogenic") fever.

influence become more susceptible to the enteric poison. The incidence of attack is heaviest upon households or districts in which drainage defects exist, although it is often difficult to dissociate their influence from that of other co-existent hygienic defects, such as want of personal cleanliness and impurity of soil and water. Buchanan has shown, from an analysis of the mortality statistics of the large English towns, that improved drainage has greatly lowered the death-rate from enteric fever. Emanations from fresh enteric excreta seem to be infective, and the same may be said of gases from sewage containing enteric excreta, whether conveyed by drains or otherwise. In towns that have been newly sewered, without due attention to the disconnection and trapping of house drains, enteric fever has sometimes become far more prevalent in large houses upon high ground, tenanted by the wealthier classes, than in the poorer districts down below, in which very commonly there were no drain-inlets within the houses. Here, however, the presence of enteric excreta in the sewage may be suspected. Precisely the same conditions are recognised, and with equal justice, to be conducive to outbreaks of diphtheria, a totally distinct disease, and in either case the presence of a specific poison is doubtless essential for the manifestation of the specific disease, be its mode of access what it may. Grossly insanitary conditions may exist for years without any outbreak of either disease. Men working in sewers do not appear to be specially liable to enteric fever, nor do those employed in scavenging in pail-closet towns, although they come into close and frequent contact with enteric excreta.

Locality. — Enteric fever is more prevalent in towns than in the country, and often fixes persistently upon one district, where the predisposing conditions mentioned elsewhere will usually be found to exist.

In such districts new-comers are especially liable to attack; this has been observed on a large scale as regards soldiers newly arrived in India. As a rule, but by no means always, the areas in which enteric fever is endemic are occupied by the poorest class, among whom insanitary conditions abound, and little care is taken for preventive measures.

Age.—According to Handford, "the susceptibility to enteric fever decreases with age from the earliest years onwards, though the decrease is slight between fifteen and twenty-five, whereas the risk of a fatal termination steadily increases with age." The Registrar-General's figures, however, tend to show that the incidence is less during the first five years of life than between five and ten years. The registered mortality is low in infancy, high in the second to the fifteenth year, and then rises further to a maximum between twenty and twenty-five years, 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 at those ages are due to faulty diagnosis.

Sex.—More males than females die from enteric fever, but the mortality is greater among females from the fourth to the twentieth year of age. The susceptibility, according to recent investigations,* is greater among males from about the fifth to about the twenty-fifth year, and greater among females at all other ages. The average severity of attack is somewhat greater among females; 18·8 per cent. of female cases end fatally, and 17·1 of male cases.

The most frequent mode of infection is by the mouth, the virus either being contained in water, milk, or other food, or conveyed more directly by the unwashed hands after contact with infected matter. The latter is especially liable to happen to nurses in

* Registrar-General's Fifty-First Annual Report, p. 26.

attendance upon enteric patients. In cases where the disease is apparently due to air-borne infection, it may still be suspected that the virus is swallowed.

The latent period is long and variable. The possible range seems to be from two or three days up to three or even four weeks, and perhaps the most usual duration is about twelve to fourteen days. Parkes has pointed out that the incubation is often shorter when the poison is introduced by water. In some of Budd's cases it was only two or three days, at Guildford (*Buchanan*) ten or eleven days, in the Caterham outbreak (*Thorne Thorne*) fourteen days. The insidious mode of onset renders exact determinations difficult. The duration of illness is usually about three to four weeks, but may be protracted by relapses. Second attacks are not uncommon.

That the excreta are infective is certain, but there is much doubt as to the breath. Enteric patients are treated in many large general hospitals side by side with other cases, and apparently without danger to the latter. With scrupulous cleanliness, especially as regards the nurse's hands, and any clothing that may have become soiled in however minute degree with the patient's discharges, it seems that the infection has little tendency to spread. It is otherwise in crowded homes.

The preventive measures to be adopted are isolation, disinfection of all clothing and other articles that have been exposed to risk of contamination, however slight, and lastly the investigation and suppression of conditions that are conducive to outbreaks of the disease.

The greatest care is needed to prevent all risk of contamination of milk supplies or water. The disposal of the excreta is a matter of great importance. They should be disinfected with mercuric chloride or other potent reagent, and disposed of at once. In the

country it is customary to bury them away from houses or sources of water supply; in towns they are usually dealt with like other excreta, but where pail-closets are used enteric excreta may be separately collected and cremated.

The microbe of enteric fever has not been identified with absolute certainty, although the mesenteric glands, spleen, and other parts contain bacilli and micrococci in abundance. In the absence of successful inoculation experiments the proof is incomplete, but the bacillus discovered by Eberth is now generally regarded as pathogenic in this disease. It is killed by sunlight or by acid liquids, but not by drying for three months, or by soaking in water for six weeks, and it thrives in milk. It does not form spores readily.

Simple continued fever is still assigned as the cause of a considerable number of deaths, but is steadily losing ground year by year with improving diagnosis and certification. Many of the deaths so returned are probably due to enteric fever, others to septic conditions, pneumonia, etc. Longstaff has shown that the seasonal mortality curve for "simple continued fever" is very different from that of enteric fever, and resembles the typhus curve rather closely, having its maximum in winter and spring.

Diarrhœa is returned as the cause of a death-rate that steadily averaged 0·9 per thousand from 1850 to 1880, but has since then fallen greatly. In many cases it is merely symptomatic, but the existence of an epidemic disease of which diarrhœa is *the* prominent manifestation is now recognised and hence diarrhœa is grouped with the zymotic diseases. Much light has been recently thrown on the subject by Ballard, upon whose Report the following summary is chiefly based.

Density of population.—Epidemic diarrhœa is essentially a disease of towns, or, in more general

terms, of crowded areas. The diarrhœa death-rate in 1888 in the twenty-three large towns of England was 0·60, in fifty other large urban districts 0·50, and in the rest of the country 0·31.

An analysis of the diarrhœa mortality in the various counties according to their average density of population gives a similar result. Thus, in 1871-80 the mean annual diarrhœa mortality per 1,000 at ages under five years was

In 6	counties	with	more	than	4	acres	per person	2·6
„ 9	„	„	„	3 to 4	„	„	„	3·6
„ 12	„	„	„	2 „ 3	„	„	„	4·2
„ 11	„	„	„	1 „ 2	„	„	„	4·8
„ 6	counties	with	less	than	1	acre	„	7·1
In all England and Wales, with an average of					1·5	acre	„	5·6

Density of buildings upon an area increases the tendency to diarrhœa mortality, irrespective of the density of population that usually, though not always, accompanies it.

Elevation of site tends to reduce diarrhœa mortality, but only in the same degree that it affects infant mortality from all causes.

Want of ventilation and light is conducive to diarrhœa mortality. Among the common conditions that are harmful in this way are narrow dark courts and streets, obstructive walls or buildings, back-to-back houses, overcrowding, and neglect of ventilation of rooms.

Want of cleanliness has a similar effect and is usually found in association with the above.

Foul air from sewers, cesspools, and filth accumulations of any kind promote diarrhœa mortality. Smoke and mere chemical effluvia seem to be inoperative.

Drinking-water may cause outbreaks of diarrhœa, independently of season, but is not responsible for ordinary epidemics of summer diarrhœa.

Social position.—By far the greatest incidence is upon the poorest class.

Food may "ferment" or become contaminated by exposure to telluric or filth emanations, and then cause diarrhœa. Breast-fed children are remarkably exempt, and those partially breast-fed come next; the mortality is much higher among children artificially fed, and especially if fed by the bottle.

Maternal neglect.—The mortality among illegitimate children is higher than that of legitimate children from all causes, but the excess is greatest in regard to diarrhœa. The difference is most marked in years of low epidemicity, and tends to disappear in years of high diarrhœa mortality, but in the latter the average age of attack is earlier among illegitimate children. Occupation of mothers from home contributes to neglect and improper feeding of infants.

The preceding points had been generally recognised, but the following are new and important:—

Soil.—Diarrhœa mortality is low in places built upon solid rock, high where the soil is loose and porous. Sand and deep mould are the worst, clay is far better. Organic pollution of the soil, whether vegetable or animal in origin, is a most potent factor, and occurs especially upon such sites as "made ground," town refuse, market gardens, or in soil polluted by leakage from drains or cesspools. Dampness of soil, accompanied by aëration, is the most favourable condition for diarrhœa, dryness or saturation being alike preventive.

Temperature.—High temperature of the air has long been observed to be associated with high diarrhœal mortality, and the reverse with low air temperature, but Ballard shows that the relation is indirect. The maximum mortality by no means necessarily coincides with the highest readings of the

air-thermometer. The temperature of the soil is the essential point.

"(*a*) 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.

"(*b*) The maximum diarrhœal mortality of the year is usually attained in the week in which the temperature recorded by the 4-foot earth-thermometer attains its mean weekly maximum.

"(*c*) The decline of the diarrhœal mortality . . . coincides with the decline of the temperature recorded by the 4-foot earth-thermometer, which temperature declines much more slowly than the atmospheric temperature or than that recorded by the 1-foot earth-thermometer.

"(*d*) The influence of the atmospheric temperature, and of the temperature of the more superficial layers of the earth . . . . is little if at all apparent until the temperature of the 4-foot earth-thermometer has risen as stated above; then their influence is apparent, but it is a subsidiary one."

Tomkins has found that epidemic diarrhœa does not occur in Leicester until the temperature of the 1-foot thermometer reaches 60° F.

Rainfall is operative mainly by its effect upon the temperature of the soil. Diarrhœal mortality is greater in dry and less in wet seasons.

Wind tends to reduce diarrhœa mortality, calm in the diarrhœal season promotes it.

Upon these and many other observations Ballard bases the "provisional hypothesis":—

That the essential cause of 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 . . . . on conditions of season and the presence of dead organic matter, which is its pabulum.

That 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 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.

Age.—Diarrhœa is fatal at both extremes of life. The first year of life, especially from the third to the ninth month, has by far the greatest mortality. In 1871-80, 63 per cent. of the deaths attributed to diarrhœa were at ages under one year, 80 per cent. under two years. It was by far the most fatal of the zymotics in infancy, and caused a mortality of over 25 per thousand births. From infancy the mortality diminishes until about the 20th year, after which it again increases until the end of life.

The curve of attacks is somewhat different, as appears from the following table :—

Per 1,000 living.	0–1	1–2	2–3	3–4	4–5	0–5	5–10	10–15	15–25	25+	+	45+	55+	65+
Attacks[1]	143	187	87	53	30	102	17	14	9	19	22	32	26	33
Deaths[2]	19·5	5·5	0·97	0·32	0·18	5·73	0·07	0·02	0·02	0·06	0·10	0·16	0·41	1·80

[1] Ballard. Islington Records, 1857–62.
[2] Reg.-Gen. England and Wales, 1871–80.

These figures relate to different localities and different periods, but the variations of each series according to age may be assumed to be in the main

independent of locality or year. The liability to attack would therefore seem to be greater in the second year than the first, and 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.*

No age is exempt from attack, but only severe and acute attacks kill at ages between infancy and old age. Tomkins states that "infants and young children form only a small proportion of those attacked, although they furnish nearly the whole of the deaths," his opinion being based upon the ages of patients to whom medicine for diarrhœa was gratuitously given in Leicester.

Sex.—The mortality is greater among females from the third to about the 45th year, but greater among males in infancy and old age. The liability to attack, however, is greater among males at all ages (*Ballard*).

Season.—Fatal diarrhœa occurs at all seasons, but always increases greatly in summer. In London the mortality curve based upon the records of many years shows 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 little variation. The outburst of epidemic diarrhœa occurs every year, but the date and intensity of the epidemic vary considerably from year to year, and according to locality. The relation to temperature and other atmospheric and telluric conditions has already been discussed. There is very frequently an

* Ballard found that of the 682 recorded attacks under twelve months, 92 were under three months, 212 three to six months, and 167 nine to twelve months. The last figure (167) is probably understated and the attacks in the second year are correspondingly overstated.

alternation of years of high and low diarrhœal mortality, but this is due to temperature changes.

Locality.—Diarrhœa may be regarded as endemic in many large English towns, notably Leicester and Preston, and causes very heavy mortality every year. Others, such as Bristol, Derby, and Halifax, are affected much less, though all show the summer rise every year.

Previous health affects the chances of recovery more than the liability to attack. The incubation is apparently very short, from a few hours to a day, or at most two days. Half the fatal cases terminate within a week, and the course is more rapid in the later periods of an epidemic (*Ballard*). Characteristic pathological changes are found in the kidneys as well as in the intestines, a fact that goes far to prove the specific character of epidemic diarrhœa. Pneumonia is common and fatty degeneration of the liver almost invariable.

In many instances diarrhœa has appeared to be highly infectious by means of the excreta, but this is not always the case.

The microbe of diarrhœa has not been identified with certainty. Tomkins has shown that the air during diarrhœa prevalence contains large numbers of bacteria and fungi, which grow rapidly on gelatine, liquefy the medium, and give off offensive gases, differing in these respects from samples of air taken in the same localities before the commencement of the epidemic. Among other microbes were certain small bacilli, cultivations of which caused diarrhœa when swallowed. Samples of polluted soil, from various depths, gave upon cultivation the same results in all respects.

Outbreaks of diarrhœa occur from time to time, especially in public institutions, which cannot be referred to the climatic conditions hitherto considered,

but upon investigation are traced to articles of food, and especially to water and milk. Water may acquire the power of causing diarrhœa in many ways, including the presence of suspended mineral matter, such as clay or mica (*Parkes*); excess of dissolved mineral matter; suspended or dissolved sewage matter or other animal impurity, especially if undergoing putrefaction; suspended vegetable matter; absorption of fœtid gases, including sulphuretted hydrogen and "sewer gas." Milk is a frequent cause of diarrhœa, owing either to fermentative changes in itself, or to contamination by specific poison or effluvia. An outbreak at Moorfields Hospital was traced to butter (*Shirley Murphy*). Putrid food of any kind tends to cause diarrhœa and fish is especially prone to be injurious if not fresh. Lastly, specific diseases must be mentioned in this connection, as for example the Welbeck cases described in an earlier chapter.

Asiatic Cholera has its endemic area in certain parts of India, including the delta of the Ganges. The first great epidemic in India occurred in 1817. At irregular intervals it spreads in epidemic or pandemic form over a greater or lesser part of the world. It follows the lines of traffic by land or water, but no reason has been found for the apparently capricious selection of some routes and omission of others. The invasion of each new country along its line of march is almost invariably traceable to infection through some point of communication with a country already attacked. In temperate climates the outbreak often subsides or disappears in winter, but frequently reappears with the warm weather in the late spring or early summer; and may even recur again in the third year, apparently without fresh introduction.

Cholera gained a firm footing in England on four occasions, viz. 1831-2, 1848-9, 1853-4, and 1865-6, the epidemic extension from India having occupied

respectively five, two, one, and two years in transit. On several other occasions the disease has invaded Europe, but failed to reach England, notably in 1871-4 and 1884-7. In 1892 it again spread to many parts of Western Europe, notably Hamburg, but apart from imported cases none appeared in England until September, 1893, when a few occurred at Grimsby, Hull, and elsewhere. In 1831 infection was carried to Sunderland and Newcastle, from Baltic ports, in October, and in the course of the next year caused great mortality in almost all the populous parts of the kingdom, but no exact figures can be given, as the system of registration of deaths was not then in operation. According to Hirsch, the total mortality in England was 30,924. In 1848 Hull was infected from Hamburg early in October, and the disease at once spread. Only 988 deaths were recorded in England from October to March, but the epidemic made rapid progress in the summer, and before its final disappearance in December, 1849, it had caused 53,293 deaths, besides a heavy diarrhœa mortality, part of which may be supposed to be due to cholera. In 1853 the invasion was again from Germany, London being attacked in August. The outbreak continued through the winter, especially in the north; became more active in July, 1854, and overran the country, causing during the year 20,097 deaths in England and Wales. The 1865 epidemic had a somewhat different history. Cholera was brought to Southampton from the Mediterranean several times during and after July, but only gave rise to an outbreak in September, October, and November, affecting about 60 persons in Southampton, and a few more in Dorsetshire and Essex. In the spring the disease was again repeatedly imported from the Continent; from Holland to Bristol in April, and to Liverpool and Swansea in May. Southampton was re-infected

from the East in June, and in July the epidemic began in London. There were 5,548 deaths attributed to cholera in London during 1866, and 14,378 in the whole of England.

Climate, season, and temperature.—Heat is a predisposing condition of great importance, but is not in itself sufficient to cause an outbreak of cholera, nor does cold necessarily arrest it. Severe epidemics have occurred in Sweden and Russia in the depth of winter. Even in India the seasonal curve of cholera prevalence is by no means always parallel with that of temperature. In Bombay the maximum of cholera deaths is in April; in the N. W. Provinces and the Deccan, in August; in Madras there are two maxima, in February and September; and in Calcutta a chief maximum in April and a smaller one in November. In all these regions, except one, the highest mean temperature is reached in May; in the N. W. it is in June. In Madras cholera mortality is at its minimum in June, when the mean temperature is at its highest. In Europe, as a rule, epidemics attain their maximum in August, but sometimes in September or July.

Rainfall also has a marked influence upon the prevalence of cholera, and supplies a clue to many of the discrepancies mentioned above. In Calcutta the onset of the rainy season in April and May is attended with lowered cholera prevalence, although the temperature is still rising; and cholera increases again in November, when the rains terminate, although the temperature is then falling. The case is similar in Bombay. In the N. W. Provinces the maximum cholera mortality coincides with the maximum rainfall in August, two months later than the highest mean temperature. Outbreaks during the dry season in the N. W. are usually associated with sudden rains. Both temperature and rainfall are

indirect or predisposing causes only, and the maximum of either may actually coincide with small prevalence of cholera. This is readily explained if we assume, with Pettenkofer, that *moisture* of the soil (as distinguished from dryness or saturation), heat, aëration, the presence of organic matter, and the specific poison itself, are the essential telluric conditions for the propagation of cholera. Rainfall sufficient to saturate the soil (*i.e.* to raise the level of the ground water) will tend to arrest cholera, however high the temperature may be ; but so long as it merely moistens a previously dry soil, the other conditions being present, rain is apt to induce an outbreak. Given a moist soil, prolonged heat and drought may be the conditions most conducive to cholera.

Soil.—The probability that heat and moisture, in the endemic region of cholera, at all events, are operative mainly by influencing telluric conditions, has been already implied, and is strengthened by Ballard's researches into the etiology of epidemic diarrhœa. A direct relation between earth temperature, at a depth of 3 to 6 feet, and the prevalence of cholera during an epidemic, has been affirmed by Pfeiffer as regards England and Prussia. Pollution, and especially animal pollution, of the soil is doubtless an important factor. The subsoil water, according to Pettenkofer, by its movement affects very materially the development of cholera as well as enteric fever. In a dry, porous soil its influence may be trifling, but in general its fall—especially after great height—leaves the soil above it moist and aërated, and is therefore favourable to cholera if the other conditions are present. Its rise to a high level has the reverse effect. The level of the ground water in Calcutta is highest in September, lowest in May, and therefore accords closely with the inverse relation to cholera affirmed by Pettenkofer.

Cholera rarely occurs at sea, and during a voyage usually disappears from ships infected in harbour. So far this tends to confirm the view that telluric conditions are essential, but there are several striking exceptions on record in which severe outbreaks have occurred at sea.

Epidemics are especially apt to follow the banks of rivers and lakes, whether navigable or not. Hilly regions seem to escape frequently, although outbreaks may occur on high ground. The influence of elevation is often recognisable even in the distribution of cholera in a single town.*

Particular quarters, streets, and even houses are often selected for attack in a town invaded by cholera, and the selection can usually be explained by the existence of some filth condition in or about the houses, some pollution of water supply, or other insanitary condition predisposing the inhabitants to the disease.

Drinking-water has been found to be so closely associated with several outbreaks of cholera in England and India, as to leave no room for doubt that it is a factor of the highest importance. A few classic instances may be quoted here. The 1849 epidemic was very fatal in a part of London supplied mainly by two water companies—the Southwark and the Lambeth—both of which distributed polluted Thames water after imperfect filtration. The incidence of cholera was substantially the same upon

* London. Cholera mortality per 1,000 inhabitants, at certain elevations above the Thames :—

Elevation.	Mortality. 1848–49.	1853–54.
Under 3 feet	14·5	10·7
3 to 10 ,,	8·9	9·4
10 ,, 20 ,,	6·0	5·0
20 ,, 40 ,,	6·2	3·3
40 ,, 60 ,,	4·4	1·6
60 ,, 80 ,,	2·5	2·7
Over 80 ,,	1·5	1·2

the customers of both companies, whose mains supplied the same districts and even houses in the same streets. In 1854, however, the population supplied by the Southwark Company suffered in 14 weeks a mortality from cholera of 13·0 per 1,000, and the customers of the Lambeth Company only 3·7 per 1,000. The disease singled out the houses supplied by the Southwark Company, whose intake remained as in 1849 ; while the Lambeth Company had in the meantime obtained a purer supply from a point many miles higher up the river.

The 1866 epidemic in London chiefly affected Poplar, and Netten Radcliffe found a similarly close coincidence between the area affected and the distribution of polluted water by the East London Company. In 1854 a sudden and intense outbreak occurred among the inhabitants of a small area near Golden Square, upwards of 400 persons being attacked within five days. The incidence of the disease was limited to those who had drunk the water from a pump in Golden Square—including persons residing at a distance who had sent for the water—and upon investigation the well was found to be polluted with sewage. A few fatal cases had occurred in the vicinity during the month previous to the outbreak,* and there was strong probability of specific pollution of the well.

Pettenkofer and other German authorities do not accept these conclusions, but Hirsch admits a probable connection between cholera and the use of infected

* Up to August 30th . . . . 9 deaths.
On August 30th, at least 8 cases (afterwards fatal).
,, August 31st . . . . 56 cases.
,, Sept. 1st . . . . 143 ,,
,, ,, 2nd . . . . 116 ,,
,, ,, 3rd . . . . 54 ,,
,, ,, 4th . . . . 46 ,,
,, ,, 5th . . . . 36 ,,
,, ,, 6th . . . . 28 ,,

drinking water. Koch's "comma" bacillus is found in polluted tank water.

Milk has been shown by Simpson to be capable of disseminating cholera.*

Air has been regarded by some authorities as the usual means of convection of cholera, but there is no clear evidence of this, and many facts are strongly opposed to the assumption that the infection of cholera can travel great distances in the air.

Race.—The incidence and severity of cholera are greater among negroes than Europeans, but apparently less among natives of hot countries in which cholera occurs than among European settlers.

Insanitary conditions of air, water, food, soil, drainage, and housing determine the points of attack of cholera. Hence the disease attacks more especially the poorest quarters of towns. Excremental filth is most dangerous of all.

The poison doubtless gains access to the system by inhalation or swallowing. The incubation period is stated to be usually a few hours to three days, but may reach ten or even twenty days (*Parkes*).

The mortality is, as a rule, not far short of 50 per cent. of the cases, and may be greater.

Infection is given off in the discharges from the bowels, and probably in the vomit also. These may infect water, soil, or fomites. Sanderson (following Thiersch) fed mice with dried choleraic discharges kept for various periods. Among mice fed with matter dried after standing *one* day 11 per cent. died, *two* days 36 per cent., *three* days 100 per cent., *four* days 71 per cent. ; discharges which had stood more than four days were innocuous. The importance of

* An outbreak occurred on board a ship and was limited to those of the crew who had drunk milk. The milk was found to have been watered from a tank polluted with cholera excreta. Persons on shore drinking the polluted water were also attacked.

these results is marred by the absence of proof that cholera was the cause of death.

Koch isolated from the cholera discharges a microbe which from its shape received the name of "comma" bacillus. It is a curved rod, often about half the length of the tubercle bacillus, and motile. Strictly speaking, the "comma" bacilli are segments of a spirillum or vibrio, and not true bacilli. They are always present in choleraic evacuations, and have been found in wells polluted by such. They can be readily cultivated, and have a characteristic mode of growth; they flourish in sewage, and have been found to survive for 81 days in Marseilles harbour water, but disappear in a few days from pure water (*Frankland*). That they are pathogenic in Asiatic cholera seems to be proved by the unintentional infection of a worker in Koch's laboratory from a culture of comma bacilli, under conditions that excluded other sources of infection. They have been "intensified" in various ways, and are then pathogenic to lower animals, including dogs and rabbits. They have also been attenuated, and used as a protective "vaccine" by Haffkine and others. In cultures they grow aërobically, and produce nitrates, but can be acclimatised to anaërobic conditions, and are then more virulent but less resistant. They are killed by acid liquids, so that they cannot live in presence of the acid gastric juice, but it has been shown that the contents of the stomach may remain alkaline if only liquids are taken. It is not yet certain whether spores are ever formed.

Koch neutralised the gastric juice of fasting guinea-pigs by alkali, checked the peristalsis by opium, and then introduced cultivations of "comma" bacilli into the stomach. The animals died in a day or two, the intestines being filled with fluid containing numbers of "comma" bacilli. It is urged by Klein and others that the above experiments are inconclusive; that

death is not induced by the "comma" bacilli but by the other means adopted; that other bacilli may be substituted without altering the result; that "comma" bacilli similar in form and in manner of growth to Koch's are found in the saliva of healthy persons (*Lewis*) and in old cheese (*Denike*)*; that water contaminated with choleraic evacuations, and even cultivations of Koch's bacilli, have been swallowed with impunity. As regards the last objection, which shares the doubt attending all isolated negative evidence, it will be remembered that infected water and milk, and in one case an artificial culture, have been found to convey infection; and the acid secretions of the stomach may destroy the bacilli in ordinary conditions. It is possible that infection may occasionally occur through the respiratory tract, but this is certainly not the ordinary mode.

The "comma" bacillus is readily destroyed by heat or other disinfectants, or by mere drying (*Koch*). Spores, if ever formed, would doubtless be more resistant. Emmerich has found in cholera evacuations another still more minute bacillus, straight and immobile, which he regards as pathogenic in cholera.

Cholera nostras is the name given to a form of diarrhœa endemic in Egypt and elsewhere. It does not spread in epidemic form, nor does it cause high mortality. Finkler and Prior have detected in the evacuations a "comma" bacillus, which, however, differs in size and mode of growth from Koch's.

Yellow fever, formerly regarded as akin to malaria, has upon further investigation been found to have far more points of resemblance to cholera in its etiology. Its endemic areas are the West Indies and certain parts of the Mexican and West African coasts, but as regards America frequent and intense epidemics

* The completeness of this identity is disputed, there being minute points of difference from Koch's microbe.

occur between 33° N. and 23° S.—that is, from Charleston to Rio Janeiro. It is, therefore, essentially a tropical disease, but has occasionally occurred in epidemic form as far north as 43° N., at Leghorn and at Portsmouth in New Hampshire, and a few isolated cases occurred at Swansea (51° N.) in 1864 among persons who came into direct contact with infected vessels. Among European countries only Spain and Portugal come practically within its epidemic range. Infected ships reach European ports, but without causing any spread of the disease.

In the endemic area the greatest prevalence is between April and September, but in higher latitudes the epidemics occur in summer and autumn, beginning usually in July and August and never lasting beyond December. It is only endemic in regions where the mean winter temperature reaches 20° C. (68° F.), and epidemics do not occur in any latitude unless the temperature is above that point. A fall below 20° C., however, will not necessarily arrest the course of an epidemic when once begun, though it will usually cause a remission, but frost always arrests it completely. According to Hirsch, atmospheric humidity and rainfall are as a rule favourable to yellow fever, unless accompanied by great lowering of temperature. Parkes, however, gives its want of relation to moisture in the atmosphere as an additional distinction from malaria. With few exceptions the incidence of the disease is limited to the sea coast and the shores of great navigable rivers; only in intense epidemics does it affect elevated points. Even in the West Indies it rarely extends as high as 700 feet above the sea.

Yellow fever is a disease of towns, and has a strong tendency to localise itself in certain quarters, streets, or blocks of houses. Successive epidemics frequently single out the same local foci. As a rule these are in the filthiest and most crowded parts, where insanitary

conditions of every kind abound, and more especially excremental pollution of the air, soil, and water. Outbreaks frequently occur on board ship, and if virulent are usually associated with similar filth conditions.

Telluric conditions have probably some influence, since excavations and other disturbances of the soil, and even clearing and planting, have repeatedly been observed to be followed by outbreaks of the disease. The only point that has been clearly made out is that, contrary to former teaching, malarious soils, even in yellow fever regions, are by no means generally favourable to yellow fever, which is absent from many hotbeds of malaria, and rife in many non-malarious districts. Freire's microbe is found in abundance in the soil of graveyards where persons dead from this disease have been buried. It is not known to be conveyed by drinking-water. Many authorities believe that wind can carry the infection for short distances, not exceeding a quarter or half a mile.

Negroes, and perhaps also Chinese, have a remarkable immunity from yellow fever. Strangers of other races, and especially those from temperate climates, are very liable to attack. They may acquire a considerable and increasing degree of immunity by "acclimatisation" but for this it appears to be essential that they reside in a yellow-fever district for some years, including an epidemic period. It is possible that natives gain their immunity in the same way during childhood. Those who have undergone an attack are safest of all. It seems, however, that negroes as well as other persons may lose their immunity by a few years' residence in temperate climates, and even by migration from one yellow-fever district to another. Both susceptibility and severity of attack are found to increase in inverse proportion to the temperature of the native country. In Guiana the case mortality among West Indians was

7 per cent., Italians and French 17 per cent., English 19 per cent., Germans and Dutch 20 per cent., Scandinavians and Russians 28 per cent. Young and vigorous persons are said to be especially liable to attack, and men more so than women.

There is great obscurity as to the mode in which the infection of yellow fever originates and is disseminated. It follows almost exclusively the lines of maritime traffic, and is not carried far by land. It is certain that ships may become infected and retain the infection with much tenacity, and baggage and other fomites have often been known to convey infection without the intervention of infected persons. That a person whether infected or not may carry the infection with him appears to be undoubted, but the most intimate contact with the sick, wearing their unwashed clothes, occupying the same beds, making autopsies, and even inoculating the vomit, fail to impart the disease. Hirsch concludes that "the yellow-fever patient is a medium of spreading the disease only in so far as the morbid poison clings to him as it does to other objects." According to Parkes, however, it is highly probable that the vomited and fæcal matter spreads the disease. The latter view brings yellow fever, etiologically speaking, into close relation with enteric fever and cholera. Even as regards these undoubtedly transmissible diseases it would be easy to bring forward innumerable instances in which they have failed to be transmitted under apparently favourable conditions. A closer study of their etiology than yellow fever has yet received has shown that previously unsuspected conditions of air, water, soil, and food, play an important part, without which transmission would doubtless be very limited in range.

The incubation is stated to vary greatly, from two or three to fourteen or sixteen days. The

attack is sudden, with high fever and intense headache and lumbar and spinal pains. Vomiting sets in early, becomes incessant, and in three or four days blood is seen in the vomited matter, and often in the fæces. The urine is albuminous, and scanty or suppressed. Jaundice follows, and the patient passes into a typhoid state. A large proportion of the cases end fatally, the rest in lysis and convalescence in two or three weeks.

The preventive measures to be adopted against yellow fever are the avoidance of districts in which it is known to prevail, the selection of inland, thinly-populated, and especially elevated points for residence, and strict attention to sanitary conditions. Fatigue, exposure to sun, drinking, and improper food, are said by Parkes to predispose to infection. Infected ships should make for cooler latitudes.

Freire has discovered a microbe which he has named *Cryptococcus xanthogenicus*, and believes to be the *materies morbi* of yellow fever, and an attenuated cultivation of this is being largely employed for purposes of preventive inoculation.

Influenza stands almost alone in its purely epidemic or pandemic occurrence, with little trace of endemic localisation. Much confusion has arisen from the prevalent misapplication of the term influenza to severe catarrhs, infectious or otherwise. Many epidemics of true influenza have been observed during the last few centuries, spreading over a greater or less portion of the globe. Although there is clear indication of preference for lines of traffic, the progress of an epidemic is highly irregular. It appears simultaneously at widely separated points, often leaping over or avoiding entire countries, perhaps to appear in them later. It may be limited to particular towns or villages, sometimes even to a small section of the population in one part of a town.

The advance is frequently rapid, but not more rapid than human traffic, and at other times its progress is slow and halting. The last pandemic was first heard of in Siberia, in May, 1889, and had spread to almost every part of Europe before the end of the year. It reached London late in December, and in the course of the next three months diffused itself over England.

The epidemic quickly reaches its maximum limits in a given centre, owing probably to its infectiousness and short incubation, and the susceptibility of the greater part of the population. It seldom remains longer than a few weeks in any locality, but may return in the course of the same pandemic. The interval between epidemics is irregular. Parsons states that major epidemics occurred in England in 1803, 1833, 1837-8, 1847-8, and minor epidemics about every three years. From 1860 onwards these practically ceased, until 1889, when a new series of epidemics began, each covering almost the whole country, at intervals of about a year.

In the same district the type of the epidemic remains fairly constant as regards intensity, severity, and perhaps the tendency to one or other group of local symptoms or complications. There is, however, considerable variety in different centres during the progress of an epidemic, and the type may change in a given locality.

Climate.—Epidemics are more common in hot countries, but no country, however cold, is exempt from invasion.

Season and weather.—Neither cold nor heat, nor any known meteorological condition, has been shown to have any effect in checking or promoting the spread of the disease. Intense outbreaks occur in the hottest and coldest seasons, in good, bad, and changeable weather apparently indifferently. Each type of weather in turn has been alleged to cause

epidemic prevalence, upon the strength of narrow observation confined frequently to one locality and one outbreak. Nothing is definitely known of any relation to atmospheric electricity, or the presence of ozone. It is, however, conceivable that conditions of climate, season, and weather may affect the severity of the epidemic, and especially the mortality from the respiratory complications that usually attend it.

Telluric conditions are apparently without influence. The disease attacks persons of all ages and both sexes, sometimes to the extent of quarter or even half the entire population. In general both incidence and severity of attack are less at ages below 20 years, and less among women than among men ; though in some few localities and instances children, and especially school children, suffered more than adults. It would appear that influenza, like diphtheria, may become intensified by the aggregation of susceptible persons in a confined atmosphere. Whether it can spread through the air for long distances is doubtful. Many instances are on record in which it was apparently conveyed in that way to ships and lighthouses, but Parsons has shown that in some of these the isolation was not complete. On the whole, secluded persons and populations suffered least, the incidence being exceptionally heavy upon postal and railway officials, and others whose work brought them most into contact with the public.

Dogs and cats apparently suffer from influenza, and horses are liable to a severe and often fatal disease (termed "pink-eye" from one of its prominent symptoms), which has been regarded as a form of influenza. On several occasions in England and elsewhere epidemics of influenza have been preceded by outbreaks of "pink-eye." But in a Report to the L.G.B. (1893) Klein gives reasons for doubting the transmissibility of influenza to lower animals.

The period of incubation appears to be short, from

one to three days. The onset is sudden, with chills, elevation of temperature, and severe pain in the eyes, head, and back, and tenderness of muscles, especially of the legs and back. Three principal forms of the disease are described, with affection respectively of the respiratory or alimentary tracts, or of the nervous system alone. Intense prostration and depression and rapid loss of weight are almost invariable. The symptoms usually abate in three or four days, but complications and sequelæ may protract the duration of illness indefinitely.

The breath is in all probability infectious from the first.

The mortality from influenza is usually slight, except among persons already weakened by disease or predisposed to bronchitis or pneumonia. The increased death-rate which follows the appearance of influenza in a district is largely due to deaths attributed to respiratory diseases. The protection, if any, conferred by an attack is slight and evanescent, second and third attacks being common.

The pathogenic microbe, a short bacillus, has been identified by Pfeiffer and others.

The ordinary preventive measures—notification, isolation, and disinfection—have not yet been employed on a large scale against influenza. They would be handicapped by difficulties somewhat similar to those that have been mentioned in connection with measles and whooping cough. Nothing is yet known as to infection by water or food.

Dengue is now known to have occurred in epidemic form in the last century, but was first recognised during outbreaks in Farther India in 1824, and in the West Indies, Mexico, and the Southern States in 1827-8. Dengue resembles influenza in the intensity of its epidemics, which often affect almost every person in a town. It spreads mainly along lines of

traffic, and therefore presumably by personal communication, but it has often been observed to break out almost simultaneously in several parts of a wide area.

Climate.—Dengue is a disease of hot countries, but occasionally spreads as an epidemic or pandemic, and may then attack countries in the temperate zone during the hot season.

Season.—The relation to heat is strongly marked. Even in tropical countries its prevalence is greatest in the hot season, and elsewhere it occurs only in summer and autumn, and in years of high temperature. Cold speedily arrests it. Rain appears to have only an indirect influence by its relation to temperature.

Locality.—Epidemics are limited to towns, and especially maritime towns, and rarely spread inland. Low-lying, filthy, and overcrowded quarters are the first to be attacked, and the attack may either be limited to such, or may involve the whole of the population. No relation to telluric conditions is known. *Age and sex* have little influence.

After a short incubation of two to four days, with or without prodromata, the onset is sudden, with rigors, pyrexia, and acute pains and tenderness in the small joints of the hand and feet. Very soon the large joints become affected, then the bones and muscles, and the head and back. A transient erythema —diffuse or spotty—appears at this stage in half the cases. In one or two days a remission or intermission of all the symptoms occurs after profuse sweats of pungent odour, but after a short interval the symptoms return in a modified degree, often accompanied by glandular swellings, and a rash which is variable in its character, but as a rule consists of irregular red elevated spots. The second febrile stage passes off in three or four days at longest, and slow convalescence begins within a week from the first onset. Dengue

is fatal only in debilitated persons, or in the very young or old.

There seems to be little room for doubt that the disease is highly infectious, although some authorities still regard this as uncertain. From analogy the infection may be assumed to be usually given off by the breath, whether the secretions and the emanations from the skin are infective or not. The pathogenic microbe has not been isolated. In some epidemics the disease has apparently attacked cattle, dogs, and cats.

Pneumonia occasionally occurs in an epidemic form, and in many instances has shown distinctly infectious properties without attaining epidemic proportions. Epidemic pneumonia is, with few exceptions, of the "croupous" or "fibrinous" form, but it is not certain that all cases of sporadic croupous pneumonia are due to infection, or that infectious pneumonia is always caused by the same virus. Infectious pneumonia is very often limited to the upper lobe, and often accompanied by pleurisy or empyema. Gastric symptoms, diarrhœa, and jaundice are common, and prostration and cerebral symptoms are frequently intense, out of proportion to the physical signs of pneumonia. The latter may be delayed for days after the onset. The mortality is often high, and usually so in outbreaks limited to a few persons. Epidemics have been described in considerable numbers in England and various other parts of Europe during the last two centuries. Although more frequent in temperate climates, many are recorded in the West Indies, Mexico, Peru, and India. Nearly all occur in winter or spring, and the seasonal curve of epidemic prevalence coincides pretty closely with that of pneumonia mortality, which has its maximum in December, and is high from November to April. Hence the prevalence of pneumonia—epidemic or otherwise—is associated with the colder months, and

a closer analysis shows that in each climate the greatest prevalence of pneumonia occurs at the season of most rapid and sudden changes of temperature, be it winter or spring (*Hirsch*), and there is evidence tending to show that the prevalence varies in some measure with the intensity of the changes of temperature. Epidemics occurring at unusual seasons have often been associated with unusual meteorological conditions of the same kind.

The popular belief in "chill" as an exciting cause of pneumonia cannot be entertained as regards infectious pneumonia, in spite of the strength of the evidence which connects pneumonia outbreaks with the weather conditions in which "chill" is believed to be most liable to occur. Exposure to sudden changes of temperature or extreme cold may increase the activity of infection or the susceptibility of the individual, but nothing more. If, however, there is a non-infectious and non-specific croupous pneumonia, the question of "chill" may be argued upon different lines. It is said that croupous pneumonia has been produced by injecting irritants into the lungs of dogs, by mechanical injury to lung tissue, by experimentally injuring parts of the nervous system, and by various other mechanical means, which may be admitted as establishing some sort of *primâ facie* possibility of like effect from sudden change of temperature, especially as the whole mortality attributed to pneumonia (and not merely that part which is already recognised as due to an infectious form of the disease) reaches its maximum at times of greatest liability to "chill." On the other hand, attempts to produce pneumonia by exposing animals to sudden alternations of temperature have uniformly ended in failure, and even traumatic pneumonia may conceivably be dependent upon the co-operation of specific microbes accidentally gaining access to the injured tissue.

There are now on record many instances of outbreaks of pneumonia which remain limited to a single household or a small circle, but in which nevertheless the evidence points strongly to infection.

Nothing conclusive has been established as regards the influence of rainfall or telluric conditions upon pneumonia, although it has been asserted that absence of rain (dry cold) and low level of subsoil water are favourable conditions.

Males are far more liable to pneumonia than females, but the attacks are usually less severe and fatal. In the Middlesborough epidemic of 1888 Ballard found that the female case mortality only exceeded the male at ages above sixty-five years. Both the liability to attack and the average case mortality increase greatly as age advances.

All depressing conditions predispose to attack during epidemic prevalence, among them fatigue, anxiety, poverty, and debility from any cause. Insanitary conditions, especially filth, overcrowding, and want of ventilation, act apparently as powerful but not indispensable predisposing causes. Effluvia from graveyards have also been held responsible for outbreaks. Repeated outbreaks have sometimes been observed in the same buildings, especially barracks and prisons. In many extensive epidemics it has been found that those streets or houses suffered most which were in the worst sanitary condition, and outbreaks in barracks, prisons, and ships have usually been attributed to the same causes. Such conditions must not be regarded as more than predisposing causes in any case, and in many instances—notably in several of the small outbreaks of infectious pneumonia limited to one household—they are conspicuously absent. Negroes are especially susceptible to pneumonia, even in their native climate.

Friedländer's oval capsulated *Micrococcus pneu-*

moniæ is found in large numbers in the affected lungs, and in the blood and sputa; and was discovered to abound in the substance of the floors and ceilings of rooms in a prison at Amberg where repeated outbreaks of pneumonia had occurred for many years (*Emmerich*). Pneumonia has been produced in rabbits by the injection of cultivations. Latterly these results have been disputed, and the true pathogenic microbe asserted to be a capsulated *diplococcus*, which is indistinguishable from one which is occasionally found in normal saliva (*Fränkel* and *Weichselbaum*).

A widespread and fatal epidemic of pneumonia occurred at Middlesborough in 1888, and was investigated by Ballard. Out of 1,633 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 numerous and severe in the workhouse, where the drainage was very faulty. The workhouse children suffered six times, but adults only one and a half times, as much as the corresponding class outside. Exposure and fatigue seem to have acted as predisposing causes, and many apparent instances are recorded of direct infection from contact with a sick person. The progress of the epidemic seemed to be arrested by heavy rains, and to be most rapid during rainless periods. Klein found neither Friedländer's nor Fränkel's *pneumococcus* in the morbid tissues, but large numbers of short bacilli, which he named *Bacillus pneumoniæ*. Inoculation of human lung-juice or of cultivations of the 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 mentioned above.

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.

The incubation appears to be short, frequently about five to seven days. The onset is sudden, and usually marked by rigors and severe constitutional symptoms, the signs of pneumonia being often delayed for three or four days. The fifth day is often fatal; and, on the other hand, crisis often occurs on or about the fifth or seventh or ninth day, but sometimes the course, even in non-fatal cases, is severe and protracted, the symptoms being of a "typhoid" character.

Both the breath and sputa may be assumed to be infective.

The mortality varies considerably, but is usually high, especially in elderly persons and in the outbreaks limited to a narrow circle. In some epidemics, however, it has been as low as five per cent.

Epidemics of pneumonia often occur coincidently with outbreaks of other diseases, and especially enteric fever. Pneumonia is a common complication or sequela of enteric fever, and it has been suggested that an invasion of the system by the enteric poison may have its sole manifestation in pneumonia, the usual intestinal lesions being slight or absent. The epidemic occurrence of such literal "typhoid pneumonia" is at least questionable.

Tuberculosis is a specific and infective disease common to man and the lower animals. The principal form in which it affects man is pulmonary tuberculosis or phthisis, but all parts of the body are liable to be invaded. The mortality due to tuberculosis is enormous, but does not admit of exact statement,

owing to imperfections of diagnosis, nomenclature, and classification. Phthisis may be accepted as a fairly well-defined division, although it undoubtedly includes a certain proportion of non-tubercular destructive diseases of the lungs. Tubercular meningitis is not sufficiently distinguished in death-returns from other diseases that are attended with somewhat similar symptoms, and "tabes mesenterica," which is classed as a tubercular disease, includes a large annual number of deaths among children from wasting diseases, of which no exact diagnosis has been made.

Phthisis, "consumption," or pulmonary tuberculosis, is one of the diseases that may justly be termed preventible. It is largely dependent upon known and remediable conditions, and improved hygiene has led to a steady decline in mortality from this cause. Nevertheless it still ranks among the most fatal diseases, especially during adult life, and as recently as the decennium 1871-80 it was the recorded cause of one-tenth of the whole mortality in England, and of upwards of forty per cent. of the deaths at ages between twenty and forty-five.

Its geographical distribution is almost world-wide. Neither hot nor cold climates are exempt, but humidity, especially if the daily range of temperature is high, is frequently associated with prevalence of 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 *à fortiori* mountainous regions are less affected than lowlands, owing, it is believed, to the dryness and purity of the air and soil, and the fuller and deeper respiratory movements. A general relation between dampness of soil and prevalence of phthisis has been established by

Buchanan * in England and Bowditch in America. The most conclusive evidence is the great and immediate reduction in phthisis mortality that has, in many instances, been observed to follow artificial drainage of damp localities. In Ely the reduction was 47 per cent., and in Salisbury 49 per cent.

There are, however, exceptions to this rule. At Ashby-de-la-Zouch, Alnwick, and Carlisle, Buchanan found an increase coincident with drainage of the towns, and the same has been observed at Danzig and elsewhere. In several of these cases, however, the local conditions were such that the drainage works did not materially dry the soil. It is stated by many authorities that phthisis does not occur in marshy regions which are malarious, and in Sussex Kelly has found that the phthisis mortality is greater upon the drier soil.

Towns suffer more than rural districts, and there is a close relation between density of population and phthisis mortality, due to the co-operation of several causes, chief among which are stagnation and impurity of air. The heaviest incidence is upon the poorer classes, and especially those living in narrow streets, alleys and courts, and in back-to-back houses. Conditions inside the houses such as over-crowding and want of ventilation are even more potent, and repeated experience in barracks, workhouses, prisons, and other

* The mortality statistics of the decennium 1851-60, for Surrey, Kent, and Sussex, showed that there was less phthisis among populations living on pervious soil than among those living on impervious soils : less on high-lying pervious soils than on low-lying pervious soils ; less on sloping impervious soils than on flat impervious soils. Buchanan also demonstrated the existence of a general agreement in phthisis mortality between districts that have common geological and topographical features of a nature to affect the water-holding quality of the soil—an agreement not observed in districts differently circumstanced in such respects : and further, a general parallelism between the degree of wetness of soil and the degree of phthisis incidence.

public institutions, as well as in ships, has shown that with improved ventilation and ampler air-space the mortality from phthisis is greatly reduced. Among nomadic races the disease is rare.

Many trades have a tendency to induce phthisis, as has already been stated, and especially those industries which are carried on in overcrowded, hot, moist workrooms, or which charge the air with mineral or organic dust. Exposure to rapid alternations of temperature is very injurious. Greenhow attached much importance to a stooping posture at work, as predisposing to phthisis. Most of these points are borne out by Ogle's mortality figures, some of which are quoted in chapter xvii.

Among other predisposing conditions, intemperance and debilitating causes of all kinds are important. Attacks of pleurisy, bronchitis, or pneumonia increase the liability to phthisis, and so, too, do many forms of specific fevers (notably measles, whooping cough, and enteric fever), and other diseases, for example diabetes and insanity. The low phthisis mortality among fishermen, agricultural labourers, and others following essentially out-door employments, seems to indicate that exposure to weather has been overrated as a predisposing cause, but this condition in a great measure implies abundance of fresh air.

Rightly or wrongly, a large but decreasing number of deaths of young children under two years of age is attributed to phthisis. The mean annual death-rate at ages under four years was 1·3 in 1861–70, and 0·8 in 1871–80. From five to ten years the mortality is at a minimum (0·36), and then rises steadily to its maximum (3·7), at ages between 35 and 45, after which it declines again as age advances.

The influence of sex is very marked, but is to be explained for the most part by differences of surroundings rather than by variation in natural susceptibility.

In proportion to their numbers males suffer a higher phthisis mortality than females at all ages except between 5 and 25 years, according to the statistics of England and Wales during the decennium 1871–80. While the mortality is decreasing rapidly in both sexes, the decline among females is greater than that among males.

PHTHISIS MORTALITY IN ENGLAND AND WALES, 1851–80.

	Males.	Females.	Total.
1851–60 . .	2·6	2·8	2·7
1861–70 . .	2·5	2·5	2·5
1871–80 . .	2·2	2·0	2·1

Since 1881 there has been a further progressive reduction, the phthisis death-rate during the five years 1881-85 having fallen to 1·8, and in the next quinquennium (1886-90) to 1·6.

No race is exempt, but among Jews phthisis appears to be rare, and this comparative immunity is attributed to the care that is taken in the selection of animals slaughtered for food. Natives of hot countries migrating to cold, damp climates are very prone to phthisis.

The tendency to phthisis may be inherited, in the form of constitutional weakness, or of a narrow, contracted chest. Whether heredity can do more than strongly predispose to the disease is less certain. Tubercle has in rare instances been found in children within a few days of birth, and even in the fœtus. Various observers have obtained evidence of parental phthisis in from 15 to 30 per cent. of the cases coming under their notice, but this proportion is scarcely sufficient to establish the proof of heredity. A family history of phthisis is obtainable in fifty per cent. of hospital cases of this nature.

Deaths from phthisis are most frequent in spring (March and April), and least so in autumn (September and October). The seasonal curve of mortality is therefore later than in the ordinary respiratory diseases, but it serves to indicate seasonal conditions accelerating death rather than those primarily inducing a disease of long and uncertain course, many months in duration.

The pathogenic microbe of tuberculosis, discovered by Koch, is a motionless bacillus which, under suitable conditions, forms spores. The bacilli are very slow in growth and multiplication, taking one, two, or even three weeks to form a colony, and require for that purpose a somewhat high temperature, which must further be maintained within narrow limits, about 37° to 39° C. A peculiarity that distinguishes them from all other bacilli except those of leprosy and syphilis is that after staining with fuchsin they are not decolorised by nitric acid. These bacilli are found in all tuberculous lesions, both in man and the lower animals. They have been found also in the blood, and in certain secretions (milk), and they abound in phthisical sputa. Cultivations if inoculated or injected into susceptible animals reproduce the disease. The bacilli are readily destroyed by many chemical or thermic means, and by exposure to sunlight, but the spores are tenacious of vitality.

Tuberculosis can be acquired by inoculation, inhalation, or swallowing. Inoculation is comparatively rare, and usually causes a local lesion only. Inhalation would seem to be by far the most common source of infection. The bacilli, or rather their spores, are found in air-borne dust, especially in rooms inhabited by phthisical persons. According to Bollinger, the daily sputa of a single patient may contain 20,000,000 bacilli, and drying for months will not destroy their virulence. The prevalence of the pulmonary form of

tuberculosis, and its close relation to air-conditions, are not without significance, as pointing to air-borne infection. A further analogy to the ordinary infectious diseases is to be found in the strong evidence which has been adduced by Ransome and others to show that tuberculosis attaches itself to particular small localities ("Tuberculous Infective Areas"), houses, and even rooms. The bacilli have been found not only in the air and dust, but in the walls of rooms occupied by phthisical persons. Niven examined the records of 5,000 deaths from this cause in Oldham, and found that whereas the mathematical probability was that 68 houses would be invaded twice, and 7·6 three times, the actual numbers were 274 and 24 respectively. The endemic areas occur chiefly in the worst parts of towns, when the predisposing conditions already referred to exist in maximum intensity.

There is still much doubt as to the frequency of direct infection from person to person, but none as to its occasional occurrence, or as to the fact that almost all persons must frequently inhale and swallow living *Bacilli tuberculosis*. Fortunately the microbe is very slow in its development, and exacting in its requirements as to temperature and surroundings, so that the vast majority that gain entrance to the respiratory tract are expelled or perish. The long duration of the disease, the wide and general diffusion of the virus, the paramount importance of predisposing conditions, and the difficulty of infection in their absence, all combine to render obscure the time and source of infection. Statistics are inconclusive even in regard to transmission of phthisis between husband and wife.

It remains to consider the third mode of tuberculous infection, by the alimentary canal. Tuberculosis is common among cattle, but authorities differ greatly in their estimates of the degree of prevalence, as shown by the discovery of tubercle in animals

slaughtered for food. According to some, signs of tuberculosis are found in only one per cent. or less, while others allege that thirty or even fifty per cent. are affected. All are agreed that the proportion is greatest among stall-fed cattle.

It is notorious that tuberculosis of the udder, in the form of softening nodules or "abscesses," is not uncommon among milch cows, and that the milk from such cows, containing, as it must do, tuberculous material, still finds its way into the market. The absence of implication of the udder does not necessarily confer safety. We have now experimental evidence that bacilli may be present in the milk of tuberculous cows in which the udders are unaffected, and also that tuberculosis may be imparted to young and healthy animals by the use of such milk, even if no bacilli are discovered by the microscope. Confirmatory results have been obtained by intraperitoneal injections of the milk.

So, too, with the flesh of animals suffering from tuberculosis. It has long been customary to condemn as unfit for food all parts of the carcase in which signs of tubercle are manifest, and the whole carcase if the disease be far advanced and the animal emaciated. It has now, in the judgment of many of the highest authorities, become necessary to go much farther than this, and to condemn absolutely the whole carcase if evidence of tuberculosis is found in any part, no matter how slight in extent or how completely it may appear to be localised. The congress which assembled in Paris in 1888 affirmed the necessity of these rigorous measures, and several towns have now followed the example of Glasgow in enforcing them. They are, of course, based upon the belief that the slightest local lesion involves, or may involve, infection of the whole of the body. That the flesh of tuberculous animals, though apparently free from tubercle, may still

impart the disease if inoculated or injected, has been proved by actual experiment, and positive evidence of this kind carries more weight than the negative evidence of any number of failures.

As regards milk, all danger of infection may be obviated by boiling, but the cooking to which meat is subjected is insufficient to destroy bacilli that may be present in the deeper parts.

It should be mentioned that some authorities question the identity of human and bovine tuberculosis, and there are slight morphological differences between the respective bacilli. Rabbits inoculated with human tuberculosis develop general tuberculosis, but less rapidly and with more localisation than when bovine tuberculosis is used for the inoculation. Fowls are more susceptible to human than to bovine tuberculosis.

The heavy mortality among children from "tabes mesenterica" and "tubercular meningitis" is urged as a confirmation of the extreme prevalence of tubercular disease, but it is probable that both of these terms are employed in the loosest way in making out certificates, and it would not be safe to place much reliance upon the tubercular nature of the majority of the cases so certified.

It is now recognised that tuberculosis often ends in recovery. The records of long series of autopsies of persons who have died of other diseases show that traces of cured phthisis are found in a proportion variously estimated as from 25 to 50 per cent. It is not in any degree protective against a further attack.

Bacteriological investigations have established the identity of lupus and scrofula with tuberculosis. Guinea-pigs inoculated with tuberculous material die of tuberculosis in eighty days on an average; the same result follows inoculation with scrofulous matter after an interval averaging 100 days, and if scrapings of *lupus vulgaris* are employed for inoculation death

occurs in about 330 days (*Lingard*). The virus appears to be attenuated in scrofula, and still more so in lupus, but becomes more virulent and more rapidly fatal as it is inoculated from one guinea-pig to another.

Malarial diseases may conveniently be considered as a single group, although they include many varieties that have received specific names. Whether the malarial poison is the same in all cases is a point still undecided, but the other etiological conditions are, at all events, closely related. All have a characteristic tendency to periodicity in the course which the symptoms follow, and this peculiarity is made the basis of a broad subdivision into intermittent and remittent types of fever, the former being the less severe. Intermittent fever or ague is further subdivided into quotidian, tertian, and quartan varieties, according to the length of interval between the attacks, which may occur every one, two, or three days. Each attack is marked by a cold stage, a hot stage, and a sweating stage; but the temperature in the intervals always becomes normal. Of these sub-varieties quotidian ague, with daily attacks, is the most severe, has the longest hot stage and the shortest cold stage, and approaches the most closely to the remittent type. In remittent fevers there are one or two exacerbations every day, but the temperature during the intervals does not subside to the normal level, nor do the constitutional symptoms entirely disappear. The cold stage is very short and the hot stage protracted. Remittent fevers are met with principally in tropical regions, but are endemic in many marshy districts in Southern Europe, and occasionally spread as far north as the Baltic.

"Covering a broad zone on both sides of the equator, the malarial diseases reach their maximum of frequency in tropical and sub-tropical 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*).

As the intensity of the endemic or epidemic prevalence diminishes, the individual cases tend to assume more and more the intermittent type. Climate is therefore a factor of great importance. Broadly speaking, the tendency to malaria increases with the temperature, especially if the diurnal range of temperature is high. Atmospheric humidity is also favourable to malaria. Moisture of the upper part of the soil is an almost invariable condition in malarious districts, and the effect has been said to be heightened by a slight superficial drying. Clay soils, which retain moisture, are among the worst, but chalk, or sand, or other porous soil, may become highly malarious if from any cause the subsoil water is high. Malarious soils almost always contain vegetable matter in greater or less quantity. In such districts heavy rainfall, especially after long heat and drought, is generally followed by outbreaks of malaria, and irrigation has a similar tendency. They cease to be malarious when the ground is either completely flooded or dried —temporarily or permanently—by drainage, extensive planting (*e.g.* with *Eucalyptus globulus*), or other means. As regards the surface, the prevalence of malaria decreases with the elevation, other things being equal. High ground is the most healthy, but exception must be made in respect of spurs of hills and depressions even at high levels, and more particularly of ravines. Among other causes conducive to malaria are abandonment of cultivation, or, on the other hand, the breaking up of new ground, excavation, or cutting down trees. Volcanic disturbances and earthquakes have sometimes been followed by malarial outbreaks.

The proof of the close relation with telluric conditions is completed by the fact that malarious soil conveyed in boxes to healthy districts has given rise to outbreaks of the disease. Fodor concludes from observations at Pesth that only the superficial layers of the soil are concerned in the etiology of malaria; at any time of year a high temperature for a few days is followed in from fourteen to twenty days by an outbreak.

Such being the general characteristics of malarious districts as regards climate and soil, it must next be pointed out that they are in themselves inadequate to produce malaria, and also that some of them are entirely wanting in highly malarious localities. Malaria is unknown, for example, in many parts of Ireland, in the Bermudas, in Singapore, and the Pampas of South America, where the physical conditions would *à priori* appear to be highly favourable. On the other hand, some of the malarious districts in the Deccan and Mysore are steep mountain slopes, and many others in India and elsewhere are equally free from moisture of the soil. Instances are common in which districts, previously healthy, become temporarily or permanently malarious, without apparent change in their physical conditions. Malaria being a specific disease, the presence of a specific organism is necessary, and the conditions hitherto described are to be regarded merely as more or less favourable to its growth and dissemination.

In spite of the common relation of phthisis and malaria to dampness of soil, these two diseases rarely co-exist in the same locality. Workmen in Sicilian sulphur mines are said to suffer from malaria to the extent of only 9 per cent. of their number, while 90 per cent. of the rest of the population, living in the same villages, are affected. The microbe of malaria appears to have been discovered by Marchiafava and Celli, who found in the red blood corpuscles of malarious patients

minute bodies which they term *Hæmoplasmodium malariæ*. They found also that intravenous injection of blood containing these plasmodia produces intermittent fever in man, and that the blood corpuscles of a person so infected again contain the plasmodia. Klebs and Tommasi Crudeli had previously obtained from the highly malarious soil of the Campagna a bacillus which also has claims to be regarded as pathogenic. Outbreaks of malaria have occurred on board ship, and have been attributed to foul bilge-water.

In temperate regions the seasonal curve of malarial prevalence shows a maximum in May, and another in September and October. In warm countries there is a maximum in summer and autumn, with a minimum in spring; while in the tropics, the maximum coincides with the season of heavy rains.

The malarial poison is readily carried by air currents, but according to Parkes, rarely for more than one or two miles. It is arrested by belts of trees or broad expanses of water, and appears not to rise many feet from the ground; so that the upper rooms of a house may be healthy while the lower are exposed to malaria.

It would seem, although Hirsch is of the contrary opinion, that drinking-water may convey infection. One hundred and eleven men, out of a crew of two hundred and twenty-nine, were seized with malarial fever during a voyage from Bona to Marseilles, and thirteen died. It was found that part of the water supply was of marshy origin, and that all the sufferers had drunk of this, while those who had drunk pure water escaped entirely.

It is generally held that malaria is not transmissible from person to person.

Ague was formerly widely prevalent in England, especially in the Fens and in Essex, but has become comparatively rare even in these districts owing to

the general adoption of subsoil drainage. Great Britain is also free from the—sometimes intense—outbreaks of malaria which in other parts of Europe are recorded from time to time in districts in which it appears to be unable to gain a permanent footing as an endemic disease.

Leprosy is a disease of great antiquity in Egypt, India, China, and Japan. The Biblical term "leprosy" doubtless included many forms of skin disease, and the same ambiguity attends most, if not all, of the other records of the disease in former ages. It has especially been confounded with syphilis and *elephantiasis arabum*, true leprosy being sometimes termed *elephantiasis græcorum*. It probably made its appearance in Europe about the beginning of the Christian era, and became widely diffused during the next eight or nine centuries. A further increase—attributed to the Crusades—took place in the twelfth and thirteenth centuries, but in the sixteenth and seventeenth centuries it began to disappear, and at the present time has vanished from Europe, with the exception of certain limited districts, more especially in Norway, Sweden, Finland, Spain, Portugal, the Riviera, Italy, Greece, Turkey, South Russia, and some of the Mediterranean islands, including Sicily and Cyprus. It is prevalent in the West Indies, the west coast of South America, India, China, and the greater part of Asia; most of the islands in the Pacific, notably Hawaii, and in many parts of Africa. It is common in Mexico, and minor foci exist in Louisiana, New Brunswick, and British Columbia. Special attention has recently been directed to its increase at the Cape. Districts upon or near the coast are by far the most frequent seats of endemic leprosy.

In England, special legislation was directed against leprosy in the tenth century, and leper hospitals were established in the eleventh century in many of the

larger towns. The last record of any extensive prevalence in England was at the end of the seventeenth century, and it is now unknown except as a disease acquired abroad. The proportion of lepers to the total population has been given as 1·6 per 1,000 in Iceland (1869), 20·0 in Hawaii (1873), and from 1·0 to 4·0 in the leprous districts of India. The Indian census of 1872 gave a total of 99,073 lepers, or 0·5 per 1,000, but all estimates of the kind probably fall short of the truth.

Certain villages, or sides of valleys, or other small local areas, are in many instances specially exempt or specially stricken, without any assignable cause.

Leprosy is diminishing in its few remaining European centres, but increasing in the West Indies, Demerara, South Africa, and probably in India. Chinese immigration is said to have recently introduced it into North Australia and British Columbia.

Climate would appear to have little influence, since the geographical distribution is or has been almost world-wide, nor has anything been made out definitely in regard to more local meteorological conditions. The effect of season, if any, cannot be traced in a disease which begins insidiously and runs a protracted course. The greater incidence upon coast regions seems to give a clue to the etiology, but the disease prevails in many elevated regions far removed from the sea; for example in Mexico and the Deccan. The use of fish, and especially of decomposing fish, as a principal diet is supposed by many authorities to contribute largely to the causation of leprosy. This view is supported mainly by the prevalence of the disease in littoral districts, but also to some extent by its frequent appearance in new regions among Chinese settlers, whose skill in cookery enables them to make use of putrid fish, and lastly by its observed

disappearance from certain districts where fish diet ceased to be general. On the other hand, there are many inland leprous regions in which fish is rare, or, as in Central China, limited to the use of the wealthier classes. The disease has declined in many localities without any material change in diet, and, further, the vegetarian Brahmins are by no means exempt from leprosy. It would seem, therefore, that a fish dietary, if it has any etiological significance at all, is not operative in all cases. Another hypothesis is that deficiency of common salt in food is conducive to leprosy. Sanitary improvements in the habits and surroundings of the population have, in all probability, been chiefly instrumental in suppressing leprosy in England and elsewhere. Although never confined to the poorer classes, its incidence has been greater upon those living in filthy and unhygienic conditions.

Nothing is known as to any relation with telluric conditions, or transmission by water or air. Negroes, Hottentots, and Chinese are more affected than white races living in the same localities. Males suffer in greater numbers than females, and among the very old and the very young the disease is of rare occurrence.

Authorities are at variance as to the hereditary transmission of leprosy, and very little is known of the way in which the disease is ordinarily acquired. Danielssen affirms that it is hereditary and not contagious; Hansen, that it is contagious and not hereditary. The latter states that no sign of leprosy had appeared among the descendants of 160 Norwegian lepers who settled in the United States. Liveing believes that it is spread by means of the excreta. Arning has proved it to be inoculable, having successfully inoculated a condemned convict.

The incubation period in Arning's case was two years. It is believed to be very variable, extending over months or years, with or without premonitory

symptoms. Two chief types are described—the "anæsthetic" and the "tubercular"—in which the neoplastic growths implicate the nerve trunks and the skin respectively. The average duration is given as eight years in the former, and sixteen in the latter, but with wide variations. When the disease begins in early life, its duration is comparatively short. The result is almost always fatal, but it is stated that in Norway thirty-eight cases were cured in the five years 1881-5, and Kaurin believes that if the disease is localised, early amputation may sometimes permanently arrest it. According to Sand, the disease may exhaust itself in thirty or forty years if the constitution is exceptionally strong.

The only preventive measure that offers any hope of success in the present imperfect state of knowledge is the isolation of the sick. This is being carried out in many leprous localities, and apparently with benefit. In Norway, leper asylums were established in 1856, and the number of lepers is believed to have steadily fallen from about 3,000 in 1856, to 1,100 in 1887. The isolation in these asylums is not rigid, but in Hawaii an island is set apart for the leper settlement, and the seclusion is practically life-long. It seems clear that the infection is not acquired readily, if we take the ordinary infectious diseases as a standard, and there is some probability that even a partial segregation of lepers may have considerable influence in arresting the disease, assuming its spread to be due mainly to personal intercourse. The difficulties of obtaining a tolerably complete isolation or even registration of lepers are of course very great.

Minute bacilli, first noticed by Hansen, are found in the characteristic leprous neoplasms, internal or external. They have been cultivated, but are difficult of inoculation upon lower animals. There is little doubt that these bacilli are pathogenic. They

are not found in the blood, and are believed to spread by means of the lymphatics.

Hydrophobia is the name given to convulsive rabies occurring in the human subject. In man rabies rarely assumes the paralytic form. In spite of the numerical insignificance of the death-rate from this cause, the disease is one of great interest and importance from the point of view of preventive medicine. Of the 761 deaths from hydrophobia in England and Wales between 1866 and 1885, 225 occurred in Lancashire, 119 in London, 102 in the West Riding, and 29 in Cheshire. These centres may be regarded as "endemic foci," whence the rest of the country is subjected to repeated inroads.

Hydrophobia causes most deaths at ages between five and fifteen years; more among males than females; and more in late summer and autumn than at other seasons (*Longstaff*).

The disease is imparted to man by the bite of rabid dogs; or more rarely of rabid cats, foxes, or wolves. The incubation period is six weeks, but in exceptional cases it may apparently be as long as two years. It is stated to have been as short as one week in children bitten about the face. The disease almost, if not quite, invariably ends in death within a few days. It is not known to have been transmitted from one human being to another. Bites about the face, and especially those inflicted by rabid wolves, are more deadly than others, and in such cases the incubation is short. The danger is less when the part bitten is protected by clothing. Taking only 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 presently, this mortality may

be reduced to less than 1·5 per cent., and by other preventive measures rabies can be, and has been, stamped out altogether.

Pasteur discovered that the virus is present in the spinal cord of rabid animals as well as in the saliva, and that a portion of the spinal cord of a rabid animal (or human being dead from hydrophobia), inoculated beneath the dura mater of a rabbit, imparts the disease with certainty. This alone would be important as a certain means of diagnosis; but Pasteur has shown further that the virulent cord gradually loses its virulence if kept in perfectly dry air, and that this attenuation affords a means of protective "vaccination." He inoculates at short intervals with successively more and more virulent material, commencing with very attenuated virus, until at last fresh cord is employed. It is surmised that the protection is due to a chemical substance, and not to any real attenuation of the microbe. However this may be, the result of the course of inoculations—so far from causing rabies, as a single inoculation with fresh rabic cord would do—is to render dogs insusceptible to rabies. The same treatment is now extensively practised in regard to persons bitten by rabid animals; and the mortality among such, if treatment is commenced within a week, is no longer 15, but 1·36 per cent.

The microbe has not been isolated with any certainty, although both micrococci and bacilli have been found in the rabic cord.

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 rabies. Less isolated countries are subject to constant new importations of the disease across the frontiers, but the success of repressive measures has been very great. Thus hydrophobia, though formerly prevalent, has been

unknown in Berlin since 1874, and the Prussian provinces are practically free except on the eastern (Russian) frontier.

In England several local attempts have been made in the same direction, but none upon a large scale until 1890, when it was made compulsory for a time throughout Lancashire, Cheshire, the West Riding, and London, and was followed by the cessation of rabies.

In London muzzling was adopted in 1885, and speedily put an end to the prevalence of rabies, the result being shown both by veterinary experience and by the reduction in deaths from hydrophobia.

The same experience was repeated in Nottingham in 1886; but the muzzling order having been unwisely relaxed too soon, the number of cases of rabies rapidly increased again, to disappear once more under the renewed application of the muzzle. Nothing short of a systematic attempt throughout the island is likely to succeed in absolutely stamping out the disease; but the temporary success of even local and partial measures is unmistakable. The *Rabies Order of* 1892, issued by the Board of Agriculture, enables county authorities to make regulations for muzzling and other preventive measures.

Tetanus is now recognised as having relation to telluric and climatic conditions, and as belonging to the group of specific diseases. It is common in hot countries, and liable to what may almost be termed epidemic outbreaks; such outbreaks may follow sudden changes of temperature. Horses are affected by tetanus, and may impart it to man; hence those in attendance upon horses have a preponderant liability. Traumatic tetanus is one of the evils that result from want of cleanliness, and is absolutely preventible by antiseptic precautions. It can usually be produced experimentally in animals by inoculation with stable refuse, or soil

manured with this, and indeed from most samples of soil or dust. The specific bacillus has been identified and cultivated. It is anaërobic, and has been found to retain its virulence for three or four years. It resists the action of 5 per cent. carbolic acid, and 1 per 1,000 mercuric chloride takes half an hour to kill it.

Glanders or **farcy,** as affecting man, has only been known during the present century. Although in isolated instances it has been transmitted from one human being to another, it is practically always acquired from the horse. The virus does not appear to be capable of aërial transmission, except, perhaps, for very short ranges, and nothing is established as regards convection by water or milk. Inoculation is the almost invariable mode of infection so far as man is concerned ; but it is probable that this may sometimes occur without abrasion of skin or mucous membrane. Among animals the disease spreads rapidly. It is very rare in man, but attended with an extremely high mortality, which is stated to be not less than 50 per cent. in chronic cases, and not far from 100 per cent. in the acute variety. The usual incubation ranges from three to eight days, and is shortest in acute cases. For obvious reasons, men are much more liable to glanders than women or children. The disease affects the nasal and respiratory mucous membranes, and also the lymphatic glands. When the latter are attacked first, the disease is often termed *farcy.*

Anthrax affects man in two forms, external and internal. External anthrax, or "malignant pustule," has its usual seat about the face or neck, and is no doubt 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 border may be fringed with vesicles. The surrounding tissues and the lymphatic glands are swollen and

indurated. The disease may remain localised, and end in resolution, or at most suppuration. Usually, however, constitutional symptoms attend its course, and general infection may follow. Occasionally, malignant pustule supervenes upon internal anthrax. Internal anthrax appears to be due to inhalation or swallowing of the poison. It is only known as affecting wool-sorters, and as the result of experimental infection of animals. After a very variable incubation period, ranging perhaps from two to twelve days, the early symptoms are chills, weariness, depression, restlessness, and a feeling of constriction in the chest. This prodromal stage may last only a few hours, but more usually two to six days, and then graver symptoms set in suddenly. The prostration becomes extreme ; pulse and respiration are hurried. The temperature is somewhat elevated, but always liable to sudden remissions, accompanied by perspiration. The patient may die from heart-failure, or brain symptoms may become prominent, or pneumonia or diarrhœa may supervene. Remissions may occur.

The mortality is high, but recovery may happen even in serious cases.

Anthrax has received the name of "wool-sorter's disease" from its prevalence in the Bradford district among men employed in sorting foreign fleeces, and especially those of goats, from Van, in Armenia. Tanners, butchers, and others engaged in handling raw hides, are liable to malignant pustule.

The protection derived from an attack is very slight, if any.

The sorting of wools which experience has shown to be dangerous may be made safer by preliminary washing or disinfection of the wool, cleanliness and ventilation of the sorting-rooms, and removal of all facilities for lodgment of dust in these rooms. Fan-blasts are employed to carry away the dust during

the opening and sorting of the bales. Respirators are rejected by the workmen. Other obvious precautions are attention to cleanliness of the hands before eating, and change of garments when the work is done.

Anthrax attacks sheep, goats, pigs, cattle, and horses, and may be communicated to mice, guinea-pigs, and many other animals. As in man, the disease may be either localised or constitutional, and in the latter variety enlargement of the spleen is so prominent a characteristic that anthrax is known as "splenic fever." A field may become infected with anthrax, and healthy animals turned into 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 suggests that the spores from buried carcases are brought to the surface by earth-worms, but Klein has found that spores are not formed under such conditions, and that within a week all bacilli and all infectivity have been destroyed by putrefaction, if the carcase is buried intact.

Although exact evidence is wanting, it may be assumed that anthrax can be acquired by eating the flesh of diseased animals. The usual mode of infection so far as man is concerned is by inoculation, and it has been suggested that the poison may be carried by flies and other insects. It may also be inhaled, or swallowed in the form of dust, as has already been stated.

The pathogenic microbe is the *Bacillus anthracis*, which is capable of living in all vegetable and animal infusions, and of forming spores when exposed to air. The bacilli are readily destroyed by heat or other disinfecting agencies, but the spores are extremely resistant. It has been found that 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. Bacilli are destroyed by the gastric juice, spores are not. A further marked difference between bacilli and spores is shown by the results of inoculation (*Klein*). The former cause a slight and localised form of the disease, the latter a severe constitutional malady, which is usually fatal. Thus, the fresh blood of a mouse dead of anthrax contains bacilli only, but upon exposure to air, or artificial cultivation, spores are readily formed. Inoculation of the fresh blood into sheep is followed by slight local anthrax, but if blood containing spores is used a fatal attack ensues. Moreover, if two animals of the same species are inoculated, one with *spores* of a broth culture and the other with *bacilli* of a gelatine culture, the blood bacilli of the latter will be more "attenuated" than the former. But apart from this, anthrax virus varies in intensity according to the animal from which it is taken. Comparing the results of inoculation with virus from mice, guinea-pigs, sheep, and cattle, it is found that their virulence increases in the order stated, mouse anthrax being the least and cattle anthrax the most potent.

Martin has shown that the *Bacillus anthracis* produces toxic albumoses, which in turn yield ptomaines much more virulent than themselves.

The infection in wool-sorter's disease must be due to spores. Bacilli would form spores and perish long before the Van fleeces reach the manufacturers in England.

CHAPTER XIII.

PREVENTION OF INFECTIOUS DISEASES.

In the preceding chapters reference has been made to the various means by which specific and other diseases are disseminated or checked. It remains to consider the powers and duties of the Sanitary Authority, and of the Medical Officer of Health, in relation to preventible diseases, and especially infectious diseases. All infectious diseases may be said to be preventible, but not all are amenable to the preventive measures which at present can be enforced by the most active sanitary administration. Small-pox and rabies may be taken as types of specific diseases which can be and ought to be suppressed, and are now, as a matter of fact, limited to such persons and such populations as do not choose to adopt the measures which reiterated experience has shown to afford safety. Measles and whooping cough, on the other hand, although strictly speaking preventible diseases, always dependent (so far as we know) upon direct or indirect infection from other cases, have not yet been brought under control. No prophylaxis has been discovered, and as infants are especially liable, the susceptibility of the population is speedily renewed, even after an outbreak. Isolation and disinfection are theoretically capable of arresting the spread of these diseases if applied in every case and at the commencement of the infectious stage, but in practice this can scarcely be accomplished at present, for reasons that will be stated later.

Scarlet-fever, diphtheria, and enteric fever are examples of a different class. They are not entirely dependent upon infection from person to person, but are affected by a variety of conditions of which every

year brings us fuller knowledge. Some of these conditions, including personal infection, infection from lower animals (by consumption of milk or flesh, or in other ways), and infection by drinking-water, are more or less under our control. So, too, are the various "insanitary conditions" which conduce to the spread and malignancy of specific diseases, and telluric conditions also are to a great extent remediable. But we have no prophylactic such as vaccination, and must trust mainly to isolation to protect an always susceptible population. Experience has shown that if carried out thoroughly, isolation, disinfection, and quarantine can very greatly reduce the incidence of these diseases, but there is always danger from unrecognised cases, from the early stages of the disease before the diagnosis is made, from importation of infection, and from accidental or wilful neglect of precautions. It must also be remembered that there may be modes of infection in these diseases at present unknown to us, and this is especially probable in respect of diphtheria. A very few years ago there was no suspicion of bovine scarlet-fever.

Although it may be possible to isolate almost any case of infectious disease in a large house, where all the requisite precautions can be rigidly maintained during the whole period of infectiousness, it may be stated broadly that "home isolation" in smaller houses cannot be carried out in its entirety. In houses of the working class, for example, not one case of scarlet-fever in a hundred is, or can possibly be, properly isolated, during the whole period of still infectious convalescence, from the rest of the household, or even from the public. Medical supervision is usually withdrawn at the end of the acute stage of illness. Hospital isolation is the only means of safety, but much may be done by enforcing elementary precautions in cases retained at home, and thus

reducing the facilities for the spread of infection. For this purpose it is essential that the Sanitary Authority should be informed of each case as it arises.

No Sanitary Authority can be regarded as fulfilling its duty in the prevention of infectious disease unless it has provided for the following:—(1) isolation hospitals; (2) compulsory notification; (3) disinfection.

Hospitals for infectious diseases.—The number of beds which should be provided has been stated as one for each thousand of population, but very few towns have adopted this standard so far as permanent hospitals are concerned. It is obvious that such an estimate can only be of the roughest kind. Much depends upon the character of the population, upon the number of diseases which it is proposed to isolate, upon the compulsory notification of those diseases, upon the thoroughness or the reverse with which the policy of isolation is to be carried out, and lastly upon the question whether the hospital is intended to be a final and inelastic establishment, or merely a permanent provision sufficient for non-epidemic times but capable of rapid extension at a few days' notice in the event of serious epidemic. It is obvious also that averages are of little use as indicating the maximum possible demand for hospital accommodation at any given date, and it is not to be assumed that only one disease will be epidemic at one time.

By general consent small-pox, scarlet-fever, and typhus are diseases which, for the public safety, ought to be treated in hospital whenever possible. Experience has shown that with compulsory notification and *free hospitals* it is possible to get into hospital practically all the small-pox, and a great majority of the scarlet-fever and typhus cases, without recourse to compulsion. Diphtheria ought certainly to be added to the list, and enteric fever also if adequate accommodation is not provided for this disease in the

general hospitals of the district. For reasons stated elsewhere it appears to be very doubtful whether the time has yet come for the isolation of measles or whooping cough upon a sufficient scale to be of any practical use; if, however, cases of special urgency occurred, the small wards would afford means of isolating them.

Whether enteric fever be included or not, it is clearly impracticable to provide separately for the maximum possible requirements during epidemics of small-pox, scarlet-fever, and diphtheria.

At the present time compulsory notification is becoming generally adopted, and even apart from this, hospital isolation of infectious diseases is growing in public favour wherever the means are provided. Hence the experience of past years, under different conditions, is of little service as indicating the amount of accommodation likely to be required. On the other hand, scarlet-fever and small-pox are at present losing ground in England, although diphtheria is increasing, and it is impossible to say what further changes may occur in the incidence of these and other diseases.

To sum up, therefore, the provision of one bed per thousand population has in the past been found to be unnecessarily large and costly, but is not likely to be so in the future. Indeed, it will not suffice in the event of epidemics, according to the experience of those towns in which notification and adequate isolation have now been tried for some years; and if such diseases as measles and whooping cough are to be isolated, large additions will be necessary. It is, therefore, advisable to reserve a liberal area for future extensions, temporary or otherwise, and to construct the administrative portions upon such a scale as to suffice in case of such extension of the isolation blocks. The wards should be so constructed as to admit of disinfection, so that the greatest number of beds may

always be available for whatever disease is prevalent at the time. This can be done with safety and without difficulty if all the internal surfaces are impermeable. The wards, whatever the number of beds, must be sufficiently numerous to allow of the separation of the sexes wherever necessary, as well as the isolation of the several diseases one from another.

It is of the utmost importance, if isolation is attempted upon the large scale, to make the hospitals free, and this is only reasonable, since the public gain at least as much as the patient by his seclusion. The Sanitary Authority must not regard removal to hospital merely as a privilege sought by the patient and his friends, but as a more or less reluctant concession to the public safety. Any charges, however small and readily remitted, are deterrent in the very cases in which isolation is most needed. The revenue from patients' fees is at best a small fraction of the cost of maintenance, and the wholesale remission of them —without which the isolation of cases among the working classes is impracticable—has an appearance of charity which is naturally resented. An exception may be made in respect of the wealthy, who are willing to pay suitable fees for the use of private wards and special nurses.

Compulsory notification of infectious diseases has been in operation in several towns for many years past under special local Acts, and is now placed within the reach of all Sanitary Authorities, subject to the approval of the Local Government Board, by the Infectious Diseases Notification Act of 1889. The diseases scheduled in the Act are:—

Small-pox	Scarlet-fever
Cholera	Typhus
Diphtheria	Enteric Fever
Membranous Croup	Relapsing Fever
Erysipelas	Continued Fever

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, whooping cough.*

Under the special local Acts already referred to, the duty of notification to the Sanitary Authority was usually imposed upon both the householder and the medical attendant, but in three towns (Bradford, Norwich, and Nottingham) the system was somewhat different, the medical attendant being required to give to the householder a formal certificate which he in turn was compelled to transmit to the Sanitary Authority. These two methods are sometimes designated "dual" and "single" notification respectively, but the difference between them vanishes in practice. Under either the certificate is, by the tacit agreement of all parties concerned, sent by the medical attendant direct to the Sanitary Authority, and the householder's share in the notification allowed to lapse as an unnecessary formality, unless there is no doctor in attendance. The so-called "dual" system, which is becoming general under the new Act, is therefore likely to be dual in theory only.

The adoption of the 1889 Act is optional.† 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. "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,

* Such additions may be made permanently, or for a specified time only; and may be revoked if the L.G.B. consent.

† It does not apply to London, its provisions being included in the Public Health (London) Act, 1891.

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 way, and without receiving any fee:—"The head of the family to which such...patient belongs, and in his default the nearest relatives of the patient present... and in default of such relatives every person in charge of, or in attendance on, the patient, and in default of any such person the occupier of the building, shall, as soon as he becomes aware that the patient is suffering from an infectious disease to which this Act applies, send notice thereof to the medical officer of health for the district." The Act applies to "every ship, vessel, boat, tent, van, shed, or similar structure used for human habitation," but not to any "hospital in which persons suffering from an infectious disease are received." It gives no power of compulsory removal of patients to hospital, nor even power of entering upon the premises for the purpose of making inquiries, but it is very rarely that any difficulty is met with in the latter respect.

Among the advantages to be derived by the Medical Officer of Health from compulsory notification are the following:—

1. Early and complete knowledge of all the cases of notifiable disease, and thus of the whole prevalence and distribution in the district. Death-returns give only a small fraction of the cases, and after an interval of many days or weeks.

2. Power to exercise such supervision as may be necessary over every case during its whole course, and to enforce due observance of the provisions of the Public Health Act as regards isolation and disinfection. This has special importance in connection with

outbreaks of scarlet-fever, diphtheria, or enteric fever in dairies, school-houses, etc.

3. Opportunity of offering, though not of compelling, removal to hospital in every suitable case, unless the Sanitary Authority has failed to provide hospital accommodation. Vaccination can be offered, and is rarely refused in households invaded by small-pox.

4. Opportunity of investigating the sanitary condition of all households in which cases of enteric fever, or diphtheria, or other notified disease may occur.

5. Power to control the spread of infection through schools or other centres, by excluding members of infected households.

6. Means of detecting at once any suspicious grouping of cases around schools, milk supplies, water supplies, or other common focus. A comparison of the data obtained by the routine inquiries into each notified case will at once reveal this, although there may be nothing in any single case to arouse the suspicions of the friends or of the medical attendant.

Among the poorer classes especially the most reckless disregard of the commonest precautions prevails almost universally, and constant watchfulness is needed. It may be hoped that the discipline enforced in regard to the notified diseases will lead to increased care in dealing with other infectious diseases. However this may be, there can be no doubt that the information derived from notification, if properly utilised, will be of great service in clearing up many doubtful points of etiology. Preventive measures are employed to some extent in all towns, and notification merely supplies the means of applying the same measures in a far more thorough manner. By general consent, the partial and incomplete control over infectious diseases exercised prior to notification by the Sanitary Authority was beneficial in its effects,

and it is reasonable to conclude that proportionately greater benefit will result from the more general application of the same system.

Such being the *à priori* grounds upon which compulsory notification has been advocated, it remains to be seen how far its results have been beneficial in practice. Unfortunately, the period of trial is still too short to allow of a final judgment in this respect. Scarlet-fever and small-pox, for example, tend to recur in epidemic intensity at intervals of some years, and the averages of a short series of years are, therefore, untrustworthy.

If we look to the past history of the large towns of England in respect of infectious disease, we find that the average mortality from certain diseases, including measles and whooping cough, shows little, if any, diminution as time goes on, while others, such as small-pox, scarlet-fever, and enteric fever, have declined materially. The former are practically allowed to run their course unchecked by any action on the part of public authorities or private persons, the whole armament of vaccination, isolation, disinfection, and sanitary inspection being directed against the latter group alone.

We should, therefore, expect to find the further amelioration, if any, under notification manifested chiefly, if not entirely, among those diseases which had already proved themselves amenable to such preventive measures as are at the command of Sanitary Authorities, and that in a general way the gain would be proportionate to the increase of precautions which notification renders possible. This is precisely what has happened, so far as the present short experience of notification enables us to judge. Measles and whooping cough, which receive as little attention in notification towns as elsewhere, remain unabated. Small-pox and scarlet-fever, which have diminished in

almost every town, have decreased more markedly in notification towns than in the rest. There has been much more extensive use of vaccination and hospital isolation in regard to these diseases as a consequence of notification. In several towns it has been found possible to isolate in hospital all the cases of small-pox, and three-quarters, or more, of the scarlet-fever, and to establish a *cordon* of vaccination around each new small-pox centre. Very few towns have made adequate provision for the hospital isolation of enteric fever, nor is there any prophylactic such as vaccination to be offered, and moreover the danger of spread of infection from person to person by ordinary proximity or contact is less marked than in small-pox or scarlet-fever; hence notification brings to bear comparatively slight reinforcements of preventive measures, and it is not surprising to find that at present notification towns show little superiority over others in this respect. Diphtheria is more readily communicated from person to person, but in other respects the same considerations apply. It has been gaining ground in many towns recently, and notification has not yet shown itself capable of checking this ominous increase. The notification of diphtheria can scarcely be complete or satisfactory, owing to the number of slight and almost undistinguishable cases, and hospital isolation upon an adequate scale has not yet been tried even in notification towns.

Epidemic prevalence of disease is determined by many causes, of which some are still unknown to us, and others (including climatic conditions) are beyond human control. Against such influences, unless they should prove to be operative merely by increasing the facilities for the spread of infection in ordinary ways from person to person, notification and the precautions which it renders possible are of no avail, and epidemics will continue to occur in spite of it. Nevertheless the

known and preventible causes, such as the transmission of infection from person to person, or by means of milk, are factors of the utmost importance, and it is safe to affirm that, however great or however small may be the total number of victims, the suppression of known and preventible favouring conditions renders the danger less than it would otherwise have been. Individuals may be saved, and widespread outbreaks delayed, restricted, or averted.

The allegations of the opponents of compulsory notification have not been borne out in practice. The chief were: (1) that it must cause friction between medical men and their patients, being in itself a breach of professional confidence—the same objections which were urged against the compulsory certification of the causes of death; (2) that it must lead to the employment of unqualified practitioners, upon whom no direct responsibility of notification rests; (3) that the fear of publicity consequent upon notification must lead to increased danger by concealment of cases; (4) that the medical attendant would in any circumstances voluntarily report all cases in which the interference of the authorities was desirable, and that he is the natural and competent adviser of the household in all measures of precaution as well as treatment; (5) attempts have also been made to show that the introduction of notification has been followed by an actual increase in the total death-rate, in the zymotic death-rate, and even in the death-rate from notified diseases.

The first two of these contentions are negatived by the experience of notification towns. The third amounts only to the paradoxical assertion that the concealment of a few cases under notification would be more dangerous than the wholesale concealment that prevails without it. Voluntary notification has in almost every instance proved a failure, even when fees

were offered by the Sanitary Authority. The supervision of the medical attendant, especially among the poorer classes, is imperfect, and often ceases with the early acute stages of the disease. Sufficient reference has already been made to the statistical evidence of the results of notification. The absurdity of crediting notification of certain diseases with any increase or decrease in the death-rate from other diseases is manifest.

The question whether measles ought to be added to the list of notified diseases is an important one. It is more than doubtful if any legislation could at present bring about a complete notification of measles. It must be remembered that we are dealing with a purely epidemic disease, which has no relation to water or milk supplies, or to defects of drainage, and for which we have no vaccination. Isolation and disinfection are, therefore, the sole preventive measures which could be brought to bear against measles, even if it were possible to obtain complete notification of a disease which is often not under medical care. Isolation in the homes of the poor is impracticable, and isolation in hospitals would entail a formidable addition to their present size. Moreover, for the reasons given above, and others stated elsewhere (*see* pages 283, 365), the results of isolation are far less likely to be satisfactory in measles than in scarlet-fever, and as a very large proportion of the sufferers are infants, there would be great reluctance on the part of parents to consent to removal.

That valuable information would be derived from notification of measles cannot be doubted, and from this point of view its inclusion in the schedule of notified diseases is desirable. It is urged, also, that even an incomplete notification would be invaluable in rendering possible early control over school-infection; that hospital isolation of measles would no longer

appear impracticable if epidemics were not allowed to proceed unchecked; and that notification of measles would bring to light many cases of scarlet-fever which, in the absence of any medical inspection, are regarded by the parents as "only measles." This last argument points to the notification of rötheln and chicken-pox.

The same considerations apply to whooping cough also.

At the end of March, 1892, twenty-four out of the twenty-nine million inhabitants of England and Wales were under the operation of compulsory notification. Measles had been added to the list by 71 sanitary authorities, whooping-cough by 17, rötheln by 4, chicken-pox by 2, and hydrophobia by 1 only.

The regulations of the Local Government Board require that upon receiving information of any outbreak of dangerous infectious disease the Medical Officer of Health shall at once make full inquiries, and adopt such precautionary measures as he may consider requisite. The necessary inquiries and investigations are simplified and made more systematic by the use of printed forms with spaces for the insertion of the details. Thus, a short tabular arrangement will comprise the chief personal data:—

SEX.	AGE.	OCCUPATION.	PLACE OF WORK OR SCHOOL.	HISTORY.	LAST AT WORK.	DATE OF ONSET
M.	*36*	*Porter.*	*Railway station*	*B.*	*July 7, 1889.*	—
F.	*30*	*Housewife.*	*Home.*	*A.*	*Still at work.*	—
F.	*8*	*Scholar.*	*John St. School.*	*B.*	*July 7, 1889.*	—
M.	*5*	*Scholar.*	*John St. School.*	*C.*	*July 4, 1889.*	*July 4*
F.	*2*	—	—	*C.*	—	*July 7*
F.	$\frac{6}{52}$	—	—	*B.*	—	—

A. Has had Scarlet-fever. *B.* Has not had Scarlet-fever.
C. Now suffering from Scarlet-fever.

The following inquiries should be made in all cases :—

1. *Patient.*—Address, name, sex, age, date of onset, date of rash, present and past isolation, probable source of infection, recent contact with infected persons or things.

2. *Household* (including patient).—Sex and age of each inmate, susceptibility (as shown by history as to previous attack), date of previous attack (if any), occupation, place of work or school, and date of last attendance thereat.

3. *Work or business carried on in the house.*

4. *Water supply* and *milk supply.*

5. *Sanitary condition* of premises and surroundings.

6. *Previous cases* of the disease in the home or in the vicinity, or at the school or work-place.

In dealing with an outbreak of small-pox, further inquiry must be made regarding the condition of each individual as to vaccination and revaccination, noting the dates.

In enteric and diphtheria cases note should be taken of the previous state of health of the patient, the duration of his residence in the house, and the occurrence of any sickness among domestic animals.

The precautionary measures to be enjoined, and if necessary enforced, must vary with the nature of the disease and the circumstances of each individual case.

Isolation of the patient. — Hospital isolation should be urged in all cases where practicable, and can be enforced under the conditions specified in section 124 of the Public Health Act (page 428). Much may be done by persuasion, by pointing out the benefit to be derived by the patient as regards nursing, food, and greater liberty during convalescence, and by explaining the protracted course of the disease, the risk of infection, and the inconvenience or impossibility of maintaining due isolation at home. There

will rarely be much difficulty in removing small-pox cases. The consent of parents to removal of a child may often be secured by allowing the mother to accompany it for a few days.

Failing removal to hospital, the arrangements for home isolation must be made as complete as possible, but in an ordinary household of the working class due isolation is impracticable, except perhaps at first. In large households it may be possible to obtain complete isolation and to maintain it throughout the illness upon the lines indicated below.

(i) *Arrangement of the sick room.*—The patient should be kept in one or more rooms, preferably at the top of the house, or in a detached wing, exclusively set apart for his use. A fire should be kept burning for the sake of ventilation and destroying waste material, even when not required for heating purposes. It tends to secure an indraught at the door, but provision must be made for the constant entry of fresh air by the window or other ventilator. The door must be kept shut. A sheet is often hung outside the door, and is useful in some ways; but little is gained by wetting it with "disinfectant" solutions, since any infected air which might escape would pass under or round it rather than through it. No one except the persons in actual charge of the patient should be allowed to enter the room. No one should leave the room without washing their hands and changing their outer garments. No food should be taken out of the sick room, nor any clothing or utensils without previous disinfection. Any effluvia in the room should be prevented or removed by free ventilation; and, if necessary, the air may be "sweetened" by the moderate use of sanitas, thymol, chloride of lime, or other deodorant, in the form of spray, or solution exposed in open dishes; but reliance should not be placed upon deodorants alone, nor

should they be regarded as disinfectants. In other parts of the house they serve no useful purpose whatever.

(ii) *Disinfection during the illness.*—A plentiful supply of 1 per 1,000 mercuric chloride solution (or 10 per cent. carbolic solution) should be provided. Disinfection of excreta and secretions may be attempted by adding an equal bulk of the solution, which may with advantage be placed in the vessel before receiving the excreta. Old linen should be used in place of pocket-handkerchiefs, and thrown into the fire. Linen, etc., requiring washing should be thrown into a large vessel filled with the disinfectant solution; such articles should subsequently be rinsed in water before washing, to remove the disinfectant. All utensils should be similarly disinfected before leaving the room.

(iii) *Final disinfection at the end of the case.* (*a*) All linen, cotton, and silk articles, which can be removed, should be boiled for ten minutes, but exception must be made in respect of certain dyed fabrics and other special articles; (*b*) all movable textile materials which cannot be boiled—including blankets and other woollen materials, beds, pillows, mattrasses (not, of course, spring mattrasses), curtains, hangings, carpets, rugs, etc., must be removed and disinfected by steam or by hot air in default of steam; (*c*) the remaining articles must be laid as open as possible, and the room fumigated by sulphurous acid or chlorine; (*d*) all furniture and other movable articles should be taken out into the open air, and brushed, washed, or beaten; (*e*) the walls, ceiling, floor, and all surfaces must be swept or washed, especial attention being given to crevices and corners. It is an additional safeguard to strip off the paper, and to limewash the ceiling and walls.

None of these precautions can safely be omitted

when a patient suffering from small-pox, scarlet-fever, diphtheria, typhus, measles, whooping cough, mumps, rötheln, or varicella, is kept in a household that contains susceptible persons. In enteric fever, however, the infection appears to be limited to the excretions, with little or no tendency to aërial diffusion, and a less rigid isolation may suffice if strict attention is paid to the disinfection of everything that has been in contact with the patient, especially bedding, clothing, and other articles that almost inevitably become infected.

Quarantine.—If the patient is removed to hospital and disinfection properly carried out, it is only necessary to keep the household under observation for the maximum period of incubation of the disease in question. If the case is treated at home, the household must be kept under a certain degree of quarantine until the last case has ceased to be infectious and the final disinfection has been completed.

During the quarantine period no children from the house should be allowed to attend school, but this restriction may be relaxed if the case is one of enteric fever. The same exclusion should be insisted upon as regards certain occupations, notably milk traffic, nursing, washing, and businesses involving the handling of food; and this is especially important when the work in question is carried on in the house. Tailoring and all forms of seamstress's home-work should be forbidden. Strict injunctions should be given against admitting persons, especially children, into the infected house, but there is no power to enforce this by law, or to inflict punishment in case of default. Exposure of infected persons or articles in any public place is, however, dealt with under section 126 of the Public Health Act. As regards small-pox, the quarantine should be rigidly enforced, and no member of an infected household should be

allowed to follow his business until the period of danger is over.

In some towns quarantine stations are provided, and are usually attached to the isolation hospitals. The sick person having been removed to hospital, free lodging is offered to the rest of the household during the quarantine period, and meanwhile the house and its contents are thoroughly disinfected. This plan has been generally adopted in Leicester in cases of small-pox, and its utility is obvious.

In all these matters, and especially in the removal of the patient to hospital, due consideration must be given to the opinion and advice of the medical attendant by whom the case has been notified.

Caution bills may be left at the house, explaining in simple language the precautions that are necessary, and the penalties attending neglect of them. The bills should include directions as to isolation and disinfection, and instruction to report immediately any further cases. It is convenient also to leave a post-card addressed to the Medical Officer of Health, to be signed by the medical attendant when in his judgment the period of infection is at an end, and final disinfection of the premises is needed.

Disinfection should always be carried out under the direction of the sanitary staff at the end of the case, but disinfectants may be supplied gratuitously by the Sanitary Authority for use during the illness. Clothing and all movable articles should either be boiled at home, or removed to a disinfecting station and treated by steam or hot air; rooms, and articles that cannot be removed, should be disinfected in the manner described on page 380.

When the patient is removed to hospital the premises may be disinfected at once, but the occurrence of any later case will, of course, necessitate a repetition of the process.

Home cases offer more difficulty. The final disinfection cannot usefully take place until after the end of the infectious stage, as determined by the written certificate of the medical attendant or the judgment of the Medical Officer of Health. It is desirable, in order to prevent misunderstanding, to fix a minimum interval between onset and final disinfection, which in scarlet-fever should not be less than six weeks, and to explain this and the reasons for it upon the printed notices left at the house.

Sanitary defects must be remedied, and any clue or even suspicion as to milk or water infection must be followed up at once. It may be necessary to communicate with employers or other persons, if there is reason to anticipate neglect of due precautions against conveying infection.

In outbreaks of small-pox it is necessary to provide for immediate vaccination or revaccination, and to urge it not only upon the inmates of the infected house, but also upon all who have been in contact with the patient, and upon his neighbours and fellow workmen.

Schools and infectious diseases.—The following Memorandum, issued by the Medical Officer of the Local Government Board in December, 1890, conveys the views of the highest authorities upon a subject that often presents considerable difficulty to medical officers of health.

"1. It is attempted in these notes to bring together the information in the possession of the Local Government Board, derived from the reports of the Board's own Medical Inspectors and of local Medical Officers of Health, respecting school-closure and exclusion from school as precautions against infection. It is sought to indicate the best means of preventing the spread of disease by school children among their fellows, while avoiding any unnecessary interruption of the work of education.

"2. 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.'

"3. 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.

"4. It will be seen that Article 88, quoted above, confers upon Sanitary Authorities an alternative power

* There are special considerations that have to be borne in mind in regard to diphtheria. Conditions of school-aggregation alone seem occasionally to intensify the virulence of the type of this disease. (*See* chapter xii.)

† Small-pox has only a small incidence upon children of school age, under ordinary conditions of infant vaccination, but in districts where vaccination is now neglected it has occasionally been found necessary to close schools on account of prevalence of small-pox. Typhus is now happily so rare that it scarcely needs to be mentioned in this connection.

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.

"5.—(A) *First as to exclusion from school of particular scholars.*—Here it will be convenient to consider the circumstances under which the requirements of the public health will be satisfied by the less severe measure of the exclusion from school of particular children.

"(*a*) It may be laid down as a universal principle that all children suffering from any dangerous infectious disorder (*i.e.* of a nature dangerous to some of the persons attacked by it, however mild in other cases) should be excluded from school until there is reason to believe that they have ceased to be in an infectious condition. (*See* section 126 of the Public Health Act, 1875.)

"(*b*) Furthermore, as it is rarely possible to provide effectual separation of the sick from the healthy within the homes of children of the class attending public elementary schools, it must commonly be necessary that all children of an infected household should be excluded from school; first, because otherwise such children might attend school while suffering from the disease in a latent form, or at an unrecognised stage, and, secondly, because it is known that infection may attach itself to, and be conveyed by, the clothes of a person living in an infected atmosphere, even though the person himself remain unaffected. The same considerations will sometimes make it desirable to prohibit the attendance at school of all children from a particular street or hamlet.

"In the case of infectious diseases involving little or no danger to life, such as mumps* or skin diseases,

* The same considerations apply also to chicken-pox.

school interests may be more particularly considered. In such case, however, the rule of prohibiting the attendance of every child while in an infectious state will commonly prove to be the right one; for if disease should spread to other scholars owing to the continuance of an infected child at the school, there will be greater ultimate loss of attendance with corresponding loss of credit to the school.

"6.—(B) *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 mere fact that in an epidemic many of the sufferers are school children does not necessarily show that the disease was caught at school; but the school may with probability be regarded as spreading infection if in a large majority of households attacked the first case be a child attending school; and with still greater probability if a number of children living at a distance from one another, and with no circumstances in common, except that they attend the same school, should be simultaneously attacked, and if it can be ascertained that a child or teacher in an infectious state has actually been attending the school.

"7. 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. Absence of any child from school on the plea that it is suffering under one of the before mentioned diseases, and absence of several children of one family from school at the same time, no matter what name be given to the complaint that keeps them at home, should be reported to the health officer. In practice it has been found that this notification of absentees has materially aided the local health officer in taking measures for the suppression of infectious disease, to the advantage alike of the district and of the school. Furthermore, schoolmasters may properly be asked to take note, especially when an epidemic threatens or is present, of symptoms occurring in any of their scholars that may indicate the commencement of disease, febrile in nature. Besides heat of skin, such symptoms are shivering, headache, and languor, especially if commencing suddenly; vomiting, rashes on the skin, and sore throat. When scarlet-fever or diphtheria is about, every trace of sore throat should be looked upon as suspicious. In any case where such symptoms are observed, the safest course will be to exclude the child from school until assurance can be

* It is well always to send a second notice when the infection is at an end and the quarantine is terminated. Copies of these notices may with advantage be sent to the School Board authorities, in order that the school attendance officer may not in the meantime press the parents to send the children to school.

had that it may attend school without harm to itself or danger to other scholars.

"8. 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 of Health, who may properly be entrusted with some general duty of acting for the authority in this subject matter.

"Medical officers of health, having to specify a time during which any scholars are to be excluded from attendance at any school, should have regard, as far as practicable, to the circumstances of the particular scholars suffering from infectious disease or living in infected households. Not only the nature of the infection and the length of illness, but the environments of the individual as affecting the retention of infection, will deserve consideration. The period of exclusion, for example, will need to be different according to the conditions of a patient's lodgment, according to the sufficiency of the separation that can be effected between a patient and excluded scholars, and according to the opportunities of effectual disinfection that can be afforded to the household. Thus a hard and fast rule, such as has been laid down in some districts where scarlatina has been present, that no child shall go to school from an infected house for three months after the disease has begun in that house, is not to be commended. It is indeed possible that under the circumstances of a particular household, a child convalescent from scarlatina, or living in the same house with convalescents, should not in the interests of other children be permitted to return to school until after so long a period as this; but the same ought not to be assumed of all households in the district that may be invaded by scarlatina. The better plan would be for the sanitary authority to secure, during a shorter period, the

exclusion of individual sick persons and their housemates from school; and when that period is about to expire, to cause fresh inquiry to be made as to the expediency of further exclusion, and, if found requisite in particular cases, to cause fresh notice to be given to the school managers.

"9. In deciding whether an outbreak of infectious disease among children of school age may be best combated by closing the 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.

"10. The more prompt and full the knowledge of cases of infectious disease that the sanitary authority are able to obtain, the better will be the prospect of checking such disease by keeping away from school the children of infected households, and the less will be the necessity for closing schools. If the cases be few in number, and their origin known, the exclusion from school of the children of infected households will probably suffice, but this measure will fail where there are many undiscovered or unrecognised cases, or where the known centres of infection are peculiarly numerous.

"Commonly, the failure of carefully considered measures of exclusion to stay the spread of an epidemic which shows a special incidence upon school children, may be regarded as pointing to the continued attendance at school of children with the prevalent disease in a mild or unrecognised form, and a strong case will appear for the closing of schools.

"If by the reason of the absence or exclusion of a large number of children, the attendance at a school

be greatly reduced, it may be found better to close it altogether. This is especially apt to occur in the case of epidemics of measles, a disease which is very infectious in the early stages, before the characteristic rash has appeared, and while the symptoms resemble those of a common cold.

"11. The second material consideration, in deciding as to the desirability of closing schools during the prevalence of infectious disease, is the amount of opportunity for intercommunication between the members of different households elsewhere than at school. In sparsely populated rural districts, where the children of different households or of separate hamlets rarely meet except at, or on their way to, the village school, the closing of the school is likely to be effectual in checking the spread of disease. It is less likely to be useful in a town or compact village (particularly where houses are sub-let and yards are in common), where the children of different households, when not at school, spend their time in playing together, and often run in and out of each other's houses.* In some such places the closing of schools has even appeared to do harm rather than good.

"In rural districts, where epidemic diseases are less frequently prevalent, school closing may be required as an exceptional measure to meet an exceptional state of things. As regards more populous places, it must not be forgotten that if schools were to be closed whenever an infectious disease was prevalent, there are many places where schools would hardly ever be open.

"It will sometimes be necessary to close a school for a day or two to allow of the rectification of sanitary

* Although the close aggregation of large numbers of children, in a confined atmosphere, for several hours daily, must be regarded as affording exceptional facilities for the introduction and diffusion of infection, even greater than those (referred to in the text) which school-attendance partially obviates.

defects of a nature to extend disease, or in order that the school may be disinfected or purified. It has happened that infectious sickness in the master's family has forbidden the attendance of scholars. These more temporary and occasional closures of schools are contemplated in the Education Code, and are to be regarded as having a real importance of their own.

"12. 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 sect. 91 (5), sect. 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.

"13. 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.

"14. 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."

The following periods of exclusion are advised by the Association of Medical Officers of Schools:—

	Quarantine to be required after last exposure to infection.	Earliest date of return to School after an Attack.
Small-pox .	18 days	When all scabs have fallen off.
Chicken-pox	18 ,,	Ditto.
Scarlet-fever	14 ,,	Six weeks, and then only if no desquamation or sore throat.
Diphtheria .	12 ,,	Three weeks, if convalescence be complete, and no sore throat, albuminuria, or discharges remain.
Measles .	16 ,,	Three weeks, if all desquamation and cough have ceased.
Whooping Cough .	21 ,,	Six weeks from the commencement of the whooping, if the characteristic spasmodic cough and whooping have ceased. Earlier, if all cough be gone.
Rötheln .	16 ,,	Two to three weeks, according to the nature of the case.
Mumps .	24 ,,	Four weeks, if all swelling have subsided.

It is understood in all cases that thorough disinfection is carried out. As a further safeguard it is desirable to insist upon a medical certificate of freedom from infection when a child returns to school after an infectious illness.

Typhus and enteric fever are not included in the list. In either, three weeks may be adopted as the period of quarantine ; and four weeks as the earliest date of return to school after an attack, if all symptoms have disappeared and convalescence is complete.

The duration of ringworm, ophthalmia, impetigo, and scabies is indefinite ; and children suffering from any of these should be rigidly excluded until all trace of the disease has disappeared.

Registers of sickness.—From the report sheets the more important details can be entered into registers, a process which involves very little cost of trouble and time, and gives a comprehensive view of the facts that cannot be attained in any other way. Each disease should have its separate register, the columns of which may be headed as follows :—

Progressive number.
District.
Address.
Name of patient.
Occupation.
Sex.
Age.
Date of onset.
,, ,, notification.
,, ,, removal to hospital.
,, ,, disinfection.
Result, and date of recovery or death.
Place of work or school.
Date of last attendance at ditto.
Milk supply.
Water supply.
Sanitary notes.
Reference to other cases.
Sequence in household.*
Medical attendant.
General notes, as to precautions, history, etc.
(Vaccination : date and character.)

If such registers are kept systematically, any suspicious grouping of cases in any given locality, or in connection with any particular water supply, milk

* That is, whether it is the first case or not.

supply, school, or workplace, cannot fail to attract attention at once.

Disease maps.—Maps showing the distribution of disease according to locality can be readily prepared from the information given in the report sheets or registers. A large-scale map is needed for crowded districts. Each disease being represented by a particular colour, a spot of this colour is placed against every house invaded by the disease in question. Each map may serve for one or more diseases, and for a whole year, or such shorter time as may be determined.

Special precautions against Cholera.—The **L.G.B.** have power under the 130th section of the Public Health Act of 1875, to make (and revoke) special regulations for the prevention of Cholera. This has been done from time to time, and the latest Cholera Regulations (1890 and 1892) have the following effect:

Every Port Sanitary Authority, or other **S.A.** within whose district persons are likely to be landed from ships "coming foreign," must appoint a place for mooring 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 three 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 **S.A.** (to the Port **S.A.** 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 **M.O.H.** has reason to believe that any ship coming or being within the jurisdiction of his **S.A.** 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. The **M.O.H.** must then examine every person on board, none being allowed to leave the ship until the examination is made. All who are found to be suffering from cholera are to be removed to the hospital or place provided by the **S.A.**, if their condition admit of it, and must not leave such place until the **M.O.H.** certifies that they are free from the disease. If they cannot be removed, the ship remains subject to the control of the **M.O.H.**, without whose written consent the infected persons cannot leave the ship. Persons certified by the **M.O.H.** 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 **S.A.**, for not more than two days, in order that it may be ascertained whether their illness is or is not cholera. No person, not certified as above, is to be permitted to land unless he satisfies the **M.O.H.** as to his name, place of destination, and address at such place; and the **M.O.H.** must give such names and addresses to the clerk of the **S.A.**, who must transmit them to the **S.A.** of the districts in question. The **M.O.H.** 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. In the event of a death from cholera on board, the master must, at the direction of the **S.A.**, either bury the body at sea, properly weighted, or deliver it to the **S.A.** for interment. 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 **M.O.H.**

Where a vessel is not infected with cholera, but has passengers on board who are in a filthy or otherwise unwholesome condition, the **M.O.H.** 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 case of persons permitted to leave an infected ship.

Orders are from time to time issued, and afterwards revoked, by the **L.G.B.** prohibiting the importation of rags, etc., from foreign infected ports, or requiring that they shall be disinfected or destroyed, to the satisfaction of the **M.O.H.** For example, one dated August 11th, 1892, forbade the landing of any "rags, bedding, or disused or filthy clothing, whether belonging to emigrants or otherwise, from any foreign port in Europe north of Dunkirk, other than ports of Norway, Sweden, and Denmark." *

* It was so modified by a subsequent Order (Jan. 11th, 1893) as to allow exemption in case of rags duly certified not to have come from any places in which cholera had been prevalent. It was next rescinded by a third Order (Aug. 5th, 1893), which substituted other regulations, namely, that "no dirty bedding, or disused or filthy clothing, whether belonging to emigrants or otherwise" (coming from specified countries), shall 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 **M.O.H.**, by steam under pressure, at a temperature not less than 212° F. In default of such disinfection within 48 hours the articles are to be destroyed. It is provided that the terms "bedding" and "clothing" shall include such articles when torn up, but not rags packed in bales and imported as merchandise.

CHAPTER XIV.

MEDICAL OFFICERS OF HEALTH.

EVERY Sanitary Authority is required (Public Health Act, 1875, sections 189, 190) to appoint one or more medical officers of health and an inspector of nuisances. Two or more Sanitary Authorities may appoint the same medical officer of health; and, apart from this, the Local Government Board is empowered (section 286) compulsorily to unite districts for the purpose of appointing a medical officer of health. County Councils are authorised, by the 17th section of the 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.

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, section 191).

Qualifications.—The orders issued by the Local Government Board require that the medical officer of health shall be registered under the Medical Act of 1858, and be qualified by law to practise both medicine and surgery in England and Wales. The powers of the Board in this respect are practically superseded by the Local Government Act, 1888, section 18 of which requires that (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 shall be legally qualified for the practice of medicine, surgery, and midwifery; and further, by

the same section, he must, if appointed after the 1st of January, 1892, to a district having at the last census 50,000 inhabitants or more, appear in the Medical Register as the holder of a diploma in Sanitary Science, Public Health, or State Medicine 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 (according to 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.—The Local Government Board have no control over the tenure of office unless a portion of the salary is repaid to the Sanitary Authority.* If the **M.O.H.** be appointed under the latter condition, he 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 or resign, or be removed by such Authority with the consent of the Local Government Board, or by the Local Government 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 the power to remove the suspension. If a Sanitary Authority desire to change the duties or salary of an officer (or any change be made in the extent of the district), and he decline to acquiesce therein, they may give him six months' notice to determine his appointment, but only with the consent of the Local Government Board.

Salary.—This is only controlled by the Local Government Board in cases as above; the salary has

* These contributions, amounting to half the salary, are now paid by County Councils on the certificate of the Local Government Board, if claimed by the Sanitary Authority, and if copies of the reports have been duly received by the Board and by the County Council.

then to be approved by the Local Government Board, and with the consent of this Board a reasonable compensation may be paid by the Authority on account of extraordinary services or other unforeseen or special circumstances in connection with his duties or the necessities of the district.

Duties.—The duties of medical officers of health as prescribed by the Local Government Board are the same whether a contribution is made to the salary or not, except that in the latter case the officer is obliged to report his appointment within seven days to the Local Government Board.

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 a copy of all annual and other reports which the medical officer of health 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 alary which otherwise they would be liable to pay.

The following duties are prescribed by the Board's Order of March, 1891, for every medical officer of health appointed or reappointed after that date:—

(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 byelaws and regulations as they may have power to make, and as to the adoption by the **S.A.** 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 the spot without delay, 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 **S.A.**

(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 **S.A.,** 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, carcase, 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 byelaws 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 byelaws 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 **S.A.**

(14) He shall also make an annual report to the **S.A.** up to the end of December in each year, comprising a summary of the action taken, or which he has advised the **S.A.** to take, 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 any statute, 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, to dairies, cowsheds, and milkshops, 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.* Provided that if the **M.O.H.** shall cease to hold office before December 31st in any year, he shall make the like report for so much of the year as shall have expired when he ceases to hold office.

(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 report and of any special report. He shall make a special report to the **L.G.B.** of the grounds of any advice he may give to the **S.A.** with a view to the closure of any school or schools, in pursuance of the Code of Regulations approved by the Education Department, and for the time being in force.

(16) At the same time that he gives information to the **L.G.B.** of the outbreak of infectious disease, or transmits 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 any instructions issued by the **L.G.B.**, and 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, 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 closely parallel

* *See* Appendix.

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, 1855, on that behalf, as the circumstances of the case may justify and require . . . . . When any vessel within his district has had dangerous infectious disease on board, he shall give notice thereof to the M.O.H. of any port within the United Kingdom whither such vessel is about to sail."

The substances of Clauses 4, 5 (omitting the reference to the Infectious Disease Prevention Act), 9, 11, 12, 13, 14 (omitting the reference to trades, etc.), 15 (omitting the reference to schools), 17, and 18, of the duties of Medical Officers of Health, are applicable to Port Medical Officers of Health, *mutatis mutandis*.

The duties of county medical officers of health have not yet been authoritatively defined.

Annual reports.—The following instructions have been issued by the Local Government Board :—

"Every Medical Officer of Health appointed under the order of the Local Government Board is required to make an annual report with regard to each sanitary district, or division of a district, which is under his superintendence. This report is to be for the year ending the 31st of December, or, if the officer at that date has not been in office for a whole year, then for so much of the year as has elapsed since his appointment. The report is to be made to the Sanitary Authority, and a copy of it is to be sent to the Local Government Board by the Medical Officer of Health. It should be made as soon as practicable after the expiration of the year to which it relates. The Medical Officer of Health ought not, in general, to have any difficulty in doing this within a month or six weeks; but if from any special circumstances the report cannot be completed within six weeks, it should be understood that the delay must not be indefinite, and that the report, complete or incomplete, should be in the hands of the Sanitary Authority within, at most, three months from the end of the year. The Board's copy of the report should be forwarded to them when the original is sent to the Sanitary Authority, except where the report is likely to be printed by order of the Authority. In such cases the Board need only be supplied with a printed copy. But in all cases in which the report cannot be sent to the Board within six weeks from

the end of the year, they should be informed by the Medical Officer of Health of the reason for the delay. . . . The report should be chiefly concerned with the conditions affecting health in the district, and with the means for improving these conditions. It should consider these subjects with reference to the future as well as to the past, and the account (directed by section 14) of the sanitary state of the district generally at the end of the year, should, while marking the point that has been reached in the sanitary state and administration of the district, indicate directions for further consideration and action. The sanitary history of the year under review should include a record alike of the proceedings of the Medical Officer of Health himself and of the proceedings taken under his direction or advice. And the tabular statements of sickness and mortality in the district during the year, to be made on the forms supplied for the purpose, should be the subject of comment in the text of the report, in so far as deductions from them may assist the Sanitary Authority to an appreciation of the lines of action needful in the future.

"The Medical Officer of Health, in reporting his proceedings and advice, will find it advantageous to follow in the main the order in which the subject matters of his duty appear in the several paragraphs [of the Order of March, 1891], and herein special care should be taken in reporting on the subject of section 3. Not only the fact of having made systematic inspections, but the outcome from those inspections, should be duly put on record. They are inspections independent of such inquiries as, under other articles of the Order, the Medical Officer of Health has to make into particular outbreaks of disease, or into unwholesome conditions to which his attention may have been specially called by complaints or otherwise; and the object of these systematic inspections is that

he may assure himself that he is well acquainted with all the discoverable circumstances which are likely to affect the public health in his district. How often these inspections require to be made, and how detailed the inquiries should be, must be determined by the particular circumstances of the locality. In some neighbourhoods a house-to-house inspection should, as far as practicable, be made; in others this may not be needful; but every Medical Officer of Health should at certain times set himself to examine into the state of his district, devoting some time to each portion of it, so as to be sure that no part escapes his notice. Of these inspections, of the judgment he has formed thereon as to the sanitary state of his district, and of the advice he has in consequence given to the Sanitary Authority, and the action taken by the Authority thereon, the annual report should contain a full account. In making such systematic inspection, as in much of his other action, the Medical Officer of Health will usually require the assistance of the Inspector of Nuisances; and it will be for the Medical Officer to include in his report an account of the action which, at his instance, the Inspector may have taken for the removal of nuisances injurious to health.

"As regards the tabular statements of sickness and mortality, only one observation appears to be needful. The district under the superintendence of a Medical Officer of Health will often contain several parts evidently differing in their circumstances, or having very different rates of mortality—either of mortality from all causes, or of mortality from some particular disease or class of diseases. The observation of these differences can scarcely fail to lead to valuable information, and it is in view of such differences that the tabular statements are required in section 14 to be classified according to *localities*, and the provision for such a classification is made in the

forms supplied for returns of deaths. In the absence of any ascertained differences of the above sort it will still be desirable to classify the deaths of the district according to the part of the district in which they occur; and for this purpose any areas of known population (such as parishes, groups of parishes, townships, or wards) may be taken as representing 'localities' for the purposes of the Order. Classification on this basis will be likely to lead to the discovery of real differences when the returns for several years can be compared together.

"What has been said above with regard to the information which an annual report should contain must be understood, not as suggesting that the report should be limited to these subjects, or that more detailed or differently arranged tabular statements may not be added, but as indicating the minimum of information which will satisfy the requirements of the Board's Order. Many Medical Officers of Health will doubtless, with great advantage to the administration of their district, furnish much more information than this minimum, and this will give prominence to particular questions to which they have been led by the circumstances of the foregoing year to devote attention, or in the investigation of which they may have arrived at valuable conclusions. Any information of this kind will be appreciated by the Local Government Board."

Statistical Tables.—Two tabular forms, A and B, for statistics are issued by the Local Government Board, and must be filled up by the Medical Officer of Health, and appended to his annual report. They are given *in extenso* in the Appendix.

Further statistical details are necessary in regard to large populations, and for purposes of comparison it is most important that these should be given upon a uniform basis. Unfortunately there are still

many dissimilar forms in use, each of them having certain advantages, but perhaps the most convenient and useful series of tables is that issued by the Society of Medical Officers of Health. These tables are comparable both with the Registrar-General's returns, and those of the Local Government Board. They will be found in the Appendix.

The Annual Report is intended not merely for the guidance of the Sanitary Authority, but for the information of the Local Government Board, the County Council, and others who may not possess any detailed knowledge of the local conditions such as the Sanitary Authority is presumed to have. It is desirable, therefore, to state in every report, year after year, such facts as may suffice to make it a record of the existing sanitary state of the district, and not merely the sanitary history of the year.

The report should give, in brief outline, information upon the following points, in addition to those already mentioned :—

General character of the district as regards geology, configuration, and urban or rural condition.

Streams passing through the district, and their condition as regards pollution.

Water supply ; source, character, sufficiency.

The chief industries of the district, and their effect as regards river pollution, smoke nuisances, or the health of persons employed.

Modes of excrement disposal and scavenging, and their efficiency.

Disposal of household and other refuse.

Sewerage of the district ; its extent, construction, ventilation, and flushing. Treatment of sewage.

House drainage ; whether trapping and disconnection are general.

Burial grounds ; whether sufficient for present and immediate future requirements.

Isolation hospital; whether any available, and, if so, its position, accommodation afforded, and terms of admission. Cases of each disease admitted during the year.

Disinfecting apparatus; whether any provided, and of what construction.

Notification of infectious diseases; whether in force, and what diseases (if any) are added to the schedule. Classified statement of cases notified during the year.

Byelaws in force in the district; list of subjects, stating whether Model Byelaws or other, and whether satisfactory or not; also their date.

Other regulations in force in the district; nature of such regulations.

Canal boat inspection; whether any navigable water in the district, and whether the Authority is a Registration Authority. Number of inspections, and of boats registered.

Regulated buildings and trades; number and condition of (*a*) common lodging-houses, (*b*) "tenement" lodging-houses, (*c*) slaughter-houses, (*d*) bakehouses, (*e*) dairies, (*f*) cowsheds, (*g*) milkshops, (*h*) offensive trades.

Dwellings of the poorer classes; general condition as regards habitability, repair, dryness, ventilation, overcrowding; proportion of back-to-back houses; closet accommodation; drainage; paving of yards, etc.

The record of the year should also include a statement of the legal proceedings instituted by the Authority, and of their result; also of the action taken under the Sale of Food and Drugs Acts, the Housing of the Working Classes Acts, the Canal Boats Acts, etc. Meteorological data should be given if possible, and a note may be made of any prevalence of epizootic or epiphytic disease. Vaccination is not under the supervision of the Sanitary Authority, but

the latest available figures should be included in the Health Report.

Sources of information.—*Returns of registered deaths* should be obtained weekly from each of the registration sub-districts within the area.* These returns should give, as regards every death registered during the week, the name, age, sex, residence, and occupation of the deceased, the nature and duration (so far as stated on the certificate of cause of death) of each primary and secondary cause of death, and the name of the certifying practitioner. "Immediate notice should be given of all deaths from infectious disease in fresh localities, and all groups of deaths from such disease, or from diarrhœa, in any localities" (*L. G. B. Memorandum, dated June*, 1882). A fee of twopence for each return and twopence for each entry is payable by the Authority. Returns should also be obtained from the registrars, at weekly, monthly, or quarterly intervals, of the births registered in such intervals; these returns should distinguish between males and females, and between legitimate and illegitimate births. Deaths of non-residents in the locality must, of course, be distinguished from the rest, and the necessary indications for this purpose should be given in the returns. Arrangements must be made separately for information of the deaths in distant public institutions of residents in the locality.

* "Every registrar, when and as required by a Sanitary Authority, ... shall transmit by post or otherwise a return, certified under the hand of such registrar to be a true return, of such of the particulars registered by him concerning any death as may be specified in the requisition of the Sanitary Authority. The Sanitary Authority may supply a form of the prescribed character, for the purpose of the return, and in that case the return shall be made in the form so supplied. The registrar making such returns shall be entitled to a fee of twopence, and to a further fee of twopence for every death entered in such return, which fee shall be paid by the Authority requiring the return." (*Births and Deaths Registration Act*, 1874, *section* 28.)

Returns of pauper sickness.—An order of the Local Government Board, dated February 12th, 1879, requires all district and workhouse medical officers appointed after February 28th, 1879, to furnish the Medical Officer of Health with returns of pauper sickness and deaths, and to notify the outbreak of any dangerous infectious disease. The same is required (by an order dated June 14th, 1879) of medical officers of district schools appointed after June 24th, 1879. The Guardians should be asked to instruct their clerk to copy from the district medical officer's relief lists the new cases which are reported at each meeting of the Guardians, and to forward the same promptly and regularly to the Medical Officer of Health; and to instruct the Poor Law medical officers to give to the Medical Officer of Health the earliest possible information of cases of dangerous infectious disease under their charge.

Cases of dangerous infectious disease occurring on canal boats or in common lodging-houses (chapter xv.) must be reported to the Medical Officer of Health; and the Sanitary Authority have power to make byelaws requiring notification of such diseases in "tenement" lodging-houses, and in vans or tents.

Maps.—A good map is essential. It should show the boundaries of the district, and of each of its sub-divisions (whether parishes, townships, registration sub-districts, special drainage districts, or other) which have a bearing upon sanitary administration, and also the main sewers and water-mains. Maps showing the geology of the district, the contour lines, and the different watersheds, should be obtained, if possible. Maps showing the local distribution of disease and mortality have already been referred to.

Periodical reports, etc.—The annual and quarterly reports of the Registrar-General are indispensable.

The annual summaries and weekly returns deal only with the statistics of the large towns. Reports of the inspectors of the **L.G.B.** affecting any part of the district should, of course, be obtained.

Acts of Parliament.—In addition to any local Acts in force in the district, and those mentioned in chapter xv., the Medical Officer of Health should be familiar with any other Acts which the special circumstances of his district may render important, *e.g.* the Alkali Act. Lumley's or Glen's *Public Health Acts*, and Glen's *L.G.B. Sanitary Orders* are valuable for reference.

Byelaws and regulations.—The byelaws and regulations in force in the district can readily be obtained, and are not less important than the preceding.

Census data.—The Medical Officer of Health should be in possession of all the information regarding his district given by each census taken since its formation.

Arrangements should, if possible, be made at the time when the census is taken to obtain a record of the particulars regarding each "enumeration district" for the use of the Sanitary Authority. The enumeration districts are the smallest subdivisions for census purposes, and a knowledge of the population of such small areas is most valuable, as enabling the Medical Officer of Health to determine accurately the relative incidence of disease or death in relation to the population in any given part of the district. This information can only be obtained with the consent of the Registrar-General, and by local arrangement, and, of course, only at the time of the census.

It is desirable to keep registers showing for each village or hamlet the dates and particulars of every death, and of every notified case of infectious disease. In towns this would take the form of a "street register." If cases of disease as well as deaths are

entered, they may be distinguished by red ink. Registers of notified diseases have already been referred to. Registers of all deaths occurring among certain trades will greatly facilitate any future investigation which the Medical Officer of Health may have to make into the influence of those trades upon mortality.

The seemingly formidable records mentioned above, if well arranged in the first instance, and systematically kept, involve much less labour than would appear at first sight. They are invaluable in inquiries regarding the incidence of mortality and disease upon any given locality or occupation, and materially simplify the preparation of the annual report.

Duties of Sanitary Inspectors.—The work of the Sanitary Inspector (or "Inspector of Nuisances") is closely connected with that of the **M.O.H.,** but the broad lines separating them will be apparent from the following definition of the inspector's duties, formulated by the **L.G.B.**

"(1) He shall perform, either under the special directions of the **S.A.,** or (so far as authorised by the **S.A.**) under the directions of the **M.O.H.,** 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 **L.G.B.,** so far as the same apply to his office.

"(2) He shall attend all meetings of the **S.A.** 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

byelaws or regulations made by the **S.A.** for the suppression of nuisances, he shall, as early as practicable, visit the spot, and inquire into such alleged nuisance or breach of byelaws or regulations.

"(5) He shall report to the **S.A.** any noxious or offensive businesses, trades, or manufactories established within the district, and the breach or non-observance of any byelaws or regulations made in respect of the same.

"(6) He shall report to the **S.A.** 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 butcher's 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, carcase, 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 **M.O.H.**, with the view of obtaining his advice thereon.

"(8) He shall, when and as directed by the **S.A.**, 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 other proceedings prescribed by that Act.

"(9) He shall give immediate notice to the **M.O.H.** 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 **M.O.H.** thereof.

"(10) He shall, subject to the directions of the **S.A.,** attend to the instructions of the **M.O.H.** 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 **S.A.,** 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 **S.A.,** 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 **S.A.** may require.

"(12) He shall, at all reasonable times, when applied to by the **M.O.H.,** 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 **S.A.** 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 **S.A.** 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 **S.A.**, and the Orders of the **L.G.B.** which may be hereafter issued, applicable to his office."

CHAPTER XV.

SANITARY LAW.

UNDER this heading it is proposed to give a summary of the principal Acts of Parliament bearing upon public health questions, and more especially of those Acts which define the powers and duties of Sanitary Authorities and Medical Officers of Health.

The following abbreviations will be used :—**S.A.** for Sanitary Authority, **L.G.B.** for Local Government Board, and **M.O.H.** for Medical Officer of Health.

Public Health Act, 1875.

[*Sanitary Districts.*—Under the 1875 Act, the whole of England, except the Metropolis, consists of Urban and Rural Sanitary Districts, under the jurisdiction respectively of Urban and Rural **S.A.'s** (section 5). Urban districts include (*a*) *Boroughs*, (*b*) *Local Government Districts*, and (*c*) *Improvement Act Districts* constituted prior to the passing of the Act. The **S.A.'s** for such districts are respectively (*a*) the Corporation ; (*b*) the Local Board; and (*c*) the Improvement Commissioners (section 6). That portion of the area of a Union which is not included in any Urban District constitutes a Rural Sanitary District, and the guardians representing that part of the union are the Rural **S.A.** (section 9). These arrangements are greatly modified by the operation of the Local Government Act of 1894 (Appendix IV., page 564), which creates Urban and Rural District Councils.]

Sewers, except certain private sewers, are vested in the **S.A.** of the district (section 13). The **S.A.** may purchase (section 14) or construct (section 15) sewers. They must provide such sewers as are necessary for effectually draining their district (section 15). Powers are given by section 27 for the treatment and disposal of sewage. 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).

House drainage.—If any house is without a sufficient drain the **S.A.** *must* require the owner or occupier to provide a drain, and may prescribe the materials, size, and levels. This drain 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 **S.A.** may direct. Failing compliance, the authority may carry out the works. No house in an urban district must be built or occupied until proper covered drains have been constructed to the satisfaction of the **S.A.** The **S.A.** may make regulations as to the mode in which connections between drains and sewers are to be made. Upon giving due notice, and complying with such regulations, the owner of any premises is entitled to carry drains into the public sewers (sections 21—25).

Excrement and refuse disposal.—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 **S.A.**, who may require a separate closet for each house (sections 35—36). The **S.A.** may order the provision of separate closets for each sex in factories, etc., where both sexes are employed. Urban **S.A.'s** may provide public closets, urinals, or receptacles for refuse (sections 39, 45). Every **S.A.** must see that all drains, closets, ashpits, and cesspools are properly constructed and kept (section 40).

On written complaint that any drain, closet, ashpit, or cesspool is a nuisance, the **S.A.** may authorise their officer to enter the premises (after giving twenty-four hours' notice, except in case of emergency) and open the ground ; if any defect is found, the **S.A.** must

serve notice upon the owner or occupier; but if there be no defect, the **S.A.** must close the ground and make good any damage.

Scavenging and cleansing.—The **S.A.** *may*, and when required by order of the **L.G.B.** *shall*, themselves undertake or contract for the removal of house refuse, the cleansing of earth-closets, privies, ashpits, and cesspools, and cleansing of streets (section 42). In that case they are liable to penalty for any delay exceeding seven days after written notice from any householder.

Cleansing of Houses.—If the **M.O.H.** or two medical practitioners certify that any house or part thereof is so filthy as to endanger health, or that the whitewashing, cleansing, or purifying thereof would tend to prevent infectious disease, the **S.A.** may require the owner or occupier to cleanse, etc., and in his default may themselves do what is necessary (section 46).

It is unlawful in an urban district to keep swine in any dwelling-house, or so as to be a nuisance, or to suffer any waste water to remain within any dwelling-house for twenty-four hours after written notice from the **S.A.**, or to allow the contents of any water-closet, privy, or cesspool to overflow or soak therefrom. In case of default, the **S.A.** must abate such nuisance (section 47).

An inspector of nuisances in an urban district may give notice to the owner of any accumulation of offensive matter, or to the occupier of the premises whereon it exists, and if not removed within twenty-four hours, it becomes vested in the **S.A.** to be disposed of by them (section 49). An urban **S.A.** may give public notice requiring the periodical removal of manure or other refuse matter from stables or other premises and enforce the same under penalty (section 50).

Water supply.—Any **S.A.** may * construct works for supplying any part of their district with water; or may hire or purchase such works, or contract for a supply (section 51); and may require houses to be supplied with water when they are without a proper supply, 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 **L.G.B.** may, upon application, determine to be reasonable in the circumstances (section 62).

Heavy penalties are incurred by persons polluting any stream, pond, etc., with gas washings (section 68), and a local authority may proceed against any one polluting any watercourse with sewage (section 69). A justice's order may be obtained for the closing of a well or cistern, the water of which is used, or likely to be used, for drinking or domestic purposes, when the water is so polluted as to be injurious to health, and the court may cause the water to be analysed at the cost of the **S.A.** (section 70).

Cellar dwellings.—No cellar built or rebuilt since 1848 (the date of a previous Act) can be separately occupied as a dwelling; nor any cellar whatever, unless it comply with the following requirements:

(*a*) The height must in every part be at least seven feet, three 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 in. 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 wording here is permissive; but *see* pages 434-5.

The window of a back cellar let or occupied along with a front cellar need only be 4 square feet in area (sections 71—73).

Any one passing the night in a cellar is deemed to occupy it (section 74).

*Common lodging-houses.**—The **S.A.** are required to keep a register of common lodging-houses, and to make byelaws in respect of them (sections 76—80). It is unlawful to keep a common lodging-house unless it be registered (section 77), and this can only be done after it has been inspected and approved (section 78). The keeper when required is to affix notice of registration to the house.

When the lodging-house is without a proper supply of water, and this can be furnished at a reasonable rate, the **S.A.** may enforce it (section 81). The keeper is required to limewash the walls and ceilings in the first week of April and October of every year (section 82). The **S.A.** may require the keeper of a house in which beggars or vagrants are received, to make returns of persons who have slept there the previous night (section 83), and the keeper must always give notice to the **M.O.H.** and to the Relieving Officer of any case of infectious disease (section 84).

Houses let in lodgings.—Any **S.A.** may make byelaws respecting houses let in lodgings or occupied by members of more than one family (section 90, modified by section 8 of the Housing of the Working Classes Act, 1885).

Nuisances.—(Section 91.) The following are nuisances. (1) Any premises † in such a state as to be a nuisance or injurious to health. (2) Any pool,

* 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 inns, or lodgings let to the middle or upper classes.

† Including *buildings*, or *lands*.

ditch, gutter, watercourse, 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 work-place, 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

* "'Drain' means any drain of and used for the drainage of one building only, or premises within the same curtilage . . . ." A sewer is a drain receiving the drainage of two or more buildings.

† There is no penalty if the accumulation or deposit 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.

‡ Including schools, and also factories and other buildings in which persons are employed.

§ It is customary to adopt the standards as to air-space prescribed by the Model Byelaws, viz. 300 cubic feet per head, counting two children as one adult. In the event of a second conviction for overcrowding within three months, the justice may order the closing of the premises for any period (section 109).

‖ The provisions of this sub-section 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 Factory and Workshop Acts.

private dwelling-house) sending forth black smoke in such quantity as to be a nuisance.*

[Later Acts have extended the definition of "nuisances" given in section 91. Thus tents and vans so filthy or overcrowded as to be a nuisance or injurious to health (Housing of the Working Classes Act), and even dangerous quarries within fifty yards of a public highway, and not fenced off from it (Quarry Fencing Act, 1887), are nuisances liable to be dealt with summarily, in the manner provided by the Public Health Act.]

Procedure in respect of nuisances.—It is (1) the duty of the **S.A.** to cause to be made from time to time an inspection of their district, with a view to ascertaining what nuisances exist, but (2) the **S.A.** may be put in motion by any person aggrieved, or by any two inhabitant householders of the district, or by any officer of the **S.A.**, or by the Relieving Officer, or by any officer of the police. (3) If satisfied as to the existence of a nuisance, the **S.A.** must 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 it, and to execute such works and do such things as may be necessary. Where the nuisance arises from the want or defective construction of any structural convenience, or where there is no occupier, 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 local authority may abate the nuisance without further order. (4) If the person on whom the notice

* There is no penalty if the Court is satisfied that such 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 having the charge thereof.

is served fails to comply with its requirements, or if the nuisance, although abated, is likely to recur, the **S.A.** may apply to a justice, who shall summon the person responsible, and may make an order requiring him to comply with the notice, or prohibiting the recurrence of the nuisance, and directing the execution of any works necessary. The Court may further impose a penalty (sections 92—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 rescind 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 due diligence, is liable to penalty; and the **S.A.** 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 executed by the **S.A.** Any matter or thing removed by the **S.A.** in abating any nuisance may be sold. Where a nuisance within a district is caused by some act or default beyond its limits, the **S.A.** may, nevertheless, institute proceedings (section 108).

Ships.—Any ship or vessel lying in any water within the district of any **S.A.** 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 may be prescribed by the **L.G.B.**, and in the absence of such prescription then within the nearest district (section 110).

Right of entry upon private premises. — The **S.A.** and their officers have rights of entry between 9 a.m. and 6 p.m., and in the case of a nuisance

* This section originally brought ships under those provisions of the Act that relate to *nuisances* only; but the Public Health (Ships) Act, 1885, extended its scope to include also infectious diseases and hospitals (sections 120, 121, 124, 125, 126, 128, 131, 132, and 133).

arising in respect of any business, at any hour when such business is in progress. If admission be refused a justice's order may be obtained (sections 102 and 103).

Offensive trades.—It is illegal to establish an offensive trade within the district of an urban **S.A.** without their consent. The offensive trades are: blood-boiler, bone-boiler, fellmonger, soap-boiler, tallow-melter, tripe-boiler, any other noxious or offensive trade, business, or manufacture (section 112). An urban **S.A.** may make byelaws with respect to such trades as have been established with their consent,* to prevent or diminish nuisance arising therefrom (section 113). If the Medical Officer of Health, or two medical practitioners, or ten inhabitants, certify that any of the following places are a nuisance, or injurious to health, the **S.A.** must take proceedings against the offender, who is liable to penalty, unless he can show that he has used the best practical means for abating such nuisance, or preventing, or counteracting such effluvia. The premises in question are: candle-house, melting-house, melting-place, soap-house, slaughter-house, 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 (section 114). The same powers are applicable in the case of nuisance affecting the inhabitants of a district, but resulting from premises situated beyond the limits of the district.

[As regards the prohibition (section 112) of the establishment of any given trade without the consent of the Local Authority, it is incumbent upon the prosecuting authority to show that the trade is either one of those specifically mentioned above, or *ejusdem generis* with them; that is, that it is necessarily an

* As this consent only became necessary in 1848, the byelaws can only apply to trades established since that date.

offensive trade apart from neglect or mismanagement. 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. Nevertheless, a very large number of trade processes to which the above restriction may be considered inapplicable will come within the scope of the 114th section, if it can be shown that they are carried on so as to give rise to effluvium nuisances.]

Unsound food.—The **M.O.H.** or Inspector of Nuisances may, at all reasonable times, examine any animal,* carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk, exposed for sale, or deposited for the purpose 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, who may order it to be destroyed, and inflict a penalty upon the offender. The proof that it was not intended for the food of man rests with the person charged (sections 116, 117). Any person obstructing is subject to penalty (section 118). On complaint made on oath a justice may grant a search warrant to the Medical Officer or Inspector.

[It will be noted that eggs, butter, cheese, and other important articles of food, are not mentioned specifically, and are, therefore, not included in the scope of this (or any other) section of the Act. No proceedings can be taken in regard to articles already sold. Both these defects in the present Act are avoided in the Public Health Amendment Act of 1890, and in the Public Health (London) Act, 1891.]

Infectious diseases.—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 diseases, it is incumbent on the

* Living animals can be seized under this section.

S.A. to serve notice upon either the owner or occupier, requiring him to cleanse and disinfect. A penalty is incurred by default, and the **S.A.** may do what is necessary and recover the costs, or may undertake this duty in the first instance, with the consent of the occupier, at their own cost (section 120). The **S.A.** may destroy infected bedding, clothing, or other articles, and give compensation (section 121); may provide a disinfecting apparatus and disinfect free of charge (section 122); may provide an ambulance and pay expenses of conveyance of infectious person 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 **S.A.** 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

* This detail is omitted as superfluous in the London Act of 1891; but lodgment in a tent or van is made *per se* a reason for removal.

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 the contents disinfected to the satisfaction of a medical practitioner as testified by a certificate signed by him, is liable to penalty (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).

Special Regulations of L.G.B.—The **L.G.B.** may make regulations for the treatment of persons affected with cholera, or any other epidemic, endemic, or infectious diseases, 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 three miles of the coast thereof, as on land, and may declare by what Sanitary Authorities such regulations shall be enforced and executed (section 130). Cholera Regulations have been issued under this section (chapter xiii.).

Furthermore, whenever any part of England appears to be threatened with, or is affected by, any formidable epidemic, endemic, or infectious disease, the **L.G.B.** may make, and from time to time alter or revoke, regulations for any of the following

purposes, viz. 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 **S.A.**, 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 (section 134). The **S.A.'s** are required to do everything that is necessary to carry out these regulations.

Hospitals.—Any **S.A.** may build or contract for the use of hospitals for their district. Two or more **S.A.'s** may combine for this purpose (section 131). The **S.A.** may recover from a patient, who is not a pauper, the cost of his maintenance (section 132). The **S.A.** may with the sanction of the **L.G.B.** themselves provide or contract for a temporary supply of medicine and medical assistance for the poor of their district (sect. 133). (*See* also Appendix III., pp. 562-3.)

Mortuaries.—Every **S.A.** *may*, and, if required by the **L.G.B.**, *must*, provide a mortuary, and may make byelaws with respect to its management and charges for its use. They may also provide for the decent and economical interment, at charges to be fixed by such byelaws, of any dead body which may be received into a mortuary. A justice may, on a certificate signed by a practitioner, order to be removed to a mortuary, at the cost of the **S.A.**, (1) 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 (2) 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 **S.A.** may provide a place for the post-mortem examination ordered by a coroner.

New streets and buildings.—In urban districts all public streets (*i.e.* those reparable by the inhabitants at large) are vested in the **S.A.**, who *shall* cause them to be levelled, paved, and repaired, as occasion may require (section 149). The owners of property abutting on any private street or part of a street may be required by the (urban) **S.A.** to level, pave, sewer, light, or make good such street or part of a street; and in case of default the **S.A.** may carry out the work and recover the expenses from the owners according to the frontage of their respective premises (section 150). An urban **S.A.** may make byelaws with regard to new streets and 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 (section 159).

*Dangerous structures.**—The surveyor of an urban **S.A.**, 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. (Towns Improvement Clauses

* These and some of the following provisions are not to be found in the text of the Public Health Act, but in the incorporated portion of the Towns Improvement Clauses Act.

Act, sections 75—78, incorporated with the Public Health Act by section 160 of the latter.)

Rain-pipes and eaves-gutters.—An urban **S.A.** may 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, section 74; Public Health Act, section 160.)

Slaughter-houses.—An urban **S.A.** may provide abattoirs or slaughter-houses, and if they do so must make byelaws with respect to management and charges (section 169). 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, *i.e.* in 1875. Every place used as a slaughter-house or knackers' yard shall be registered by the owner or occupier in a book kept by the Sanitary Authority. An urban **S.A.** *must* make byelaws in regard to slaughter-houses and knackers' yards. 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 byelaws or regulations made under this 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. (Sections 125 to 130 Towns Improvement Clauses Act, incorporated in the Public Health Act by virtue of section 169.)

A legible notice bearing the words Licensed Slaughter-House or Registered Slaughter-House must be attached and maintained in some conspicuous place on every registered slaughter-house by the owner or occupier (section 170).

Combination of sanitary authorities for appointment of Medical Officer of Health.—The **L.G.B.** may (compulsorily or otherwise) unite two or more districts situated wholly or partially in the same county, for

the purpose of appointing a Medical Officer of Health ; but no urban district with more than 25,000 inhabitants shall be included without the consent of the **S.A.**, and in the event of any **S.A.** objecting to being included, the **L.G.B.** can only include their district by means of Provisional Order subject to confirmation by Parliament (section 286).

A **S.A.** may delegate all or any of its powers to a committee of its own members (sections 200 and 201) ; and a rural authority may form parochial committees consisting wholly or partially of its own members, and may give to such committees certain limited sanitary functions (section 202). (*See* Appendix IV., p. 564.)

Urban powers for rural districts.—The **L.G.B.** may give to a rural **S.A.**, as regards the whole or part of their area, any powers and responsibilities conferred by this Act upon urban **S.A.** (section 276).

Special drainage districts.—A rural **S.A.** may, with the consent of the **L.G.B.**, constitute any portion of their area a *special drainage district* for the purpose of charging thereon exclusively the expenses of works of sewerage, water supply, or other works which may be declared by the **L.G.B.** to be *special expenses*, and thereupon such area shall become a *separate contributory place* (section 277). The **S.A.** have also power to declare expenses which they have incurred to be *private improvement expenses*, and to charge a special *private improvement rate* in respect thereof upon the estate benefited (sections 213 and 232).

Union of districts for sanitary purposes.—Joint boards may be formed, by order of the **L.G.B.**, for the purpose of water-supply or sewerage, or for other purposes of the Public Health Act, as applied to a district comprising the whole or parts of two or more sanitary districts (section 279). Under this section joint Hospital Boards may be formed.

Default of **S.A.**—If satisfied, after due inquiry

that any **S.A.** have made default in providing or maintaining sewers, or in providing and maintaining a supply of pure water,* or in enforcing any provisions of the Public Health Act which it is their duty to enforce, the **L.G.B.** shall make an order limiting a time for the performance of their duty in the matter. If such duty is not performed in the time allowed, the order may either be enforced by writ of *mandamus*, or the **L.G.B.** may appoint some person to perform the work, and charge all expenses to the authority in default (section 299).

[The 7th section of the Housing of the Working Classes Act, 1885, has a wider scope.]

Port Sanitary Authority.—The **L.G.B.** may, by order, constitute any **S.A.** whose district abuts upon any port in England, the **S.A.** for the whole or for any part of such port. The Board may also combine two or more riparian authorities for the purpose; or may constitute one Port **S.A.** for any two or more ports. The Authority may be constituted permanently or temporarily. The order constituting the Authority may assign to it any of the powers or duties of an Urban **S.A.** so far as applicable to a Port **S.A.**, and to vessels, waters, or persons within its jurisdiction—namely, 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 (byelaws), 189 (appointment of **M.O.H.** and inspector of nuisances), and other sections.†

* "In cases where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply of water, and a proper supply can be got at a reasonable cost."

† The powers and duties of a Port **S.A.** and its officers consist primarily of those conferred by such of the specified portions of the Public Health Act as the particular Order may decide. They are extended by the Cholera Regulations (chapter xiii.), and the Order prescribing the duties of the Port **M.O.H.** A ship comes within the definition of "house" for many purposes (page 425).

The **Public Health (Water) Act, 1878,** applies to every Rural **S.A.,** and also to such Urban **S.A.** as the **L.G.B.** may order (sections 3 and 11). Every Rural **S.A.** shall see that every occupied dwelling-house within their district has, within reasonable distance, an available and sufficient supply of wholesome water. If the **M.O.H.** reports that an occupied house is without such supply, and the **S.A.** 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 or threepence per week, as the **L.G.B.** may, on the application of the **S.A.,** determine to be reasonable in the circumstances), the **S.A.** may require the owner (subject to appeal to the **L.G.B.**) to provide such supply within a specified time, and, in case of default, may themselves carry out the necessary works at his expense. It remains, however, the duty of the **S.A.** to provide any part of their district with a supply of water, in cases 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 reasonable cost (section 3).

The owner of any dwelling-house in a rural district that may be erected or rebuilt from the ground-floor after the date of this Act, shall not permit such house to be occupied without a certificate from the **S.A.** that it is provided with a sufficient and available supply of wholesome water; such certificate to be based on the report of the **M.O.H.** or inspector (section 6). If the **S.A.** provide a stand-pipe for water-supply, they may levy water charges upon every dwelling within 200 feet, as if the supply were given on the premises; not, however, upon such houses as have a good supply within reasonable distance, from another source, unless water from the stand-pipe is used by the inmates (section 9).

Every Rural **S.A.** must, through their officers or otherwise, provide for the periodical inspection of the water-supply of their district. 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).

Sale of Food and Drugs Act, 1875.—This Act defines "food" as including every article used by man for food or drink, except water and drugs; and "drug" as including medicine for external as well as internal use (section 2). "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 . . . ." (section 3). "No person shall, except for the purpose of compounding, ... mix, colour, stain, or powder (or permit any other person to mix, colour, stain, or powder) any drug with any ingredient or material so as to affect injuriously the quality or potency of such drug, with intent that the same may be sold in that state; and no person shall sell any drug so mixed, coloured, stained, or powdered . . . " (section 4). The penalty for such injurious admixture is a fine not exceeding £50 for a first offence; subsequent offences are misdemeanours, punishable by imprisonment with hard labour for a period not exceeding six months. No liability is, however, incurred if the accused person can show that he was unaware of the admixture, and could not, with reasonable diligence, have ascertained it (section 5).

"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 sale (section 8).

"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" (section 9). 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 every district a competent person may be (and, if required by the **L.G.B.,** must be) appointed as Public Analyst* (section 10); and any person shall be entitled to have any drug or article of food purchased by him in such district analysed by the public analyst on payment of a sum not exceeding 10s. 6d., and to receive from him a certificate of the result of the analysis (section 12). The **M.O.H.,** inspector, or constable, charged by the **S.A.** with the execution of the Act, may procure samples of food and drugs, and submit them to the public analyst (section 13). 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. He shall retain one of the three parts for future comparison, and deliver the third to the public analyst (section 14). If the seller do not accept the offer of division, the analyst must divide the article into two parts, and seal up and deliver one of them to the purchaser

* The appointment is made by the Town Council of any borough having a separate Court of Quarter Sessions, or a separate police establishment. The County Council appoints the Public Analyst for all parts of the county not included in the above. All appointments and re-appointments are subject to the approval of the L.G.B.

(section 15). Samples may be sent to the analyst by registered parcel post, if his residence is two miles from that of the purchaser (section 16). Any person refusing to sell to an officer of the **S.A.** 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 a prescribed form (section 18), and 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).

Sale of Food and Drugs Act Amendment Act, 1879. —This amending Act was passed in order to settle certain points upon which the 1875 Act was found to be insufficiently explicit.

"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 **M.O.H.**, inspector, or constable charged with the execution of the Act, may 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" (section 3). "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).

The **Margarine Act, 1887,** 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 (section 3). Every package or parcel of margarine must be so marked, in large letters of specified minimum size (section 6). All margarine factories must be registered with the **S.A.** 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 which are 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 substance not being marked as margarine is 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, viz. 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. The penalty for a first offence is a fine not exceeding £20.

Sale of Horseflesh, etc., Regulation Act, 1889.—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 horseflesh is sold there. If otherwise, the **M.O.H.** or inspector may seize the meat and carry it before a magistrate, who may order as to its

disposal as he thinks fit; and the offender is liable to penalty. These conditions apply to such flesh cooked or uncooked, and alone or mixed with other substances. It is illegal to supply horseflesh for human food to a purchaser asking for other meat, or for a compound article not usually made of horseflesh.

The Rivers Pollution Prevention Act, 1876, deals separately with (*a*) solid matters, (*b*) sewage, (*c*) trade effluents, (*d*) mining effluents.

(*a*) No solid refuse of any kind must be put into any stream, so as to interfere with its due flow or to pollute its waters (section 2).*

(*b*) No solid or liquid sewage matter must be passed into any stream; but as regards conditions in existence prior to 1876 no offence is committed under this Act if it is shown that the best practicable and available means are being used to render harmless the sewage entering the stream (section 3).

(*c*) No poisonous, noxious, or polluting liquid from any factory or manufacturing process must be passed into any stream. The saving clause as to conditions existent prior to 1876 is repeated here (section 4).

(*d*) No solid matter from mines must be put into any stream so as prejudicially to affect its flow; nor must any poisonous, noxious, or polluting solid or liquid matter from mines be passed into any stream, other than water in the same condition in which it has been raised or drained from such mine (section 5).

Proceedings may be instituted, in respect of pollution of streams by sewage or solid matters, by any private person or **S.A.** aggrieved (section 8); but in respect of manufacturing or mining effluents **S.A.'s** only can take action, and subject to the approval of the **L.G.B.** The Board, in giving or withholding consent, shall have regard to the industrial interests involved, and the circumstances and

* *See* also Public Health Amendment Act, 1890.

requirements of the locality. They shall not give their consent to proceedings by the **S.A.** 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). Any person interested may call the attention of the **S.A.** to pollution by manufacturing or mining effluents, and, if the **S.A.** refuse to move, may appeal to the **L.G.B.**, and the Board may, after due inquiry, direct the Authority to take proceedings (section 6).

The **S.A.** must afford facilities for admitting trade effluents into sewers, unless they would prejudicially affect the sewers, or interfere with the disposal of the sewage, or be injurious in a sanitary point of view, from their temperature or otherwise; or unless the sewers are only large enough for the ordinary requirements of the district (section 7).

[The fourteenth section of the Local Government Act, 1888, confers upon County Councils the powers of **S.A.'s** under the Rivers Pollution Prevention Act; and enables the **L.G.B.** to form a joint committee representing all the administrative counties through or by which a river, or any specified portion of a river, or any tributary thereof passes, and to confer upon the joint committee all or any of the powers of a **S.A.** under the Act.]

The results of this Act have been disappointing, owing partly to the inefficiency of the machinery provided, partly to the complicated but indefinite restrictions imposed in respect of trade pollution, but chiefly, perhaps, to the absence of sufficiently strong public opinion upon the subject. Few Sanitary Authorities have been in a position to take proceedings against others, being themselves for the

most part offenders against the Act, but still a large and now rapidly increasing number of districts have—voluntarily or under pressure—dealt with their sewage. Many methods are now available for the treatment of sewage at moderate cost, in such manner as to deprive it of most, if not all, of its impurities, leaving an effluent which may be passed into streams without material ill effect. As to trade pollutions comparatively little has been done. The difficulties, both legal and sanitary, are far greater than in respect of domestic or town sewage.

A short explanatory Act (R. P. P. Act, 1893) removes a technical difficulty liable to be raised by sanitary authorities who sought to evade their responsibilities under section 3.

Canal Boats Act, 1877.—The term "canal" includes all navigable waters, tidal or otherwise, within the body of a county, and the term "canal boat" includes every vessel, however propelled, used for conveyance of goods along such waters, but does not include a ship registered under the Merchant Shipping Act, unless the **L.G.B.** orders otherwise. No canal boat must be occupied as a dwelling unless it is registered under this Act, and then only by the number of persons of the age and sex for which it is registered (section 1). The registration authority must be a **S.A.** whose district abuts on the canal on which the boat is intended to ply; and the boat must be registered as belonging to some place which is within the said district, and which is also within a school district (section 7). 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 persons allowed to dwell in the boat. The master of the boat must carry one of these certificates. Every registered

boat must have conspicuously painted upon it the registered number, the place to which it belongs, and the word "registered" (section 3). If any person on a canal boat is suffering from an infectious disease, the **S.A.** of the place where the boat is shall adopt such precautions as appear necessary, upon the certificate of the **M.O.H.** or other legally qualified practitioner; and may remove such sick person and exercise the other powers conferred by the Public Health Act in this respect; and may detain the boat as long as is necessary for cleansing and disinfecting (section 4). If any person duly authorised by the **S.A.** 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 of the boat to afford him facilities for so doing, and to produce the certificate of registry of the boat (section 5).

The second section directs the **L.G.B.** 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.

Such regulations were accordingly issued by the **L.G.B.** in 1878, and the following is a summary of their principal sanitary provisions:—

There must be at least one dry, clean, and weatherproof 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 three 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 four 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 **S.A.** of the district through which the boat may be passing, and also to the **S.A.** of the place of destination; he must also inform the owner, who is required to notify to the **S.A.** of the place to which the boat belongs. If the boat is detained by the **S.A.** for purposes of disinfection, the **S.A.** must obtain a medical certificate that the boat has been cleansed and disinfected, and must give it to the master.

The Canal Boats Act, 1884, amends the 1877 Act in certain details, and makes it incumbent upon every **S.A.** through whose districts any canal passes to enforce the provisions of the Act and Regulations, and to make an annual report upon the subject to the **L.G.B.** The Board is required to make inquiries from time to time (by an inspector or inspectors specially appointed for the purpose) as to the working of the Acts and Regulations, and to report annually thereon to Parliament.

The Factory and Workshop Acts, 1878, 1883, and 1891, form a rather complicated body of legislation, the effect of which is to make the **S.A.** primarily responsible for the sanitary condition of "workshops," the supervision over "factories" (except as regards drainage and closet accommodation) being in the hands of Factory Inspectors under the Home Office. The broad line of distinction between the two classes of workplaces is the use of mechanical power. Factories comprise all in which power is used, and also the following, whether power is used or not: —blast-furnaces, copper-mills, iron-mills, foundries; manufactures of earthenware, lucifer matches, percussion-caps, cartridges, tobacco, paper, glass; paper-staining, fustian-cutting, printing, book-binding.

Factories 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 a 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. The Factory Inspector has power to require the provision of fans or other mechanical appliances if necessary for preventing inhalation of dust by the workers. If the Home Secretary certifies that any particular process or kind of

work is dangerous to the life or health of the workers, 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. (*See* Appendix VII., page 571.) All ceilings, walls, passages, and staircases must be limewashed every fourteen months; but the Home Secretary may grant exemption. He may also make special regulations as to cleanliness and ventilation which he may consider necessary for the protection of the health of children, young persons, or women employed at night or overtime.

Workshops, in addition to the requirements of the Public Health Act, 1875, must be kept free from effluvia arising from drains, closets, urinals, or other nuisances. Upon certificate from the **M.O.H.** or Inspector that cleansing, limewashing, or purifying is necessary for the health of the workers, the **S.A.** must give notice to the owner or occupier; if he makes default he incurs a penalty, and the **S.A.** may carry out the work and recover expenses. The Factory Inspector must give notice to the **S.A.** of any sanitary defect he may meet with in any factory or workshop or laundry (except such defects in a factory as he can deal with under the Factory Acts); and if after such notice the **S.A.** fail to take the necessary steps, he may act in their stead, and charge the expenses to them. Further, the Home Secretary (if satisfied that there is default on the part of the **S.A.**) may authorise Factory Inspectors to enforce the sanitary provisions of the law in respect of any class of workshops or laundries, and to recover expenses from the **S.A.**

The **M.O.H.** must give written notice to the Factory Inspector if he becomes aware that any "child" (under 14), "young person" (14 to 18), or woman is employed in any workshop. The 1891 Act prohibits

the employment in any factory or workshop of children under 11 years of age, and of women within four weeks after confinement.

One class of factories or workshops, namely bakehouses, is under special legislation. The 1878 Act required that in places having more than 5,000 inhabitants at the last census, the ceilings, walls, staircases, and passages of every bakehouse must be limewashed every six months, or painted every seven years, and washed with soap and hot water every six months; and further, that 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. The 1883 Act made it illegal to let or occupy as a bakehouse any place not so occupied before June 1st, 1883, except under the following conditions :—

(*a*) No water-closet, earth-closet, privy, or ash-pit 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.

The Cotton Cloth Factories Act, 1889, applies especially to factories in which the humidity is artificially increased for trade purposes. Notice of the adoption of such practice must be given to the Chief Inspector of Factories. 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 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.

The Alkali, etc., Works Regulation Act, 1881, applies not only to alkali works, but also to the manufacture of sulphuric acid, nitric acid, chlorine, bleaching-powder or liquor, sulphate or muriate of ammonia, and chemical manure. All these must be registered, and are under the supervision of special inspectors appointed by the **L.G.B.**

In alkali works 95 per cent. of the HCl gas evolved must be condensed, and not more than one-fifth of a grain of HCl 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 SO^3 per cubic foot. Acid drainage must not be allowed to mix with alkali waste so as to cause nuisance. The owner may require the **S.A.** 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 Act. Alkali waste must not be deposited or discharged without the best practicable and available means being used to prevent nuisance.

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 SO^3 per cubic foot. The other works scheduled also must employ the best practicable means for preventing the escape of noxious and offensive gases, and for rendering them harmless and inoffensive.

In pursuance of powers conferred by this Act, the **L.G.B.** in 1884 prescribed special precautions against

the discharge of acid and noxious fumes, to be observed in salt (brine) and cement works.

An Amending Act, passed in 1892, brings under the operation of the Act venetian red works, lead deposit works, arsenic works, nitrate and chloride of iron works, muriatic acid works, fibre separation works (wherein HCl is used to separate silk or wool from cotton fibres), tar works, and zinc works. The following also are included, unless the process adopted be such that no sulphuretted hydrogen is evolved :—alkali waste works, barium and strontium works, antimony works, and bisulphide of carbon works.

The Dairies, Cowsheds, and Milkshops Order of 1885 was issued by the Privy Council in pursuance of the thirty-fourth section of the Contagious Diseases (Animals) Act of 1878. In 1886 an amending Act was passed (C.D.A. Act, 1886), transferring to the **L.G.B.** the powers of the Privy Council under this section ; and an amending Order was issued by that Board (D.C. and M. Amending Order, 1886) substituting the Board for the Privy Council in the provisions of the former Order, and remedying certain omissions in regard to penalties. The effect of the two Orders is to throw upon every urban and rural **S.A.** 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 **S.A.** may arm itself with further powers by making Regulations under section 13, having the force of byelaws. The chief provisions of the Orders are summarised below :—

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 **S.A.** shall keep a register of such persons, and shall from time to time revise and correct

the register. (3) The **S.A.** 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 **S.A.** 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 and 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 **S.A.**, 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 **S.A.**

Section 8. It shall not be lawful 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 **S.A.** 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 **S.A.** under this Order :— (1) Every regulation shall be published by advertisement in a newspaper circulating in the district of the **S.A.** (2) The **S.A.** shall send to the **L.G.B.** 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 **L.G.B.** 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.

Housing of the Working Classes Act, 1885. —"It shall be the duty of every Local Authority entrusted with the execution of laws relating to public health and local government, to put into force from time to time, as occasion may arise, the powers with

* Where a minimum cubic space is specified for cowsheds in such Regulations, the **L.G.B.** have suggested 800 cubic feet per head, but in many districts a lower standard has been adopted.

which they are invested, so as to secure the proper sanitary condition of all premises within the area under the control of such Authority" (section 7).

A tent, van, shed, or similar structure, used for human habitation, 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 (section 9). A **S.A.** may make byelaws 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 **S.A.** or by a justice of the peace, if such person has reasonable cause to suspect any contravention of this Act or of any byelaws made under it, or that there is in such habitation any person suffering from any dangerous infectious disease (section 9).

Housing of the Working Classes Act, 1890.—Part I., superseding Cross's Acts, deals with unhealthy areas, and is applicable in urban sanitary districts only. It is the duty of the **M.O.H.** to make an official representation to the **S.A.**, whenever he sees cause to do so, that within a certain area either (*a*) any houses or courts are unfit for habitation; or (*b*) the bad arrangement or condition of the streets or houses, or the 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 rearrangement and reconstruction of some or all of the streets or houses. The **S.A.** must consider this 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. The scheme may exclude any

part of the area, or include any neighbouring lands. It must provide for proper sanitary arrangements, and may provide for widening the approaches, or otherwise opening out the area. Due publicity having been given to the scheme in a specified manner, application is to be made to the "confirming authority" for a provisional Order. The Confirming Authority (the Home Secretary, as regards the metropolis; the **L.G.B.** elsewhere) directs a local inquiry to be held respecting the correctness of the official representation and the sufficiency of the scheme. The provisional Order, if granted, is subject to confirmation by Parliament. It may modify the scheme, and must determine the extent of the provision to be made for the working classes displaced. 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. 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.

Upon complaint by two justices of the peace, or

twelve ratepayers, the **M.O.H.** must inspect and report upon any area. If he fails to do so, or reports that it is not an unhealthy area, such ratepayers may appeal to the Confirming Authority, who may then appoint a medical practitioner to inspect the area. If the latter reports that it is an unhealthy area, the **S.A.** are required to prepare an improvement scheme. In any case, if the **S.A.** 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.

Part II. (replacing Torrens' Acts) applies to rural as well as urban districts, and relates to unhealthy or obstructive dwellings. It is the duty of the **M.O.H.** to represent to the **S.A.** any dwelling which appears to him to be in a state dangerous to health so as to be unfit for human habitation; but the **S.A.** are also required to cause inspections of their district to be made from time to time for the same purpose. If satisfied that any dwelling is unfit for habitation, the **S.A.** must first take proceedings against the owner for the closure of the house, as directed by the Public Health Act, 1875. (*See* page 425.) If the closing order of the court is not terminated by a further order, the **S.A.** may proceed to make an order for the demolition of the premises; but before doing so must afford the owner an opportunity of stating his objections. There is an appeal to Quarter Sessions. Upon written complaint from four or more house-holders that any dwelling is unfit for habitation, the **M.O.H.** must inspect such house, and report to the **S.A.** If the **S.A.** (not being a rural **S.A.**, or in the county of London) fail to take action within three months, the complainants may appeal to the **L.G.B.**, who may, after local inquiry, order the **S.A.** to proceed.

Obstructive Buildings.—If the **M.O.H.** finds that any building—though not in itself unfit for habitation

—by its proximity to other buildings, either (*a*) stops ventilation, or otherwise conduces to make them unfit for habitation, or (*b*) prevents the proper remedy of any nuisance or other evils in respect of such other buildings, he must make a representation to the **S.A.**, stating that in his opinion the obstructive building should be pulled down. A similar representation may be made by any four or more inhabitant householders. In either case the **S.A.** must make inquiry as to the facts, and as to the cost of acquiring the land and pulling down the building. If they decide to proceed, the **S.A.** can make an order for the demolition of the building, after giving the owner an opportunity of stating his objections, and subject to appeal to Quarter Sessions. The compensation to be paid by the **S.A.** to the owner, and also the amount recoverable by the **S.A.** from the owners of the houses benefited by the demolition, are settled by arbitration in case of dispute.

The **S.A.** may 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 Part II., if it appears 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. Such schemes require confirmation by provisional Order of the **L.G.B.** after a local inquiry, and with or without modification. The Order may require provision to be made for the accommodation of persons of the working-classes displaced. When an official representation has been made under Part II., or a closing order obtained, a rural **S.A.** must forward a copy to the County Council, and report from time to time all further proceedings. The same applies to all Vestries and District Boards in the county of

London. If it appears to the County Council that a closing order should be applied for, or an order for demolition made, and if the Local Authority, after due notice from the County Council, fails 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. Except in boroughs, a representation by the county **M.O.H.,** if forwarded by the County Council to any **S.A.,** has, for the purposes of Part II., the same effect as if made by the **M.O.H.** of the district.

In the county of London, Part I. is entrusted to the County Council, and Part II. primarily to the District Authorities. In the event of doubt, the Secretary of State has to decide under which part of the Act a given area shall be dealt with. But the County Council may prepare schemes under Part II. if they think fit, and may apply to a Secretary of State to order a contribution from the District Authority, who, in like manner, if they proceed, may apply for a contribution from the County Council.

Part III. authorises the **S.A.** to provide lodging-houses for the working classes, subject to the sanction of the **L.G.B.** as regards urban authorities, and of the County Council in rural districts; and to make byelaws respecting such houses. The administration of this part of the Act in the county of London is vested in the County Council.

The administration of Parts I., II., and III. in the district of the City of London is vested in the Commissioners, and the County Council have no jurisdiction in this area.

Part IV. contains supplemental provisions, of which the following is important:—"In any contract made after August 14th, 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."

Local Government Act, 1888.—The sanitary provisions of this important Act are few. Besides the powers in respect of pollution of streams conferred upon County Councils by the fourteenth section (page 442), and the provisions as to the appointment and qualifications of County and other Medical Officers of Health contained in the seventeenth and eighteenth sections (page 397), only the following require mention here :—

A County Council may, subject to the approval of the **L.G.B.,** make byelaws in relation to the whole or any specified part of their county (boroughs always excepted *) for various purposes, including the prevention and suppression of nuisances not already punishable in a summary manner by virtue of any Act in force throughout the county (section 16).

Every **M.O.H.** for a district in any county shall send to the County Council a copy of every periodical report,† of which a copy is, for the time being, required by the regulations of the **L.G.B.** to be sent to the Board; and if the **M.O.H.** fail to send such copy, the County Council may refuse to pay any contribution towards his salary. If it appear to the County Council from any such report that the Public Health Act, 1875, has not been properly put in force within the district to which the report relates, or that any other matter affecting the public health of the district requires

* Boroughs have the same power under the twenty-third section of the Municipal Corporations Act, 1882.

† The new Regulations of the **L.G.B.** require the **M.O.H.** to furnish the County Council with copies of special as well as annual reports. (*See* page 403.)

to be remedied, the Council may cause a representation to be made to the **L.G.B.** on the matter (section 19).

County Councils have now certain powers under the Housing of the Working Classes Act, and they have, of course, power to make formal or informal representations to the **L.G.B.** or other controlling authority, upon any matter.

"Adoptive" Acts.—The three following Acts are "adoptive," at the discretion of the **S.A.** :—Infectious Diseases Notification Act, 1889 (*see* chapter xiii.); Infectious Diseases Prevention Act, 1890; Public Health Amendment Act, 1890.

The Public Health Amendment Act, 1890, is an "adoptive" Act, of which Part III. is concerned with sanitary matters. Urban **S.A.'s** may by resolution adopt any part of the Act; rural Authorities can adopt those powers which are not expressly limited to urban districts, and as regards the rest, can apply to the **L.G.B.** for full urban powers in the same manner as under the 1875 Act.

The following are the chief provisions of Part III.

Sewers.—It is unlawful to pass into any drain or sewer (*a*) any substance which may injure it or impede the flow of its contents; or (*b*) any chemical refuse, or waste steam, or water or other liquid heated above 110° F., which either alone or in combination with sewage causes a nuisance or is dangerous to health.

Closets, etc.—Where any sanitary convenience is used in common by the occupants of two or more houses, any person fouling or injuring it is liable to penalty; and if nuisance arises from want of cleanliness of any part of it or of the approaches, each of the persons having the right of use is liable to penalty, in the absence of proof as to which of them is in default. Sufficient and suitable sanitary conveniences must be provided in all workshops and manufactories; with

separate accommodation for each sex, where persons of both sexes are employed.

Byelaws.—Urban **S.A.'s** may make byelaws respecting public sanitary conveniences provided by them. Section 157 of the 1875 Act is extended so as to enable any urban **S.A.** to make further byelaws 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 byelaws respecting closets and drainage may be made applicable to old as well as new houses. Similar power of framing byelaws respecting buildings (under section 157 as amended) is given to rural **S.A.'s,** but with certain exceptions. [Apart from this the **L.G.B.** can, as already stated, grant full urban powers to rural Authorities.] Any **S.A.** may make byelaws to prevent buildings erected in accordance with byelaws from being altered in such a way that if at first so constructed they would have contravened the byelaws.

An urban **S.A.** may make byelaws respecting the carriage through the streets of offensive matter or liquid, prescribing (*a*) certain hours for such removal, (*b*) proper construction and covering of the receptacle used for the removal, and (*c*) the cleansing of any place fouled by matters dropped or spilled.

Any **S.A.,** themselves undertaking or contracting for the removal of house-refuse, may make byelaws imposing upon the occupier duties in connection with such removal.

Polluted sites.—No new building may be 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. 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 ash-pit, it is illegal to occupy it, or suffer it to be occupied, as a dwelling-place, sleeping-place, work-room, or place of business.

Cleansing of common passages.—If in an urban district any private court or passage, leading to the back of several buildings separately occupied, is not regularly and effectually swept and kept clean, the **S.A.** may cause it to be swept and cleaned, and recover the expenses from the occupiers.

Pollution of streams by solid refuse.—It is forbidden "to throw or place . . . . in any . . . . watercourse within any district in which this part of this Act is adopted, any cinders, ashes, bricks, stone, rubbish, dust, filth, or other matter which is likely to cause annoyance."

Food.—Sections 116—119 of the 1875 Act are extended so as to apply to "all articles intended for the food of man, sold or exposed for sale, or deposited in any place for the purpose of sale, or of preparation for sale." The justice may condemn any such article and order it to be destroyed, if satisfied that it is diseased, unsound, unwholesome, or unfit for the food of man, even if it has not been formally seized under § 116.

Slaughter-houses.—Licences granted after the adoption of this Act are to remain in force only for such period, not being less than a year, as the **S.A.** shall specify in the licence. Every change of occupation of a licensed slaughter-house must (under penalty) be notified in writing to the inspector of nuisances; and notice of this requirement must be endorsed on all new licences. If the occupier of any licensed slaughter-house is convicted under sections 116—119 of the 1875 Act, the court may revoke the licence.

Common lodging-houses.—A penalty is imposed

upon the keeper if he fails to give notice of any case of infectious disease, as required by section 84 of the 1875 Act (page 422).

The Act does not apply to London.

The Infectious Diseases Prevention Act, 1890, is another adoptive or optional Act; and any extra-metropolitan **S.A.** may by resolution adopt all or any of its sections, and may by further resolution rescind them. For London its leading provisions are merged in the Public Health (London) Act. The infectious diseases to which this Act applies are those specified in (or added to) the Infectious Diseases Notification Act. The principal provisions are as follows:—

Milk supplies.—If the **M.O.H.** has reason to believe that the consumption of milk from any dairy* (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 consumption of the milk, he must report to the **S.A.,** forwarding also any report furnished to him by the veterinary surgeon. The **S.A.** may then give not less than 24 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 **S.A.** and the County Council of the district in which the dairy is situate, and to the **L.G.B.** The order must be forthwith withdrawn on the **S.A.** or the **M.O.H.** being satisfied that the milk

* Including any farm, farmhouse, cowshed, milk store, milk-shop, or other place from which milk is supplied or in which it is kept for the purpose of sale.

supply has been changed, or that the cause of infection has been removed. Penalties are provided for contravention of this section of the Act.

Disinfection.—Where the **M.O.H.** or any registered medical practitioner certifies that the cleansing and disinfection of any house, or part thereof, and of any articles therein, would tend to prevent infection, the **S.A.** may, after 24 hours' notice to the owner or occupier, proceed to carry out such disinfection or cleansing, unless within that time he informs the **S.A.** that he will, within a period fixed in the notice, himself carry out the work to the satisfaction of the **M.O.H.** If he fail to do this within the specified period, it is to be done by the officers of the **S.A.**, under the superintendence of the **M.O.H.**, 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. Where the section is adopted, the 120th section of the Public Health Act, 1875, is repealed.

The **S.A.** may, by written notice, require (under penalty) any infected clothing or other articles to be delivered to their officer for disinfection. The **S.A.** must take away, disinfect, and return such articles free of charge, and, in the event of any unnecessary damage, must compensate the owner.

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, (*a*) 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 (*b*) must give to the owner notice of the previous existence of such disease; and (*c*) 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 are provided in each case. The **S.A.** must give notice of the provisions of this section to the occupier of any house in which they are aware there is a person suffering from an infectious disease.

Prompt interment.—The body of a person who has died of any infectious disease must not, without a certificate from the **M.O.H.** or a registered medical practitioner, be retained for more than 48 hours else where 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 **M.O.H.**, order the body to be removed by the **S.A.** 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 **M.O.H.** or a registered 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.

Detention in hospital.—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 **S.A.**) for any specified period, and such period may be extended as often as necessary.

The **S.A.** shall 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 **S.A.**

Infectious rubbish must not be thrown into any receptacle for refuse without previous disinfection. Notice of this prohibition must be served by the **S.A.** upon the master of any house in which there is any case of dangerous infectious disease.

The Public Health (London) Act, 1891, forms a sanitary code for London, and includes (with many important additions and improvements) the main provisions of the Public Health Acts, the Infectious Diseases Notification Act, and the Infectious Diseases Prevention Act. It may be regarded as an indication of the lines which future legislation for the rest of the country will probably follow, and a brief summary of the principal points of divergence from the Acts named above therefore becomes necessary.

Water supply.—Absence of proper water supply, or of proper fittings, is held to render a house unfit for habitation. A new house must not be occupied until the **S.A.** grant a certificate that it has a proper water supply. A water company cutting off the supply of any house must give immediate notice to the **S.A.** For closure of polluted wells, etc., the **S.A.** have only to satisfy the Court that the water is "so polluted, or likely to be so polluted, as to be injurious or dangerous to health."

Closets.—A new house must have "one or more water-closets, as circumstances may require," with proper water supply and trapped soil-pan, and other accessories. The same applies to all houses, irrespective of date, under notice from the **S.A.** Substitution of privies or earth-closets is only permissible if the available sewerage or water supply is insufficient for a water-closet. Penalties are prescribed for (*a*) wilfully injuring any drain or closet or water supply in

connection therewith; (*b*) discontinuing any such water supply without lawful authority; (*c*) so constructing or repairing a water-closet or drain that it is a nuisance or injurious to health.

Scavenging.—The **S.A.** must cleanse streets, footpaths, cesspits, earth-closets, privies, and cesspools. They must remove house-refuse at proper intervals; and trade-refuse also, if required to do so, on payment. They may undertake the collection of manure and other refuse, on request; or may by order require periodical removal by the owner.

Cellar Dwellings.—No underground room not let or occupied separately as a dwelling before January 1st, 1892, can be so let or occupied, unless

(*a*) Every part is seven feet high, and at least three feet above the level of the adjoining ground; but if the outside area is six feet wide, or if its width is not less than the depth of the floor below ground-level, then only one foot of the height need be above the ground-level.

(*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 whole frontage, four feet wide in every part, and six 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 under the room is made of gas-tight pipe.

(*g*) The room is effectually secured against the rising of any effluvia or exhalation.

(*h*) There is proper water-closet and ashpit accommodation.

(*i*) There is effectual ventilation.

(*j*) There is a fire-place, 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, at least half made to open, and in each case opening to the top.

The same conditions apply (after July 1st, 1892) to underground rooms occupied separately as dwellings before January 1st, 1892; but the **S.A.**, 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.

Keeping of animals.—Swine must not be kept within forty 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.

Offensive trades.—None of the following must be established anew in London:—blood-boiling, bone-boiling, manure manufacture, soap-boiling, tallow-melting, or knacker's yard. Nor any of the following, without the sanction of the County Council:—fell-monger's, tripe-boiling, slaughtering of cattle or horses, or other business which the County Council may, with the approval of the **L.G.B.**, add to the list. Slaughter-houses and knackers' yards must obtain licences, issued by the County Council, lasting for one year only, but renewable at the discretion of the County Council. The same applies to cowsheds.

Notification is compulsory throughout London. The medical certificate must state the patient's full name, postal address, age, sex, whether attended in public or private practice; if in hospital, the date of admission, and the place from which brought. The **M.O.H.** must, within twelve hours of receipt, send a copy of the certificate to the Metropolitan Asylums

Board, and another to the head-teacher of the schools attended by the patient or by other inmates of the house. The Asylums Board must furnish to the County Council, and to every **M.O.H.,** such weekly returns of certificates so received by them as the County Council may prescribe. Any **S.A.** may, with the consent of the **L.G.B.,** add other dangerous infectious diseases to the list, temporarily or permanently, and the County Council have like power for the county as a whole.

Isolation.—A person who knows himself to be suffering from a dangerous infectious disease must not milk any animal, or pick fruit, or engage in any business in such manner as to be likely to spread the disease. He must not enter any public conveyance, nor must any other person place him, or convey him, in such.

Disinfection.—Every **S.A.** must provide disinfecting apparatus.

Mortuaries.—Every **S.A.** must provide a mortuary; the addition of a room for post-mortems is optional, unless ordered by the County Council. The County Council may provide other mortuaries wherein bodies may be kept for identification, and must provide proper accommodation for inquests.

Appointment of M.O.H. must not be for a limited period only. It is not terminable by the **S.A.** without the consent of the **L.G.B.** The **M.O.H.** must live in his district, or within a mile of the boundary. He must be qualified as stated on page 398.

Sanitary Inspectors appointed after January 1st, 1895 (if they have not held office as sanitary inspector during three consecutive years prior to that date in a London district or in an urban district outside London with a population of not less than 20,000) must hold a certificate of competence granted after examination by such body as the **L.G.B.** may from time to time approve.

Default of S.A.—In the event of default of the **S.A.** with respect to the removal of any nuisance, the institution of any proceedings, or the enforcement of any byelaw, the County Council may act in their stead, and recover the expenses from the **S.A.** If the **L.G.B.** are satisfied, upon complaint from the County Council and after due inquiry, that the **S.A.** have made default in carrying out any part of this Act, they may order the **S.A.** to perform the duty within a specified time; and if this is not done, the order may be enforced by mandamus, or the **L.G.B.** may appoint the County Council to perform such duty, at the cost of the **S.A.**

Byelaws.—The London County Council *must* make byelaws

(1) As to the time and manner of conveying offensive matters by road or water.

(2) As to the closure and filling up of cesspools and privies, removal and disposal of refuse, and duties of householders in facilitating removal of house-refuse.

(3) As to water-closets, earth-closets, ashpits, cesspools, and receptacles for dung, and the proper accessories thereof in connection with new buildings or old.

They *may* also make byelaws as to the conduct of certain offensive trades, the buildings in which they are carried on, and the mode of application for sanction. These trades are fellmonger, tripe-boiler, slaughterer of cattle or horses; but other businesses may be afterwards added to the list.

The County Council have control over dairies, cowsheds, and milk-shops, and power to make byelaws concerning them.

Every London **S.A.** *must* make and enforce byelaws relating to nuisances and keeping of animals, houses let in lodgings, and also the following:—

(1) For the prevention of nuisances arising from offensive matter running out of any manufactory, brewery, slaughter-house, knacker's yard, butcher's or

fishmonger's shop, or dunghill, into any uncovered place, whether enclosed or not.

(2) For the paving of yards and open spaces in connection with dwellings.

(3) For securing cleanliness and freedom from pollution, of tanks, cisterns, and other receptacles of drinking-water.

(4) For maintaining the efficiency of flush for water-closets.

The **S.A.** *may* also make byelaws relating to ship-borne infectious cases, public conveniences, mortuaries, and inhabited tents and vans (pages 474–476).

CHAPTER XVI.

BYELAWS AND REGULATIONS.

Byelaws, having the force of law, may be made by Sanitary Authorities for the better government of their districts, but only in respect of certain matters, and under certain conditions, expressly stated in the Public Health Act and other Acts. They are designed to supplement, not to summarise, vary, or supersede, the express provisions of the statute law. It is, of course, quite open to any Sanitary Authority to append to their byelaws a statement or summary of the requirements of the statute law bearing upon the same matters. In some cases this course is advised by the Local Government Board. Byelaws must be reasonable, and must not in any particular be repugnant to the provisions of the general law. They have (as a rule) no force until approved by the Local Government Board. Any byelaw may be altered or repealed by a subsequent byelaw. In framing byelaws, a Sanitary Authority should impose reasonable penalties, not exceeding £5 for each offence; and in the event of a continuing offence, a further penalty not exceeding £2 per day.

Urban authorities are empowered to make byelaws as follows :—

1. *Private scavenging.*—For imposing upon occupiers the duty of cleansing pavements and footways, of removing house-refuse, and of cleansing earth-closets, ashpits, privies, and cesspools. Such byelaws are only to be made if the Authority do not undertake or contract for these matters * (Public Health Act, section 44).

* But see the Public Health Amendment Act, 1890, page 460.

2. *Prevention of nuisances.*—For the prevention of nuisances arising from snow, filth, dust, ashes, and rubbish.* For the prevention of the keeping of animals on any premises so as to be injurious to health (Public Health Act, section 44).

3. *Common lodging-houses.*—For regulating the number of lodgers and the separation of the sexes; for promoting cleanliness and ventilation; for giving notice and taking precautions in case of infectious disease; and for the general well-ordering of such houses (Public Health Act, section 80).

4. *Houses let in lodgings.*—For regulating the number of persons and separation of the sexes in a house or part of a house let in lodgings or occupied by members of more than one family; for the registration and inspection of such houses; for drainage, privy accommodation, cleanliness and ventilation; for cleansing and whitewashing at fixed times; for paving of yards; and for giving notice and taking precautions in case of infectious disease† (Public Health Act, section 90).

The Merchant Shipping (Fishing Boats) Act of 1883 gives power to Sanitary Authorities to make bye-laws for the regulation of seamen's lodging-houses.

5. *Hop-pickers.*—For securing the decent lodging and accommodation of persons engaged in picking hops (Public Health Act, section 314).

6. *Fruit-pickers.*—For securing the decent lodging and accommodation of persons engaged in picking fruit and vegetables [Public Health (Fruit-pickers) Act, 1882].

* For further powers, see pages 460 and 420.

† The Medical Officer of Health must on request inspect any house wholly let in tenements at rents not exceeding 7s. 6d. weekly, and (if satisfied) certify that the accommodation and sanitary arrangements are suitable. The effect is to exempt from inhabited house duty. The Sanitary Authority may appoint another practitioner, qualified to act as Medical Officer of Health, to give such certificate (Customs and Inland Revenue Act, 1890).

7. *Tents and vans.*—For promoting cleanliness in, and habitable condition of, tents, vans, sheds, and similar structures used for human habitation; for preventing the spread of infectious disease by the occupants thereof; and generally for the prevention of nuisances in connection with the same (Housing of the Working Classes Act, 1885).

8. *New streets and buildings.*—With respect to the level, width, construction, and sewerage of new streets; with respect to the structure of walls, foundations, roofs, and chimneys of new buildings, for securing stability and for the prevention of fires, and for purposes of health; with respect to ventilation, and sufficiency of air-space about buildings; with respect to drainage, closets, ashpits, and cesspools; with respect to the depositing of plans and sections of proposed new streets and buildings; with respect to the power of the Authority to remove, alter, or pull down, any work begun or done in contravention of the bye-laws; and with respect to the closure of buildings unfit for habitation * (Public Health Act, section 157).

9. *Mortuaries.*—For the regulation of charges and management of public mortuaries (section 141).

10. *Cemeteries.*—For the regulation of charges and management [Public Health (Interments) Act, 1879].

11. *Slaughter-houses.*—For the licensing, registering, and inspection of slaughter-houses and knackers' yards; for preventing cruelty therein; for cleanliness and daily removal of filth; and for providing a supply of water (Public Health Act, section 169).

12. *Offensive trades.*—For preventing or diminishing the noxious or injurious effects of any offensive trades (Public Health Act, section 113).

13. *Markets and fairs.*—For preventing nuisances in markets and fairs; for inspection of slaughter-houses, and daily removal of refuse therefrom; for

* For further powers, see page 461.

preventing the sale or exposure for sale of unwholesome provisions; and for many other purposes (Public Health Act, section 167).

14. *Open spaces.*—For the regulation of public walks and pleasure grounds (Public Health Act, section 164). For the regulation of any open space, churchyard, cemetery, or burial ground over which the Sanitary Authority has control (Open Spaces Act, 1887).

15. The 23rd section of the Municipal Corporations Act, 1882, gives power to the Council of a borough to make byelaws for the prevention and suppression of nuisances not already punishable in a summary manner by virtue of any Act in force throughout the borough. County Councils have similar power under the 16th section of the Local Government Act, 1888.

16. For the regulation of buildings provided under the Housing of the Working Classes Act, 1890, or the Acts superseded by it.

17. By adopting certain portions of the Public Health Amendment Act, the **S.A.** may make byelaws as to public conveniences provided by them; and also additional byelaws as to new (and old) buildings, removal of house-refuse, and prevention of nuisances (page 461).

Rural Authorities have similar powers in respect of the following:—

Private Scavenging (1, 17).	Hop-pickers (5).
Common Lodging-houses (3).	Fruit-pickers (6).
Houses let in Lodgings, and Seamen's Lodging-houses (4).	Tents and Vans (7).
	Mortuaries (9).

and also under the Housing of the Working Classes Act (16). By adopting portions of the Public Health Amendment Act, they can make certain byelaws as to new (and old) buildings (8, 17). The **L.G.B.** may confer upon them any other powers as to byelaws which the Public Health Acts give to Urban Authorities (Public Health Act, 1875, section 276).

Byelaws as to common lodging-houses must be made by every **S.A.**, and as to slaughter-houses by every urban **S.A.**; the rest are optional.

Any **S.A.** may make regulations under the Dairies Order for any of the following purposes:—(*a*) for the inspection of cattle in dairies; (*b*) for prescribing and regulating the lighting, ventilating, cleansing, drainage, and water supply of dairies and cowsheds; (*c*) for securing the cleanliness of milk-stores, milk-shops, and milk-vessels used for containing milk for sale; (*d*) for prescribing precautions to be taken by purveyors of milk against infection or contamination. (*See* page 452.)

A Sanitary Authority may make regulations (to be approved by the **L.G.B.**) for the removal to hospital, and detention in hospital as long as necessary, of persons brought within their district by ship or boat, and infected with any dangerous infectious disorder (Public Health Act, section 125). They may also make regulations for the management of places provided by them for post-mortem examinations ordered by a coroner.

Model Byelaws have been prepared by the **L.G.B.** in respect of certain of the matters upon which Sanitary Authorities have power to frame byelaws. The following have been issued up to the present time:—

1. Private Scavenging.
2. Prevention of Nuisances.
3. Common Lodging-houses.
4. New Streets and Buildings.
5. Markets.
6. Slaughter-houses.
7. Hackney-carriages.
8. Public Bathing.
9. Baths and Wash-houses.
10. Pleasure Grounds.
11. Horses, etc., let for Hire.
12. Pleasure-boats.
13. Houses let in Lodgings.
14. Cemeteries.
15. Mortuaries.
16. Offensive Trades.
17. Hop-pickers.

These Models* are now very generally adopted, with occasional slight modifications, by Sanitary Authorities

* The semi-official *Annotated Model Byelaws* (Knight and Co.) contain many important notes, additions, and illustrations.

seeking to frame byelaws. The following summary includes only those which have a more direct bearing upon sanitary matters :—

1. 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.

2. Prevention of nuisances.—(*a*) *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.

(*b*) *Scavenging.*—The refuse from any premises shall only be removed in a suitable covered receptacle or carriage ; and if from premises within 20 yards of any dwelling, public building, or place of business only between [7.0 and 9.30 a.m.] from November to February, and between [6.0 and 8.30 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.

(*c*) *Deposit of nightsoil and other refuse.*—No load of filth must be deposited for more than [24] hours within [100] yards of any street, dwelling, public building, or place of business. Nightsoil deposited for agricultural purposes upon land within

* Applicable to districts where the Sanitary Authority do not undertake these duties.

[100] yards of a street, dwelling, etc., and not deodorised must at once be dug or ploughed into the ground.

(*d*) *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, etc., must be provided with proper receptacles for manure, and with efficient drainage; the receptacle must be watertight, 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.

3. Common lodging-houses. — (*a*) *Number of lodgers.*—The Sanitary Authority may specify by notice in writing the maximum number of lodgers to be accommodated in each room, and the keeper must not allow this number to be exceeded; notice stating the maximum number allowed must be exhibited in each room.* The Sanitary Authority may vary the number from time to time by further notice.

(*b*) *Separation of sexes.*—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*) *Cleanliness of premises.*—The yards, etc., must be kept clean and in good order; all floors swept daily and washed once a week; all windows, painted

* It is usual to require at least 300 cubic feet of air-space per head, but to count two children as one adult.

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 must be thrown into ashpits designed for dry refuse only.

(*f*) *Management of sleeping-rooms.*—The windows must be opened fully for an hour in the morning, and an hour in the afternoon, except in case of stress of weather or occupation of the room by a sick person, or other sufficient cause. Beds must be stripped of clothes and exposed freely to the air for an hour each day, and must not be reoccupied 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, bedclothes, and utensils, for the use of the maximum number of lodgers to be received therein.

(*g*) *Facilities for washing.*—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*) *Precautions in respect of infectious diseases.*—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 by the Medical Officer of Health 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 instructions of the Medical Officer of Health. 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 byelaws* in force with respect to Common Lodging-Houses, supplied by the Sanitary Authority, must be placed in some conspicuous place in the house, and must not be concealed, altered, obliterated or injured.

[As some of the most important regulations regarding common lodging-houses are contained in the Public Health Act, and are, therefore, omitted in the byelaws, it is desirable that a statement of the provisions of Sections 75 to 89 of the Public Health Act should accompany the copy of byelaws supplied to each common lodging-house.]

As regards the question of the suitability of any particular premises or particular rooms for registration, a memorandum, issued by the **L.G.B.,** points out that a Common Lodging House should, in the first place, possess the conditions of wholesomeness needed for houses in general, and secondly, that it should have arrangements fitting it for the special purpose of receiving a given number of lodgers. 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 ten gallons per head per day for the

maximum number of inmates, and one closet for every twenty registered lodgers. Wherever practicable, there should be a separate place for washing, not in the bedrooms, with fixed basins and trapped and disconnected waste-pipes.

4. New streets and buildings.

(*a*) *Streets.*—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*) *Sites.*—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 $2\frac{1}{2}$ 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. Walls of new houses must be at least 9 inches thick, increasing according to a prescribed scale when the height is greater than 25 feet, or the length greater than 30 feet. 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*) *Open space.*—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*) *Ventilation beneath floors.*—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*) *Windows* opening directly into the external air must be provided in every habitable room. 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.

(*h*) *Ventilation.* — Every habitable room must 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.*

* The semi-official Model Byelaws under the Public Health Amendment Act prescribe a minimum height of nine feet in every part, except in attics used as bedrooms, when a minimum height of five feet is permitted, if in two-thirds of the area the height is not less than nine feet.

(*i*) *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 watertight 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 flow.

(*j*) *Ventilation of drains.*—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 (*i.e.* 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 the drain, and in no case less than 4 inches; and bends and angles are to be avoided as far as practicable.

(*k*) *Disconnection of drains from house.* — 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 (except where unavoidable), to such a height and such a point as to afford a safe outlet for sewer air. 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 gulley grating at least 18 inches distant.

(*l*) *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, etc. 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.

(*m*) *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 (*forty ?*) cubic feet, and it must in every part be (*three ?*) inches above the ground. (The maximum limit of size may with advantage be reduced to *two* cubic feet in the case of earth-closets placed inside houses.)

(*n*) *Privies* must not be erected within 6 feet of a dwelling, public building, or place of business, nor within (*fifty ?*) 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 the ground in all parts, with a fall of half an inch per foot 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 must not exceed 8 cubic feet ;* means must be provided for the application of ashes and dry refuse to the excreta, and for the exclusion of rainfall and drainage, and for convenient access for scavenging ; the materials and construction must be such as to prevent absorption or leakage, and there must be no connection with any drain.

(*o*) *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, etc., 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 convenient removal of the contents, and to allow also of being closed and fastened. The ashpit must not be connected with any drain.

(*p*) *Cesspools* must not be constructed within (50 ?)

* These dimensions are based upon the assumption of weekly scavenging.

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; and must be constructed of brick in cement, rendered inside with cement, and with a backing of at least 9 inches of clay.

(*q*) *Closure of premises unfit for occupation.*—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.

(*r*) *Plans and sections* must be submitted, showing in detail the construction of all proposed new streets or buildings. (The Public Health Act, section 158, requires that the Sanitary Authority shall signify their approval or disapproval of the plans within a month after receiving them.)

(*s*) *Inspection.*—Notice must be given to the Surveyor of the dates upon which work is to be commenced, and upon which any sewer, drain, or foundation is to be covered up; notice must also be given of the completion of the work. Free access for inspection must be afforded to him at all times during the progress of the work.

(*t*) *Demolition of illicit works.*—If any work to which the byelaws apply is done in contravention of

such byelaws, the Sanitary Authority are empowered to remove, alter, or pull down such work.*

5. Slaughter-houses.—(*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, etc., 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.

* The Model Byelaws contain no provision for the sewerage of new streets, owing to the wide variation in the conditions in different localities. "It may be doubted whether any powers, which under such byelaws may be lawfully assumed by Sanitary Authorities, will, as regards extent and efficacy, compare with the powers which they derive from the express provisions of the Public Health Act."—*Letter addressed by the Local Government Board to all Urban Sanitary Authorities, July*, 1877.

(*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 24 hours, and the vessels forthwith cleansed. All skins, fat, and offal must be removed within 24 hours.

"In framing a model series of byelaws ..... the Board have considered that the statutory terms do not warrant the extension of the scope of the byelaws to regulations directly affecting the structure of the premises. But ..... in the exercise of the discretionary power of licensing which has been conferred upon the Sanitary Authority, the following rules as to site and structure should influence their decision upon each application for 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 six 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."—*Memorandum issued by the Local Government Board, dated July 25th*, 1877.

6. Houses let in lodgings (or "tenements").—(*a*) *Definitions.*—A "lodging-house" is defined as a house or part of a house let in lodgings, or occupied by members of more than one family. The "landlord" is the person letting such "lodging-house," or entitled to receive the profits of such letting; and a "lodger" is a person to whom any room or rooms in such house, or part of a house, have been let for his use and occupation. (*b*) *Limitation as to class.*—A lodging-house is exempt from the operation of these byelaws (1) if the rateable value exceed ....., and the rent payable by each lodger for unfurnished rooms be not less than ..... per week; or (2) if the rateable value exceed ....., and the rent payable by each lodger for furnished rooms be not less than ..... per week. (*c*) *Cubic space.*—A room used exclusively as a sleeping-apartment shall not be so used at any one time by a greater number of persons than will admit of the provision of 300 cubic feet of air-space for each person over ten years of age, and 150 cubic feet for each person under ten years. A room not exclusively used as a sleeping-room shall not be used at any one time by a greater number of persons than will admit of the provision of 400 cubic feet of air-space for each person over ten years of age, and 200 cubic feet for each person under ten years. (*d*) *Landlord to furnish returns.*—The landlord shall, if required by the Sanitary Authority, furnish the following particulars:—(1) Number of rooms in the house; (2) number of rooms let in lodgings or occupied by members of more than one family; (3) the manner of use of each room; (4) the number, age, and sex of the occupants of each room used for sleeping; (5) full name of the lessee of each room; (6) the rent payable by each lessee. (*e*) *Inspection.*—Facilities for inspection shall be afforded

to the Medical Officer of Health, Inspector, or Surveyor at all times by the landlord and lodgers. (*f*) *Closet accommodation.*—The landlord shall provide sufficient closet accommodation, in the proportion of at least one closet for every twelve persons of the maximum number of lodgers allowed by the byelaws, and maintain the closets and all necessary appurtenances in efficient order. All closets must be kept clean, and supplied with dry earth (if earth-closets) or water (if water-closets) as required.* (*g*) *Ashpits* must be maintained in repair by the landlord, and must be kept clean; no filth or wet refuse must be thrown into an ashpit designed for dry refuse only. (*h*) *Cleanliness of rooms.*—The floors of all rooms must be swept daily, and washed every week. All windows, all wood, stone, or metal fixtures, and all painted surfaces must be kept clean. All solid or liquid filth or refuse must be removed from every room every day, and all receptacles thereof cleansed. (*i*) *Keeping of animals.*—No animal must be kept upon the premises in such manner as to render the premises filthy. (*j*) *Water storage.*—All cisterns for storing water must be kept clean. (*k*) *Ventilation.*—The landlord must maintain in efficient order the means of ventilation of all parts of the house. (*l*) *Annual cleansing of premises.*—Every year, in the first week of the month of ..... the landlord must cleanse every part of the premises, and whitewash the ceilings and walls throughout the house, except surfaces to which limewashing may be unsuitable, and these must be cleansed and, if necessary, painted. (*m*) *Yard and open spaces.*—The yard and all open spaces must be kept clean and in good order. The yard must have a hard, impervious pavement laid upon concrete, and sloped to a channel leading to a

* If the byelaws respecting new streets and buildings are not in force in the district, those of them which refer to the construction of closets may be introduced here.

trapped gulley grating; all these must be kept in repair by the landlord. (*n*) *Ventilation of sleeping-rooms.*—The window of every sleeping-room shall be kept open for an hour in the forenoon and an hour in the afternoon, except in case of stress of weather, or occupation of the room by a sick person, or other sufficient reason. (*o*) *Infectious diseases.*—The landlord must immediately give written notice to the Medical Officer of Health if he learns that any person in the house is ill of an infectious disease. A lodger must immediately give written notice to the Medical Officer of Health, and verbal or written notice to every lodger in the house, if he has reason to believe that any occupant of any room is ill of an infectious disease. Where a justice's order has been obtained for the removal to a hospital of a person suffering from any dangerous infectious disease, both the landlord and the lodger in whose tenement such sick person is shall take such steps as may be requisite on their respective parts for the safe and prompt removal of such person; and shall adopt all such precautions as may be most suitable, in accordance with any instructions of the Medical Officer of Health.

The landlord is made responsible for the structural repair of every part of the premises, for the efficiency of the closets and of the means of ventilation, for the annual cleansing, and for the detailed cleansing of all parts (including yards, closets, staircases, and passages) which are not let for the sole use of one tenant. The tenant is responsible for the cleanliness and management of the rooms rented by him, and of all other parts of the premises of which he has the sole use.

7. Cemeteries.—(*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 three 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 four feet if the age of the deceased was over twelve years. A layer of earth, not less than one 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 two 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.

Regulations for Burial-Grounds provided under the Burial Acts, issued by the Home Secretary, 1863.

(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 ft. by 4 ft., and those for the burial of children under twelve years of age, 6 ft. by 3 ft., or, if preferred, half the measurement of the adult grave space—namely, $4\frac{1}{2}$ ft. by 4 ft.

(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 four feet of the ordinary level of the ground, unless it contains the body of a child under twelve years of age, when it shall not be less than three feet below that level.

8. Mortuaries.—The only provisions of sanitary importance suggested in this series 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.

In an introductory memorandum the Local Government Board advise that Sanitary Authorities should, for the present, defer the fuller exercise of their powers of making byelaws under Section 141 of the Public Health Act, until the voluntary use of mortuaries has become more general. The Board make the following general suggestions in regard to construction and management:—

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 eight 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 $2\frac{1}{2}$ ft. to 3 ft. 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.

9. Offensive trades.—The offensive trades in regard to which Model Byelaws have been issued by the Local Government Board are those of—

Blood-boiler.	Leather-dresser.
Bone-boiler.	Tanner.
Fellmonger.	Fat-melter or Fat-extractor.
Soap-boiler.	Glue-maker.
Tallow-melter.	Size-maker.
Tripe-boiler.	Gut-scraper.
Blood-drier.	

Of these the first six only are specifically mentioned in the 112th section of the Public Health Act, the rest being examples of "other offensive trades." 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 character :—

(i) *Storage of offensive materials.*—Materials not required for immediate use or treatment shall be so stored as to prevent effluvium. (ii) *Offensive vapours* emitted during boiling, melting, etc. The best practicable means shall be adopted for rendering such vapours innocuous. The vapour shall either (*a*) be discharged into the external air in such a manner and at such a height as to admit of its diffusion without noxious or injurious effects, or (*b*) shall be passed directly from the pan, etc., through a fire, or (*c*) into a condensing apparatus, or (*d*) through a condensing apparatus and then through a fire, in such manner as effectually to consume the vapour or deprive it of all noxious or injurious properties. (iii) *Drainage* must be kept in efficient order. Bone-boilers are required to cool all hot liquid refuse before passing it into any drain. (iv) *Floors* must be kept in good order so as to prevent the absorption of filth. In respect of several trades it is required that at the

close of every working day the floors shall be swept (*e.g.* tanner's, leather-dresser's) or washed (blood-drier's, etc.) or scraped, or otherwise cleansed. All refuse collected by sweeping or scraping shall be forthwith removed from the premises in covered receptacles, unless intended to be forthwith subjected to further trade processes on the premises. (v) *Walls* shall be kept in good order so as to prevent the absorption of filth, and, if necessary, be scraped. Limewashing of walls and ceiling twice yearly is required in regard to certain trades, fellmonger's, for example. (vi) *Apparatus*, including all implements and vessels, to be kept clean; daily cleansing is required in some cases. (vii) *Waste lime* (fellmonger's, tanner's) must be removed at once, and under close cover. (viii) *Tanks* used by fellmongers for washing or soaking skins shall be emptied and cleansed as often as necessary to prevent effluvia. (ix) Free access for the purpose of inspection shall at all reasonable times be afforded to the Medical Officer of Health, Inspector of Nuisances, Surveyor, or any committee specially appointed by the Sanitary Authority on that behalf.

10. Hop-pickers.—(*a*) *Application.*—These bye-laws apply to all tents, sheds, barns, or other places occupied as temporary dwellings by hop-pickers, but not to places inhabited throughout the year. (*b*) *Habitable condition.*—Such temporary habitations are required to be clean, dry, weatherproof, and to be ventilated and lighted. (*c*) *Closet accommodation.*—There must be adequate privy accommodation for the separate use of each sex. (*d*) *Water.*—There must be a sufficient supply of good water for drinking, cooking, and washing. (*e*) *Cooking.*—There must be a separate cooking-place for every fifteen persons authorised to be received. (*f*) *Area.*—An average floor space of 15 square feet must be allowed for

each occupant, but two children under ten years of age may be counted as one adult. (*g*) *Bedding.*—Clean straw or other suitable material must be supplied for bedding, and renewed as required. The beds must be screened off in places occupied by adults of different sexes. (*h*) *Cleansing.*—The premises and appointments must be thoroughly cleansed immediately before occupation, the internal surfaces limewashed, and all offensive accumulations cleared away. The cleansing must be repeated as required from time to time during the period of occupation.

(Similar byelaws may be made in respect of the accommodation of persons engaged in picking fruit or vegetables.)

CHAPTER XVII.

VITAL STATISTICS.

STATISTICAL methods are indispensable in almost every department of Hygiene, and have been employed in several of the preceding chapters, but it is now necessary to refer in greater detail to the statistics of populations, births, deaths, and diseases.

Ratio.—The mere number of births or deaths in a district conveys no clear idea unless the population or some other basis of comparison is also given. For the sake of convenience it is customary to state the ratio of births, etc., in one year per thousand persons living in the district. Thus the annual birth-rate

$$= \frac{\text{No. of births in the year}}{\text{Population in middle of year}} \times 1{,}000.$$

A year, and a thousand persons living, are the usual standard terms. Sometimes, however, it is necessary to compare the death-rates or birth-rates for shorter periods, such as quarters or weeks; but in order to avoid confusion the standard terms are still retained by the simple device of adopting the annual rate per 1,000 living which would result if the conditions during the period in question were continued during an entire year.

Thus the birth-rate during $\frac{1}{x}$th part of a year is—

$$\frac{\text{No. of births during the period in question}}{\text{Population at the middle of the year}} \times x \times 1{,}000.$$

A "quarterly birth-rate" of 32·0 therefore implies not 32 but 8 births during the quarter per thousand living.

For ordinary purposes it is sufficient to regard the year as consisting of 365 days, or 52 weeks; but if greater precision is required, the astronomical year may be used—namely, 365·24 days, or 52·177 weeks. Thus 100 births in a week in a population of 200,000 would give a "weekly birth-rate" of

$$\frac{100}{200{,}000} \times 52{\cdot}177 \times 1{,}000 = 26{\cdot}0885, \text{ or say } 26{\cdot}1.$$

Population.—A decennial census has been taken since 1801 (Appendix V., p. 569), and gives detailed information regarding each county, union, registration district and sub-district, and urban sanitary district. The chief data 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.

The estimate of the number of inhabitants of any area in any year is made by assuming that the population has gone on increasing or diminishing since the last census at exactly the same rate that it did between that and the previous census.

This assumption is, of course, quite arbitrary, and seldom accords with the facts as ascertained by the next census; but it may be corrected in certain instances by local observations to be mentioned presently. It is more trustworthy in large than in small communities, but the 1891 census has again shown how uncertain the results must be towards the close of the decade. The population of England and Wales was over-estimated by about $2\frac{1}{2}$ per cent. only, but in Liverpool and Salford the errors in excess were no less than 20 and 27 per cent. respectively, while for Portsmouth the official estimate was 9 per cent. below the actual figure, and for Newcastle 11 per cent. Taking Liverpool as an extreme case, 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 actual enumeration in 1891 being, that instead of increasing the population had diminished, and that the death-rate, instead of falling to 23·6 had risen to 27·8. The importance of a more frequent census is now generally admitted.

If a population of 100,000 in 1881 becomes 101,000 in 1882, it is evident that the 1883 population will be greater than 102,000, for the yearly increase has now to be reckoned upon 101,000, not upon 100,000 as before. In mathematical language the increase is geometrical, not simply arithmetical, and in the above instance the correct estimate would be 102,010.

If p = the population in any given year, and r = the factor of annual increase (in the above example $r = 1{\cdot}01$), then in one year the population will become $p \times r$, in two years $p \times r^2$, and in n years $p \times r^n$.

The rate of annual increase is determined from the data of the two previous censuses, by the aid of logarithms. The census is taken, not at the middle of the year, but at the end of the first quarter.

If a town had a census population of x in 1881, and y in 1891, the rate of *decennial* increase is $\frac{y}{x}$, that of *annual* increase $\sqrt[10]{\frac{y}{x}}$, and that of *quarterly* increase $\sqrt[40]{\frac{y}{x}}$. Hence—

$$\text{log. } y - \text{log. } x = \text{log. ratio of decennial increase,}$$

$$\text{and } \frac{\text{log. } y - \text{log. } x}{10} = \text{log. ratio of annual increase,}$$

$$\text{and } \frac{\text{log. } y - \text{log. } x}{10 \times 4} = \text{log. ratio of quarterly increase.}$$

Thus the logarithm of the estimated population at the *middle* of 1891 is, log. $y + \frac{\text{log. } y - \text{log. } x}{10 \times 4}$; and at the middle of the year 1898,

$$\text{log. } y + \frac{\text{log. } y - \text{log. } x}{10 \times 4} + 7\,\frac{\text{log. } y - \text{log. } x}{10}.$$

And in more general terms, the logarithm of the estimated population at the middle of the nth year after a census = log. census population + log. quarterly increase (to bring the census population up to the mid-year population) + n times the log. of annual increase.

Taking Norwich as an example, the estimated population in 1895 would be found as follows :—

(*a*) The population at the 1891 census was 100,970; . . . . log. 100,970 =	5·0041924
(*b*) The population at the 1881 census was 87,842; . . . . log. 87,842 =	4·9437022
(*c*) By subtraction, the logarithm of *decennial* increase was, therefore	0·0604902
(*d*) Dividing by 10, we find the log. of *annual* increase . . . . . =	0·0060490
(*e*) Again dividing by 4, we have the log. of *quarterly* increase . . . . . =	0·0015122
(*f*) Adding together log. 1891 census population (*a*), and log. quarterly increase (*b*), and four times log. annual increase (*d*), we get the log of 1895 mid-year population . =	5·0299017

And on referring to the tables, the number corresponding to this logarithm is found to be 107,128, which is, therefore, the estimated population at the middle of 1895.

There are certain obvious limitations to this method of estimating the population. For example, we cannot assume that the rate of increase is the same in the centre of a town as in the growing suburbs. New houses are springing up and becoming inhabited in the latter, apart from the "natural increase" by excess of births over deaths; while in the former there is often an actual decrease of population, owing to the displacement of dwellings by business premises, or at all events the increase is very limited. Again, in villages,

where the local conditions are well known, it will often happen that a better estimate of population can be made by considering the natural increase, the number of inhabited houses, and the known migrations, than by calculation from census data alone.

The actual increase is dependent upon the balance between births and immigration on the one hand, and deaths and emigration on the other. No available record is kept of local migration, which, however, is sometimes sufficiently great to render estimates based upon census data comparatively valueless. The excess of births over deaths is termed the "natural increase." As regards towns, the *actual* is, upon the average, greater than the *natural* increase, since there is a tendency to migration from rural to urban districts. In times of depression of trade, especially if the depression is limited to a few centres, there is considerable emigration to other districts; whereas, when trade is flourishing, labour is attracted from rural districts and from other towns.

If the estimated population is very wide of the mark, some indication of this may be given by an excessively high or low birth-rate and death-rate; by the number of inhabited houses, as ascertained from the rate-books or other sources; by returns of those who by migration have evaded vaccination; by returns of school attendance; or by inference from the condition of the local industries.

The average number of persons per inhabited house is fairly constant for each locality, though varying considerably in different towns, according to the proportion of "tenement houses," and houses occupied by one family. In 1891 there were 4·5 persons per house in Norwich, 5·7 in Liverpool, 10·6 in Westminster, and 5·3 in England as a whole.

The age-distribution of a population is ascertained by each census, and may be assumed to remain

constant until the next census ; that is, the rate of increase in numbers is assumed to be uniform at all ages. There are, however, very material differences among towns as regards the age-distribution of their populations, and as the tendency to death is much greater among the very young and very old, it often becomes important to allow for these variations in comparing the death-rates of dissimilar localities. Owing to the immigration of young adults from rural districts, town populations almost always contain a smaller proportion of persons at the extremes of life than is found in the country at large. The following are examples of the variations met with in different parts of England :—

DISTRIBUTION OF POPULATION ACCORDING TO AGE AND SEX. NUMBERS (OF EACH SEX) LIVING AT CERTAIN GROUPS OF AGES, PER THOUSAND LIVING AT ALL AGES. CENSUS 1891.

——	Man-chester.		Norwich.		English Urban Districts.		English Rural Districts.	
Population.	505,368		100,970		20,895,504		8,107,021	
Years of Age.	M.	F.	M.	F.	M.	F.	M.	F.
0–5	61	62	61	62	61	62	61	62
5–10	55	57	57	57	57	58	61	61
10–15	55	56	52	54	54	55	59	57
15–20	51	54	46	57	50	54	52	45
20–25	46	52	38	51	44	51	40	40
25–35	79	85	68	81	75	83	66	69
35–45	61	64	51	59	57	61	52	55
45–55	41	46	37	46	40	45	43	45
55–65	21	27	27	35	24	29	33	34
65–75	9	13	18	25	13	17	22	23
Over 75	2	3	7	11	4	6	9	11
All ages	481	519	462	538	479	521	498	502

If we take three periods—namely, from birth to 15 years, from 15 to 45 years, and from 45 years upwards—the differences between the ages of urban and rural populations are plainly seen.

Persons.	Urban.	Rural.
0–15 years . . .	35 per cent.	37 per cent.
15–45 ,, . . .	47 ,,	41 ,,
45 upwards . . .	18 ,,	22 ,,

The proportion of persons aged 15 to 45 years is greater in towns, while the country districts include a larger proportion of persons whose ages are below 15 or over 45 years.

Births must, according to the Births and Deaths Registration Act of 1874, be registered within 42 days of their occurrence.

The English birth-rate has declined greatly in recent years, and is now about 30 or 31 per thousand per annum. It fell continuously from its maximum (36·3) in 1876 to a minimum (30·2) in 1890. It is higher in towns, and in times of prosperity; lower in rural districts, and in times of depression of trade. The birth-rate is very high (approaching 40) in Germany, Austria, Hungary, and Italy; very low (latterly below 25) in Ireland and France.

More males than females are born, in the proportion of 104 to 100. This excess of male births prevails among all European races, and is said to be greater among first-born children. It is diminishing in England. Illegitimate births now form about 5 per cent. of the whole, but this proportion is steadily decreasing.

The English returns do not include still-births, which Farr estimated at 4 per cent. of the total births. A slight seasonal curve is noticeable in the birth-rate, with a maximum (about 5 per cent. above the annual

mean) in June and July, and a minimum (about 5 per cent. below the mean) in February and March.

ENGLAND AND WALES: CHANGES IN MARRIAGE-, BIRTH-, AND DEATH-RATES, 1841–1890.

	Persons married per 1,000 living.	Births per 1,000 living.			Illegit. Births per cent. of Total.	Births of Males per cent. of Births of Females.	Deaths per 1,000 living.			Male Deaths per cent. of Female Deaths in equal numbers living.
		Total.	Legit.	Illegit.			Total.	Male.	Female.	
1841–50	16·1	32·6	—	—	—	104·9	22·4	23·1	21·6	107·0
1851–60	16·9	34·1	31·9	2·2	6·5	104·6	22·2	23·0	21·3	107·9
1861–70	16·6	35·2	33·0	2·2	6·1	104·2	22·4	23·6	21·3	110·9
1871–80	16·2	35·5	33·7	1·8	5·0	104·8	21·3	22·6	20·0	113·1
1881–85	15·1	33·5	31·9	1·6	4·8	103·9	19·4	20·5	18·3	112·1
1886–90	14·7	31·4	30·0	1·4	4·7	103·6	18·9	20·0	17·8	112·4

Deaths must be registered within five days of their occurrence. The number of deaths in a district as obtained from the Registrar's returns is practically complete, and only a few days behind date. Some delay often occurs in the case of deaths in public institutions, while a few live-births are undoubtedly slurred over as still-births, and thus escape registration altogether.

The mode of calculating annual and other death-rates has already been explained. Certain corrections may with advantage be applied to the "gross death-rate"—that is, the ratio of total deaths in the district to each thousand of population.

1. *Correction for non-residents.*—The deaths of strangers who happen to die in the district should be excluded from the calculation. The accidental disturbance due to this cause may be very great if the district contains large hospitals, workhouses, or asylums, to which non-residents are admitted. Similarly, persons resident in the district may die outside it, and such deaths should be included. The materials

for these corrections are obtained from the returns of the sub-registrars.

2. *Correction for age- and sex-distribution.*—A district containing a larger than average proportion of infants and aged people will almost necessarily have a higher death-rate than it would if the average distribution prevailed. The Registrar-General has given "factors" for all the large English towns, based upon the age- and sex-distribution, as ascertained by the last census, the effect of which is to neutralise this disparity, and to raise or lower the gross death-rate to what it would be if the local age- and sex-distribution were the same as those of the country generally. This new rate he calls the "*corrected death-rate*"; and the

$$\frac{\text{corrected local death-rate}}{\text{death-rate for the whole country}} \times 1{,}000$$

is the "*comparative mortality figure*" for the district.

	Factor for correction for Age- and Sex-distribution.	Recorded or Uncorrected Death-rate. (1883.)	Corrected Death-rate. (1883.)	Comparative Mortality Figure.
England and Wales	1·0000	19·53	19·53	1,000
London . . .	1·0615	20·44	21·70	1,112
Norwich . .	0·9565	19·64	18·79	963
Manchester . .	1·1143	27·64	30·80	1,578

In almost all towns the factor is greater than unity, so that the corrected death-rate exceeds the uncorrected. The case of Norwich is exceptional.

Male and female death-rates.—The death-rate among males is uniformly higher than among females, except at ages between 10 and 20 years. The total death-rate among females, calculated of course upon the female population alone, was 18·1 in

the decennium 1881–90, that among males being 20·3. Both are decreasing, owing to the great saving of life in the earlier years of age; but, as will be seen presently, the male death-rate is actually increasing at ages over 35 years, and the female death-rate at ages over 45 years.

Urban and rural death-rates. — Urban districts have upon the whole much higher death-rates than rural districts, quite apart from the correction for age-distribution mentioned above. In the ten years 1881-90 the death-rate in England among 18·6 million people living for the most part under urban conditions, averaged 20·3, while the death-rate among 10·5 millions living in rural districts was only 17·3. The death-rate is diminishing in both urban and rural areas, but more rapidly in the former than the latter, so that the difference between them grows less.

Comparison of Urban and Rural Mortality, 1888.

	All causes.	Small-pox.	Measles.	Scarlet Fever.	Diphtheria.	Whooping Cough.	"Fever."	Diarrhœa.
England and Wales . .	17·8	0·04	0·33	0·22	0·17	0·40	0·18	0·43
28 great towns .	19·2	0·06	0·47	0·29	0·21	0·58	0·20	0·60
50 other town districts .	18·4	0·04	0·43	0·22	0·12	0·41	0·21	0·50
Rest of England and Wales .	16·9	0·02	0·24	0·18	0·16	0·30	0·16	0·31

Death-rates at different ages.—The tendency to death is very high in infancy, reaches its minimum in the 10 to 15 year age-period, and afterwards increases steadily throughout life. These points are true of both males and females.

In the following table the infant population is that

enumerated at the census, but in practice it is much simpler and much more accurate to utilise the birth-returns, which are precise and free from many of the errors attendant upon estimates. The "infant mortality," or death-rate among infants, is therefore

$$\frac{\text{deaths of children under 1 year}}{\text{births registered during the year}} \times 1{,}000.$$

1871–80.—Mean Annual Death-rates per 1,000 living at each Age. England and Wales.

Age.	Persons (Both Sexes).	Male.	Female.
0–1	177	197	157
1–2	66	68	64
2–3	28	30	27
3–4	18	18	18
4–5	13	13	13
"Infant mortality" .	*149*	*163*	*134*

Mean Annual Death-rates in England and Wales in the Three Decennia, 1851–1880, per Thousand Persons living at each Group of Ages.

Age.	Persons (Both Sexes).			Males.			Females.		
	1851–60.	1861–70.	1871–80.	1851–60.	1861–70.	1871–80.	1851–60.	1861–70.	1871–80.
0–5 .	67·6	68·3	63·1	72·4	73·2	68·1	62·7	63·4	58·1
5–10 .	8·5	8·0	6·4	8·5	8·1	6·7	8·4	7·8	6·2
10–15 .	5·0	4·5	3·7	4·9	4·5	3·7	5·1	4·5	3·7
15–20 .	7·0	6·4	5·3	6·7	6·2	5·2	7·4	6·6	5·4
20–25 .	8·7	8·2	7·0	8·8	8·5	7·3	8·5	8·0	6·8
25–35 .	9·8	9·8	8·9	9·6	9·9	9·3	9·9	9·7	8·6
35–45 .	12·3	12·7	12·6	12·5	13·5	13·7	12·1	12·0	11·6
45–55 .	16·5	17·3	17·7	18.0	19·2	20·0	15·2	15·6	15·6
55–65 .	28·9	30·3	31·5	30·9	33·0	34·8	27·0	27·8	28·5
65–75 .	61·7	62·5	64·9	65·3	66·7	69·6	58·7	58·8	60·8
Over 75 .	159·8	158·8	161·6	165·4	164·6	169·1	155·5	154·3	155·8
All Ages	22·2	22·5	21·4	23·1	23·7	22·7	21·4	21·4	20·1

In Appendix VI. (page 570) the preceding table has been expanded. The total death-rate is decreasing, but the reduction is chiefly effected in the earlier years of life, and is inconspicuous at ages over 40, owing, perhaps, partly to the increasing wear and tear of modern life, and partly to the more frequent survival of weakly persons at middle life who under former conditions would have died in youth. The earlier table shows continuous increase in the mortality at ages above 35 in males and 45 in females; but, as the table in the Appendix proves, this was not fully maintained in the last decade.

Density.—Reference has been made (page 22) to the effect of overcrowding in increasing the death-rate in Dundee. The following table shows the same result from another point of view, and in another town. The figures relate to the Greengate District of Salford, which had in 1881 a density of 77,000 persons to the square mile, and is inhabited by the poorer labouring class. The district was divided into three parts, according to the proportion of back-to-back houses, and the incidence of mortality upon each was determined for the mean of the five years, 1879–83. It is noted that the average surroundings and class of population were practically the same in each district.*

	Average Proportion of back-to-back Houses.	Population.	Death-rates from				Zymotic Death-rate.
			All Causes.	Phthisis.	Other Respiratory Diseases.	Diarrhœa.	
District I.	0	8,713	27·5	2·8	6·6	1·4	4·5
,, II.	23%	11,749	29·2	2·3	7·8	1·6	4·8
,, III.	56%	11,405	39·5	3·6	7·9	2 1	6·2

* Barry and Gordon-Smith (quoting Tatham): *Report on Back-to-Back Houses*, 1888.

Ogle gives the following striking illustration of the relation between density of population and rates of mortality. All the districts in England and Wales were arranged in groups according to their respective death-rates in 1871-80, and the density of population was calculated for each group as a whole :—

Death-rates.	Persons to a Square Mile.
14 and under 15	253
15 „ „ 16	200
16 „ „ 17	258
17 „ „ 18	211
18 „ „ 19	194
19 „ „ 20	217
20 „ „ 21	458
21 „ „ 22	677
22 „ „ 23	1,301
23 „ „ 24	1,819
24 „ „ 25	2,166
25 „ „ 26	2,819
26 „ „ 27	2,944
27 „ „ 28	6,144

It appears, therefore, that when there are more than about 400 persons per square mile, the death-rate increases with the density. Below that point the density has no important bearing upon mortality.

Farr found that, other things being equal, urban death-rates vary as the twelfth root of the density of the population. The rule is of very limited practical application, as many variable conditions are involved. Newsholme regards the number of persons *per room* as the true density to be considered, 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 higher mortality

from phthisis, scarlet fever, diphtheria, measles, and whooping-cough.

The average density in England in 1892 was about 500 per square mile, or 0·8 per acre.

Influence of the birth-rate upon the death-rate.—Other things being equal, a high birth-rate *in a given year* would theoretically increase the death-rate, since the mortality among the extra members thus added to the community would necessarily be greater than that of the population generally. Farr has shown, however, that the "other things" are rarely, if ever, equal, and that low death-rates accompany high birth-rates. An unusually high birth-rate almost always implies that the population includes an unusually large proportion of persons at the reproductive ages. Moreover, in a few years it causes of necessity a large population of children and young adults, since under the most adverse conditions a large majority of the infants survive. The mortality among all such persons is so low as to more than counterbalance the infant mortality.

Cause of death.—The death-returns obtained from the registrars are copied from the certificates signed by the medical attendants, or, in case of inquest, by the coroner. Very commonly two or more causes are assigned—one being regarded as "primary," and the other as "secondary." As only one cause in each case can be accepted for statistical purposes, it is often necessary to make a somewhat arbitrary selection. Preference should be given to zymotic diseases over all others, to specific over non-specific diseases, and to primary as compared with secondary causes; in cases of doubt the disease first named in the certificate may be accepted. Thus, "convulsions, diarrhœa," would be entered as *diarrhœa;* "phlebitis, gout," as *gout;* and "bronchitis, heart-disease," as *bronchitis.*

For the purpose of tabulation the classification

advocated by the Society of Medical Officers of Health may be adopted. (*See* Appendix, Table III., page 554.)

Many of these causes are really almost as vague as those referred to the "ill-defined" section: for example, *tabes mesenterica*, which is often loosely used for infantile wasting diseases in general; *convulsions*, often only a final symptom in infantile diseases; *premature birth* and *old age; bronchitis*, a heading which undoubtedly includes many cases of disease of the heart, kidneys, and other organs. *Cholera* and *dysentery* in England rarely mean more than fatal acute diarrhœa; and *croup* is usually diphtheria or laryngitis. Deaths due to *venereal diseases* and *alcoholism* are commonly attributed to some less invidious secondary symptom, and it is certain that many cases of *puerperal fever* are returned under other headings. "*Simple continued fever*," *slow fever*, *low fever*, *worm fever*, *gastric fever* still appear upon death certificates. They are frequently applied to imperfectly diagnosed cases of enteric fever, more especially in children, but may include specific diseases of which as yet we have no exact knowledge.

There is, however, a marked improvement in respect of almost all of these points, and the registration of the causes of death is becoming more and more accurate and complete.

Progressive changes are noticeable, in regard to the death-rate from certain well-defined diseases, in the direction of increase or decrease. The change does not necessarily affect both sexes alike, phthisis, for example, having decreased much more rapidly among females than among males (page 518). It may extend to all ages, or be more or less limited to certain periods of life; the mortality from small-pox and from "all causes" has increased at one-age period, while decreasing at others.

ENGLAND. MEAN ANNUAL DEATH-RATES PER 1,000 LIVING.

	1861–65.	1866–70.	1871–75.	1876–80.	1881–85.	1886–90.
Small-pox	0·22	0·10	0·41	0·08	0·08	0·013
Measles	0·46	0·43	0·37	0·38	0·41	0·47
Scarlet-Fever	0·98	0·96	0·76	0·68	0·44	0·24
Whooping Cough	0·52	0·55	0·50	0·53	0·46	0·44
Diphtheria	0·25	0·13	0·12	0·12	0·16	0·17
Typhus	0·92	0·85	0·08	0·03	0·02	0·007
Enteric Fever			0·37	0·28	0·22	0·18
Simple Continued Fever			0·14	0·07	0·03	0·02
Diarrhœa	0·87	1·06	1·00	0·83	0·66	0·67
Puerperal Fever	0·06	0·06	0·09	0·06	0·09	0·08
Erysipelas	0·09	0·08	0·11	0·08	0·08	0·05
Thrush	0·050	0·050	0·050	0·048	0·029	0·022
Alcoholism	0·042	0·035	0·038	0·042	0·048	0·056
Rheumatic Fever	0·11	0·12	0·13	0·14	0·10	0·09
Rheumatism					0·03	0·03
Cancer	0·37	0·40	0·45	0·50	0·55	0·63
Phthisis	2·53	2·45	2·22	2·04	1·83	1·64
Diabetes	0·03	0·03	0·04	0·04	0·05	0·06
Diseases of Nervous System	1·55	1·61	1·72	1·80	1·81	1·78
Convulsions	1·26	1·20	1·11	0·97	0·85	0·77
Diseases of Circulatory System	1·00	1·10	1·26	1·42	1·47	1·69
Diseases of Respiratory System	3·32	3·39	3·69	3·80	3·55	3·64
Croup	0·29	0·21	0·18	0·15	0·16	0·13
Diseases of Digestive System	1·22	1·18	1·17	1·17	1·12	1·11
Diseases of Urinary System	0·25	0·29	0·33	0·37	0·42	0·45
Diseases of Parturition	0·11	0·11	0·11	0·08	0·07	0·066
Accident and Negligence	0·69	0·68	0·67	0·63	0·58	0·54
Homicide	0·019	0·019	0·017	0·014	0·013	0·011
Suicide	0·065	0·066	0·066	0·074	0·075	0·079
Ill-defined Causes	2·21	2·12	1·83	1·39	1·14	0·94

Decrease is manifest in the mortality from small-pox, scarlet-fever, diarrhœa, typhus, enteric fever, simple continued fever, thrush, phthisis, convulsions, croup, diseases of the digestive system, and diseases of

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parturition; also from accident, negligence, homicide, and "ill-defined causes." As regards the first five, the reduction is undoubtedly real, and attributable in great part to improved measures of precaution and sanitation. Phthisis has been greatly lessened by better drainage and ventilation, but there has probably been some transfer of cases by improved diagnosis from phthisis to other respiratory diseases. Better diagnosis and better certification are responsible for the gradual disappearance of "croup," "convulsions," and "simple continued fever," and also, of course, for the lessened total of "ill-defined" diseases; nearly all these are cases of transference to other headings, and not true reductions in mortality.

On the other hand, there is a distinct increase in the mortality attributed to cancer, rheumatism, diabetes, suicide, and diseases of the nervous, circulatory, respiratory, and urinary systems. It is probable that some real increase has occurred in respect of nervous and circulatory diseases, and perhaps also urinary diseases. How far the increase is real in these and the other diseases named, and how far due to improvement in diagnosis, it is at present impossible to say. It has been pointed out, as regards cancer, that the apparent increase is greater proportionately among males, as would be expected on the assumption that it is due to the detection of obscure cases, since cancer among males is usually deep-seated. On the other hand, there is no question of early diagnosis, the cases all ending fatally before the certificate is written, so that the nature of the disease will usually have made itself plain; and the increase in female mortality from cancer, though relatively smaller than the increase in mortality among males, is very heavy. There has been a true increase in diphtheria in the last few years, especially in urban districts, although it was previously decreasing, and it is interesting to note a

tendency to parallelism in "croup." Puerperal fever has apparently gained ground slightly, but it is not improbable that this is due to more correct certification, and to the systematic inquiry which is now made by the Registrar-General in respect of doubtful entries.

The high average mortality due to measles and whooping cough shows little tendency to decrease. These diseases have no demonstrated relation to filth-conditions, as diarrhœa, enteric fever, and diphtheria have, nor has any serious attempt been made to cope with them—as with scarlet-fever and small-pox—by efficient hospital isolation and disinfection; nor have we any prophylactic such as vaccination.

Zymotic death-rate is a term applied commonly, not to the mortality from all diseases classed as zymotic, but to the death-rate from the "seven principal zymotic diseases"—namely, small-pox, measles, scarlet-fever, diphtheria, whooping cough, "fever" (typhus, simple continued, and enteric), and diarrhœa. It was 2·34 in England and Wales in the decennium 1881-90, but is liable to great fluctuation, according to the epidemic prevalence of one or other of the diseases included.

Deaths due to protracted sequelæ of acute specific diseases are usually credited to the secondary and not to the true primary cause. It will be found that the mortality from bronchitis and pneumonia is increased by outbreaks of whooping cough and measles, and scarlet-fever prevalence is followed by deaths referred merely to kidney diseases.

Sex has an important bearing upon the mortality from certain diseases, owing partly to differences in constitutional predisposition, and partly to exposure to the conditions favourable or unfavourable to the development of the diseases in question. Some of the following show a marked inequality between the two sexes in respect of the tendency to increased or decreased mortality:—

	1851–60.		1861–70.		1871–80.		
	Male.	Female.	Male.	Female	Male.	Female.	
I.—*Excess among males.*							
All Causes.	23·05	21·32	23·61	21·28	22·61	20·00	
Small-pox . .	0·24	0·20	0·18	0·15	0·27	0·21	
Measles . . .	0·43	0·40	0·46	0·42	0·40	0·36	Excess among males entirely due to ages below 5 years. After 5 years of age, mortality is greatest among females.
Scarlet-Fever .	0·91	0·85	1·01	0·93	0·75	0·68	Mortality is higher among females after 10 years of age, owing probably to greater exposure to infection.
"Fever" . .	0·91	0·91	0·90	0·88	0·49	0·48	Male mortality higher up to 20 years; female higher at subsequent ages.
Diarrhœa . .	1·14	1·03	1·15	1·01	1·01	0·87	Male excess only below 5 and over 45 years.
Phthisis . . .	2·58	2·77	2·47	2·48	2·21	2·03	Higher among females from 5 to 25 years of age. Until 1870 the female excess extended to the 35th year, and until 1860 to the 45th.
Nervous Diseases . . .	3·00	2·50	3·07	2·51	3·04	2·51	Male excess at all ages except 15 to 20 years.
Diseases of Circulatory System	0·78	0·77	1·03	1·01	1·31	1·30	Higher among females from 5 to 25 years. In the decade 1881-90, the female mortality exceeded the male.
Respiratory Diseases . .	3·32	2·73	3·69	3·05	4·13	3·41	Higher among females at ages below 15.
Digestive Diseases . . .	1·01	1·00	1·00	0·96	1·00	0·96	Higher among females from 20 to 45 years of age.
Urinary Diseases . . .	0·32	0·12	0·42	0·18	0·53	0·27	
Violence. . .	1·10	0·38	1·18	0·38	1·17	0·37	
II.—*Excess among females.*							
Diphtheria. .	0·11	0·11	0·18	0·19	0·12	0·13	The few cases at ages over 45 show a greater mortality among males than among females.
Whooping Cough. . .	0·46	0·55	0·49	0·57	0·47	0·55	
Cancer . . .	0·20	0·43	0·24	0·52	0·32	0·62	

Many other diseases might be added to either division; for example, the male mortality exceeds the female in typhus, hydrophobia, glanders, syphilis, gonorrhœa, pyæmia, septicæmia, alcoholism, rickets, tabes mesenterica, tubercular meningitis, diabetes. Female mortality exceeds the male in erysipelas, rheumatism, and anæmia (including chlorosis and pernicious anæmia). Puerperal fever and diseases of parturition are of course limited to the female sex. Among the more vague causes, "premature birth" is assigned with greater frequency to males, and "old age" to females.

It must be remembered, however, that the true influence of sex and age in respect of disease cannot be ascertained by returns of mortality alone. It is necessary, in the first place, to obtain statistics of the number of persons living, of each sex and at each age-period, and then to calculate, for each sub-group, (1) the *incidence* of disease, that is, the proportion of attacks to population, and (2) the *case-mortality*, or proportion of deaths to attacks. The mere number of deaths at each age-period conveys little information, since the numbers living diminish rapidly as age advances. The death-rates—that is, the proportion of deaths to population in each group—tell only of the liability to death, but nothing as to the incidence of sickness or the chance of recovery. The variations in incidence and in severity, according to age and sex, are not always parallel, and indeed are often inverse.* The only satisfactory evidence as to incidence of disease at different ages is that derived from notification returns. Hospital statistics are misleading, since age materially affects the chances of removal to hospital. As regards case-mortality, however, both hospital and notification data may be admitted.

* *See* Scarlet-Fever and Enteric Fever, chapter xii.

Other disturbing influences that have to be taken into account in drawing conclusions as to the real influence of age and sex upon liability to disease are (1) acquired protection, and (2) degree of exposure. Vaccination completely alters the age-curve in small-pox. In all protective diseases the accumulation of protected survivors must be allowed for before any lessened average susceptibility at higher ages can be inferred. Differences in the degree of exposure to infection, or to the several exciting or predisposing causes, are accountable for much of the observed inequality in the incidence of certain diseases upon the two sexes. The phthisis death-rate, usually higher among men, is higher among women in many districts, owing to local industrial conditions.

Age in relation to mortality from certain diseases.—The maximum mortality from small-pox,* whooping cough, erysipelas, and diarrhœa, occurs in the first year of life, from measles in the second, from scarlet-fever in the third, and from diphtheria in the fourth. A second maximum follows in small-pox about the 25th year; and from about the same point diarrhœa mortality again rises until the end of life. Phthisis is at its minimum from the 5th to the 10th year, increases up to the 45th, and afterwards diminishes. Cancer mortality is unimportant in the earlier years, but increases rapidly from about the 25th year to the end of life. The single curve, with a minimum from the 10th to the 15th year, which is characteristic of the total death-rate (page 510), is common also to the mortality from nervous, respiratory, digestive, and urinary diseases, and violence; diseases of the circulatory system increase steadily in mortality from birth to the end of life.

The varying influence of age is seen even in infancy.

* Under present conditions. Apart from vaccination, the second year appears to be the most fatal.

Mean Annual Death-rates per 1,000 living at each Age in Sub-periods of the First Year of Life.*

	Under 3 months.	3 to 6 months.	6 to 12 months.
All Causes . . .	313·43	129·29	105·43
Small-pox . . .	1·57	0·89	0·79
Measles . . .	0·38	0·84	4·88
Scarlet-Fever . .	0·30	0·69	2·35
Diphtheria . . .	0·32	0·30	0·63
Whooping Cough .	4·56	6·14	8·12
"Fever" . . .	0·38	0·58	0·78
Diarrhœa . . .	21·00	20·14	11·86
Erysipelas . . .	1·91	0·77	0·27

Mean Annual Death-rates per 1,000 living at each Age in each of the First Five Years of Life.†

		First Year.	Second Year.	Third Year.	Fourth Year.	Fifth Year.	Years taken.
Small-pox .	M.	1·04	0·43	0·37	0·34	0·31	1854–87
	F.	0·95	0·45	0·38	0·33	0·30	
Measles .	M.	3·01	5·81	2·88	1·60	0·93	1848–87
	F.	2·52	5·46	2·94	1·68	0·96	
Scarlet-fever	M.	1·66	4·17	4·68	4·48	3·64	1859–85
	F.	1·38	3·87	4·49	4·33	3·56	
Diphtheria .	M.	0·46	0·72	0·68	0·76	0·69	1859–87
	F.	0·36	0·67	0·73	0·84	0·78	
Croup . .	M.	1·04	1·87	1·63	1·42	1·01	1848–87
	F.	0·75	1·57	1·52	1·29	0·91	
Whooping Cough .	M.	6·77	4·93	2·07	1·09	0·58	1848–87
	F.	7·31	6·22	2·95	1·63	0·86	
Diarrhœa & Dysentery	M.	18·97	5·02	1·04	0·39	0·23	1848–87
	F.	15·90	4·95	1·06	0·38	0·22	
Enteric Fever .	M.	0·18	0·31	0·36	0·34	0·34	1869–87
	F.	0·17	0·30	0·36	0·37	0·37	

* Reg.-Gen., Fifty-first Annual Report. The rates are calculated upon the statistics of 1852–70 and 1881–87.

† Reg.-Gen., Fifty-first Annual Report.

Mean Annual Death-rates from certain Causes at Different Age-periods per 1,000 living at each Age-period. England and Wales, 1871–80.

	0-5	5-10	10-15	15-20	20-25	25-35	35-45	45-55	55-65	65-75	75+
All Causes.	63·12	6·44	3·70	5·33	7·04	8·93	12·62	17·72	31·49	64·85	161·59
Small-pox .	·53	·28	·14	·20	·30	·24	·17	·11	·07	·05	·04
Measles . .	2·57	·21	·02	·01	·01	·01	·00	·00	·00	·00	·00
Scarlet-Fever	3·49	1·52	·33	·10	·06	·05	·02	·01	·01	·00	·00
Diphtheria .	·47	·29	·09	·03	·02	·02	·02	·01	·02	·02	·01
Whooping Cough . .	3·65	·14	·01	·00	·00	·00	·00	·00	·00	·00	·00
"Fever" .	·65	·52	·44	·54	·51	·41	·38	·40	·46	·55	·50
Diarrhœa. .	5·73	·07	·02	·02	·04	·06	·10	·16	·41	1·19	3·51
Cancer . .	·01	·01	·01	·02	·03	·13	·53	1·26	2·21	3·12	3·33
Phthisis . .	·77	·36	·66	2·04	3·12	3·62	3·75	3·13	2·45	1·48	·49
Diseases of Nervous System .	9·08	·57	·33	·36	·38	·60	1·20	2·25	4·91	11·43	21·28
Diseases of Circulatory System . .	·09	·14	·24	·30	·34	·62	1·31	2·27	4·81	9·48	12·09
Diseases of Respiratory System . .	12·20	·56	·20	·30	·45	·78	1·62	3·26	7·43	16·08	30·24
Diseases of Digestive System . .	1·28	·18	·15	·21	·26	·44	·90	1·67	3·01	4·84	5·69
Diseases of UrinarySystem . . .	·15	·09	·07	·10	·15	·25	·43	·66	1·20	2·21	3·31
Violence . .	1·22	·39	·35	·44	·50	·56	·72	·93	1·19	1·46	2·56

Statistical evidence of the Health of Communities.—The usual criteria adopted are the death-rate, "zymotic death-rate," and infant mortality, together with others of a different class, which are regarded as tests of the average longevity of a population—namely, "expectation of life," "probable duration of life," "mean age at death."

1. The gross death-rate, or, still better, the corrected death-rate (p. 508), affords a simple and, in the main, accurate measure of the comparative prevalence of disease. It is liable to become misleading if the figures are so small as to be exposed to violent fluctuations; thus, the "weekly death-rate" is only

useful in very large communities. Other sources of error are (i) uncertainty as to population, and (ii) severe epidemics, which may have no known relation to impaired public health in general.

2. The zymotic death-rate is a popular but very unsafe standard. A high death-rate from enteric fever, diphtheria, or diarrhœa may in general fairly be taken to imply a defective sanitary state; but may also be due to temporary and accidental causes, such as climatic conditions or accidental contamination of milk or water. Little is known of the determining causes of epidemics of small-pox, measles, whooping cough, and scarlet-fever; but their predisposing causes are all widely different, and are for the most part not affected by what are known as "sanitary conditions." The death-rate due to such a heterogeneous group denotes simply the presence or absence of grave epidemics, and connotes nothing as to the health condition of the community in other respects.

3. Infant mortality is influenced chiefly by the prevalence of epidemic diarrhœa in early autumn, by epidemics of whooping cough or measles, and by the want of proper care and management on the part of mothers. It is sometimes high in towns that have a low general death-rate—Leicester, for example; and a high infant death-rate cannot, therefore, be regarded as necessarily indicating a high tendency to death among the rest of the population. It is highest in those towns in which the causes of epidemic diarrhœa are operative, and, as a rule, high in districts where female labour is largely employed in manufactures.

At least equally significant with the zymotic death-rate and infant mortality is the *phthisis death-rate*, which, if excessive, indicates dampness of soil, unhealthy workrooms, or over-crowding of tenements.

The death-rate from respiratory diseases (other than phthisis) is also important.

4. "Mean age at death" is obtained by adding up the ages and dividing by the number of deaths. This is a very rough and imperfect measure of longevity, and is largely controlled by the birth-rate. A high birth-rate gives a large proportion of infants in the population, and hence a correspondingly large proportion of infant deaths, which must necessarily reduce the average age at death. The mean age at death is 42 years for males, and 45 years for females.

5. "Probable duration of life" is the age at which exactly half of any given number of children born will have died. It can only be ascertained from a life-table, and is of no great value or convenience as a test of longevity. The latest English life-table gives the probable duration of life for males as 47, and for females as 52 years.

6. "Expectation of life," at any age, is the average number of years which a person at that age will live, as shown by a life-table. The expectation of life at age 0—*i.e.* at birth—is also known as the "*mean duration of life.*" * At other ages than the time of birth it is sometimes termed "*mean after-lifetime,*" and the present age *plus* the mean after-lifetime is the age to which a person may expect to survive.

The expectation of life is the true measure of the vitality of a community. The expectation at birth is the most convenient for comparative purposes, but if necessary we can eliminate the influence of infant mortality by taking the expectation at later age.

* The "mean duration of life" differs from the "probable duration of life" just as the arithmetical mean of a list of numbers differs from the middle value of the series. The fact that one term has as many terms above as below it does not render it the mean of the series.

The "mean duration of life" must also be carefully distinguished from the "mean age at death." The latter expression is not employed in reference to a life-table population.

A Life-table shows how many, out of a million persons supposed to be born simultaneously, will survive at the end of each year or each term of years. The data required are (1) a census population—that is, a population of which the distribution according to ages and sexes is known; (2) returns of deaths (grouped in the same age-periods as have been adopted for the census population) for one or more years among this same population. The simplest plan is to take only the deaths in the census year, when the population is known with precision; but as it is important to obtain large numbers, it is better to use the death returns of a series of three or more years, in which the census year is central. Thus the 1881 census population may fairly be assumed to be substantially the same as the average population in the years 1880-81-82. A still more satisfactory method is to take the death returns for a whole inter-censal period, and the *mean* population. A separate table should be constructed for each sex.

Having decided upon the intervals to be taken (annual or quinquennial), the first step is to ascertain from the census returns the number living at each group of ages, and, from the death returns, the mean annual number of deaths among each group. As already explained, $\frac{\text{number of deaths}}{\text{number living}} \times 1{,}000 = \text{D} =$ the death-rate for that group of ages per thousand living. These D deaths (among 1,000 living) are assumed to be evenly distributed over the whole age-period included in the group, so that half $\left(i.e.\ \frac{\text{D}}{2}\right)$ will occur in the earlier half of the ages, and half in the later.*

* In other words, "the number of the living in any year of their age is an arithmetical mean proportional between the numbers that annually enter upon and that annually complete that year."

Hence the 1,000 persons may be regarded as decreasing from $1{,}000 + \frac{D}{2}$ at the beginning of the period to $1{,}000 - \frac{D}{2}$ at the end of it; and the ratio of the final to the initial population is $\frac{1{,}000 - \frac{D}{2}}{1{,}000 + \frac{D}{2}}$ or $\frac{2{,}000 - D}{2{,}000 + D}$. Having found the value of this ratio for each age or group of ages, we have all the data necessary for the construction of a life-table. Let us assume, for example, that the infant mortality per 1,000 births is 200.

For the first year of life the formula is not required, since it is evident from the data that 1,000,000 persons at birth (*i.e.* living at the *commencement* of the year in question) will be reduced to 800,000 during the year. The number commencing the second year is 800,000; taking the death-rate during that year of age as 65 per thousand living, the formula becomes $\frac{2{,}000 - 65}{2{,}000 + 65}$, or $\frac{1{,}935}{2{,}065}$, and, as already explained, the 800,000 living at the beginning of the second year will be reduced to $\frac{800{,}000}{1} \times \frac{1{,}935}{2{,}065}$, or 749,637 at its close. In like manner the survivors at the end of the third, fourth, and fifth years are determined. After the fifth year it is usual to proceed by 5-yearly periods, but the method is substantially the same. Suppose, for instance, that we have already found that of the million only 700,000 survive at the end of the fifth year; and that the mean annual

(Milne, quoted by Farr). An earlier hypothesis (De Moivre's) assumed that the numbers living decreased in arithmetical progression down to nothing at the age of eighty-six years.

death-rate among persons aged five to ten years is 6·5. This death-rate is assumed to be true of each of the five years, hence the formula of reduction for each year is $\frac{2{,}000-6{\cdot}5}{2{,}000+6{\cdot}5}$, and for the *five* years $\left(\frac{2{,}000-6{\cdot}5}{2{,}000+6{\cdot}5}\right)^5$. At the end of the tenth year, therefore, the 700,000 will have become reduced to $700{,}000 \times \left(\frac{2{,}000-6{\cdot}5}{2{,}000+6{\cdot}5}\right)^5$ —which, by the aid of logarithms, is readily found to be 677,615.

The process is repeated for each quinquennium until no more survivors are left.

In general terms, if P = the number of persons living at the beginning of any age-quinquennium, and P^1 = the number surviving at the end of it, and D = the death rate per 1,000 per annum for that age period, then

$$P^1 = P \times \left(\frac{2000-D}{2000+D}\right)^5.$$

Decennial may of course be substituted for quinquennial periods. If this is done, the annual death-rate D must be calculated for the ten-year age period as a whole, and the formula will be

$$P^1 = P \times \left(\frac{2000-D}{2000+D}\right)^{10}.$$

A life-table, therefore, traces the history of a hypothetical generation which lives through each period of its life under the conditions that attend each such period during the era under examination. It eliminates the disturbing influence of a variable birth-rate and migration-rate, which introduce many fallacies into any attempted estimation of longevity from mere death-rates in a changing population. A census return gives the numbers living at ages *between* certain fixed points; a life-table, on the other hand, shows the relative numbers surviving *at* certain points of time, or rather of age, and thus enables us to calculate the expectation of life at any such point.

English Life-Tables, based upon the Mortality in 1838–54 (Farr) and 1871–80 (Ogle).

Age	Males.				Females.			
	Survivors at each Age out of 1,000,000 born.		Expectation of Life.		Survivors at each Age out of 1,000,000 born.		Expectation of Life.	
	1838–54	1871–80	1838–54	1871–80	1838–54	1871–80	1838–54	1871–80
0	1,000,000	1,000,000	39·9	41·4	1,000,000	1,000,000	41·9	44·6
1	836,405	841,417	46·7	48·1	865,288	871,266	47·3	50·1
2	782,626	790,201	48·8	50·1	811,711	820,480	49·4	52·2
3	754,849	763,737	49·6	50·9	782,990	793,359	50·2	53·0
4	736,845	746,587	49·8	51·0	764,060	775,427	50·4	53·2
5	723,716	734,068	49·7	50·9	750,550	762,622	50·3	53·1
10	689,857	708,990	47·1	47·6	715,769	738,382	47·7	49·8
15	672,776	696,419	43·2	43·4	696,917	724,956	43·9	45·6
20	651,903	680,033	39·5	39·4	674,119	707,949	40·3	41·7
25	624,221	657,077	36·1	35·7	644,342	684,858	37·0	38·0
30	595,089	630,038	32·8	32·1	612,774	658,418	33·8	34·4
35	564,441	598,860	29·4	28·6	579,908	628,842	30·6	30·9
40	531,657	563,077	26·1	25·3	545,844	596,113	27·3	27·5
45	495,770	522,374	22·8	22·1	510,403	560,174	24·1	24·1
50	455,727	476,980	19·5	18·9	473,245	520,901	20·8	20·7
55	409,460	424,677	16 5	16·0	433,331	477,440	17·4	17·3
60	356,330	365,011	13·5	13·1	383,974	422,835	14·3	14·2
65	294,588	297,156	10·8	10·6	324,165	356,165	11·5	11·4
70	223,490	222,056	8·5	8·3	253,161	277,225	9·0	9·0
75	148,076	144,960	6·5	6·3	174,800	190,566	6·9	6·9
80	80,343	77,354	4·9	4·8	100,394	108,935	5·3	5·2
85	32,979	30,785	3·7	3·6	44,419	47,631	4·0	3·9
90	9,321	8,015	2·8	2·7	13,802	14,225	3·0	2·9
95	1,628	1,183	2·2	2·0	2,704	2,533	2·3	2·2
100	154	82	1·7	1·6	295	225	1·8	1·6

The expectation of life at any age A is calculated by adding together the years of life lived through by the whole of the life-table population after that age, and dividing by the number of survivors at age A. Thus to find the expectation of life at fifty years of

age in males according to the 1871–80 life-table, the first step is to add together the numbers surviving at each later age : this gives the number of complete quinquennia lived through = 1,571,279. But in addition to the quinquennia which he completes, each of the 476,980 males surviving at age 50 lives through some portion of that quinquennium in which he dies. By a further application of Milne's principle this fraction is averaged as half a quinquennium, and hence we have to add 476,980 half-quinquennia to the 1,571,279 quinquennia. We thus get a total of 1,809,769 quinquennia or 9,048,845 years of future life; and this divided among the 476,980 who are alive at age 50, gives the expectation of life as 19 years.

The expectation of life is somewhat greater among females than among males, at all ages. It is greatest in both sexes at about four years of age, when the dangers of early childhood have been safely passed. Comparing the old and the new life-tables, the expectation of life is seen to be greater under the new than under the old conditions up to the nineteenth year of life in males, and the forty-fifth in females. Beyond these ages it is less, owing to the increase which had taken place in the death-rates in males over thirty-five, and females over forty-five years of age, as shown in an earlier table. Nevertheless, the number of survivors at ages up to sixty-seven in males and ninety-two in females remained greater under the new table, the apparent paradox being due to the fact that the saving in life during the earlier years was sufficiently great to withstand for a long time the increased death-toll at higher ages. Out of a million persons born, there were so many more survivors at the age of forty-five, for example, that although they died faster than formerly they retained their numerical superiority for many years.

The net result is that the average length of life has increased, and Humphreys has shown that two-thirds of the increase occurs in the period of greatest usefulness—namely, at ages between twenty and sixty.

In the absence of a life-table, an approximation to the expectation of life may be obtained by the use of one of the following formulæ.

(1) If x = expectation of life at any age a between 25 and 65 years, then $x = \frac{2(80 - a)}{3}$. (*Willich.*)

(2) If x = expectation of life at birth, and D = death-rate per 1,000, and B = birth-rate per 1,000, then $x = \frac{2{,}000}{3\text{D}} + \frac{1{,}000}{3\text{B}}$. (*Farr.*)

(3) If x = expectation of life at birth, and b = birth-rate per unit of population, and d = death-rate per unit, then $x = \frac{\log. b - \log. d}{\log. (1 + b - d)}$. (*Bristowe.*)

Sickness-rates, unlike death-rates, involve the question of duration, and also the adoption of some fixed standard of "illness," applicable to persons of all ages.

Estimates have been made of (1) the years of constant sickness in a given population, per one annual death; the average is from two to three years. (2) The weeks of sickness to which each individual is liable on the average during each year. For ages from fifteen to sixty-five this average is 1·3 week, and it has been given as about 2 weeks, including all members of Friendly Societies. (3) The average number of cases of illness to each death. In Manchester this was found to be about 30. (4) The average duration of each illness.

Most of the statistical evidence is drawn from the experience of Friendly Societies, industrial organisations, and the army, navy, and police. All of these

are more or less selected bodies, and cannot be regarded as fairly representing the whole of the population in more than a general way, either in composition as to age and sex, or in average liability to disease and death.

Farr quotes from Neison certain Friendly Society data of fifty years ago, upon which the following figures are based :—

	No. of years of Constant Sickness corresponding to 1 annual death.	Annual average duration of sickness per head, in weeks.	Average duration of each illness, in weeks.
10 to 20 years.	2·5	1	6
20 to 30 ,,	2·4	1	5
30 to 40 ,,	2·3	1	5
40 to 50 ,,	2·6	2	6
50 to 60 ,,	2·7	3	13
60 to 70 ,,	4·2	8	32
70 to 80 ,,	5·3	21	93
Over 80 ,,	4·4	29	212

It seems, therefore, that after 40 years of age the average duration of each illness steadily increases, and with it the "expectation of sickness," and even the proportion of sickness to deaths.

More recent statistics, based upon the experience of the Manchester Unity of Oddfellows, are fairly in accordance :—

	Average Annual No. of Weeks of Sickness	
AGES.	Males.	Females.
15 to 20	·67	·67
20 to 25	·74	·74
25 to 45	·99	·99
45 to 65	2·74	2·75
15 to 65	1·31	1·33

And these figures, applied to the census returns of 1881, indicate a loss to the community of ten million

weeks per annum of male work and the same of female work, at ages from 15 to 65 years.

Seasonal variations in the incidence of disease.—The admirable statistical investigations of Buchan and Mitchell have shown that most diseases, and well-defined groups of diseases, have a fairly constant relation to season, so that it is often possible to predict the time of their maximum and minimum mortality. Little is known of the exact climatic conditions upon which this seasonal rhythm of disease depends, but, as will be seen, many of them have an obvious relation to heat and cold; thus there is a winter maximum in deaths from apoplexy and diseases of lungs, heart, and kidneys; and a summer maximum as regards diarrhœa, tabes mesenterica, and thrush. Scarlet-fever, enteric fever, diphtheria, puerperal fever, erysipelas, and rheumatism, have their maximum about November; small-pox and whooping cough have a spring maximum; and so, too, have phthisis, "convulsions," gout, and laryngitis.

It will be understood that the seasonal curves are based upon the statistics of many years, and are liable to great variation as to time and range in any given year, owing to the irregularity of the meteorological conditions upon which they are probably dependent.

In the following table the average season of maximum and minimum prevalence is stated for certain diseases; and in order to afford some idea of the range of seasonal variation in each case, an approximate statement is given of the percentage excess or deficiency of the extreme points, as compared with the average prevalence of the disease in question throughout the whole year. The table is based upon London mortality returns only.

Measles and a few more have a double seasonal curve, with two maxima and two minima (page 280).

Cancer is an instance of an important cause of death which has no characteristic seasonal curve.

SEASONAL CURVE OF MORTALITY FROM CERTAIN DISEASES (LONDON). [Fig. 23.]

Cause of Death.	Greatest Mortality.	Per cent. excess above annual mean.	Least Mortality.	Per cent. below annual mean.
ALL CAUSES.	(1) Dec. to March.	10	(1) June.	15
	(2) July to August	5	(2) October.	10
Small-pox	January to May.	30	Sept. and Oct.	40
Measles	(1) December.	40	(1) September.	30
	(2) June.	20	(2) February.	20
Scarlet-Fever	October.	60	March to May.	35
Diphtheria	Nov., December.	20	May, June.	15
Whooping Cough	March, April.	40	Sept., Oct.	40
Enteric Fever	November.	30	June.	30
Typhus	January.	20	September.	20
Erysipelas	Nov., December.	30	May to Aug.	20
Puerperal Fever	November.	40	August.	30
Other deaths from childbirth	Dec., January.	20	June, July.	15
Diarrhœa*	July (4th week), Aug. (1st and 2nd weeks).	300	Dec. to May.	70
Rheumatism	November.	30	August.	30
Alcoholism	July. †	20	Dec. to Mar. †	20
Gout	April.	30	September.	30
Phthisis	March, April.	10	September.	10
Apoplexy, Paralysis‡	Dec. to March.	20	July, August.	20
Convulsions §	March. ‖	20	September. ‖	20
Diseases of Circulatory System	Nov. to January.	20	August.	20
Laryngitis	March.	60	Aug., Sept.	40
Bronchitis	January.	70	August.	60
Pneumonia	Jan. and March.	50	August.	50
Pleurisy	December.	30	August.	30
Kidney Disease	Nov. to April.	15	June to Aug.	10
Old Age	January.	35	June to Oct.	25

* The seasonal curve of thrush (range + 90 per cent. to − 30 per cent.) is practically identical with that of diarrhœa. Tabes mesenterica (+ 50 per cent. to − 20 per cent.) has a very similar curve, but less pronounced; so, too, with enteritis (+ 50 per cent. to − 20 per cent.), and also with atrophy and debility (+ 30 per cent. to − 20 per cent.).

The next table shows the seasonal curves of mortality from all causes at certain ages :—

Ages.	Period of Maximum Mortality.	Per cent. above Annual Mean.	Period of Minimum Mortality.	Per cent. below Annual Mean.
0–1	4th wk. in July to 2nd wk. in Aug.	75	Apr., May, June	25
1–5	(1) Feb. to April	10	June, July .	20
	(2) July, Aug. .	nil	September .	10
5–20	December . .	5	July, August .	5
20–40	December . .	15	August . .	15
40–60	December . .	30	August . .	20
60–80	December . .	40	August . .	25
80 upwards	December . .	50	August . .	35

The mortality at ages from 5 to 20 is scarcely affected by season, but shows a slight excess at mid-winter and a slight falling-off at mid-summer.

The position of the maximum and minimum points remains the same at all later ages, but a rapidly increasing sensitiveness to cold is manifested by the wider range of seasonal curve. The winter maximum is only about 5 per cent. above the annual mean at ages from 5 to 20 years, but reaches 50 per cent. at ages over 80 years.

Below five years of age a similar increase in sensitiveness to climatic conditions is found; but the greatest danger is from heat, not from cold. From one to five years the principal maximum occurs in the

† There is, however, a brief second maximum at the end of December and beginning of January.

‡ Epilepsy has a similar curve (+ 20 per cent. to − 20 per cent.).

§ The curve for "teething" is practically identical with this (+ 25 per cent. to − 25 per cent.).

‖ A small secondary maximum occurs at the end of July.

early spring, owing to seasonal prevalence of whooping cough and measles; but there is also a distinct rise in

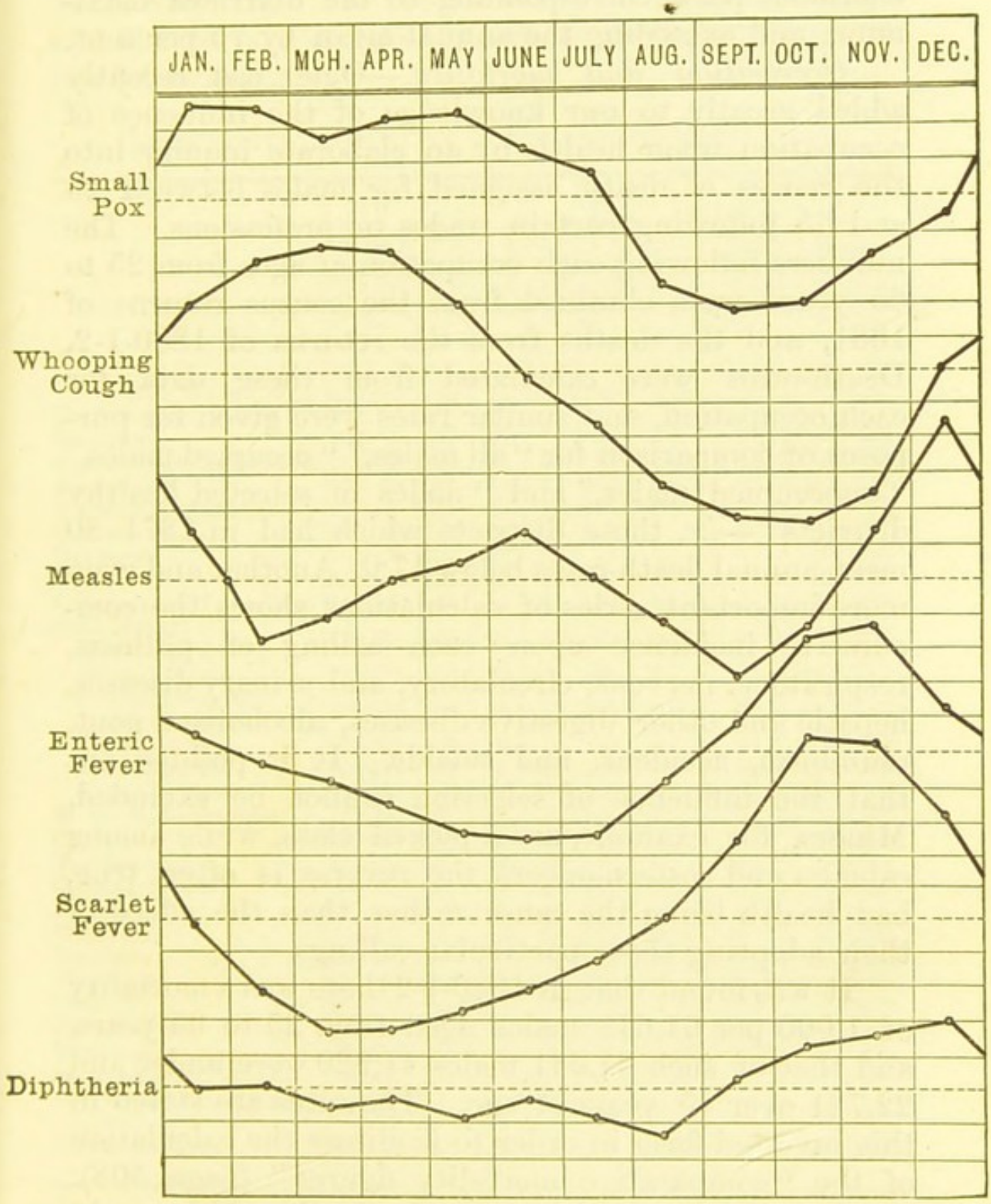

Fig. 23.—Seasonal Curves of Mortality (London). Mean of 40 Years except Diphtheria (20 years), and Enteric Fever (12 years).

Each division corresponds to 10 per cent. above or below the mean annual mortality indicated by the dotted line.

July and August, due to diarrhœal diseases. Under one year of age this minor elevation becomes an enormous peak, corresponding to the diarrhœa maximum, and exceeding the annual mean by 75 per cent.

Occupation and mortality.—Ogle has recently added greatly to our knowledge of the influence of occupation upon health by an elaborate inquiry into the causes of death assigned for males between 25 and 65 following certain trades or professions. The numbers following each occupation at ages from 25 to 65 years were obtained from the census returns of 1881, and the deaths from the returns of 1880-1-2. Death-rates were calculated from these data for each occupation, and similar rates were given for purposes of comparison for "all males," "occupied males," "unoccupied males," and "males in selected healthy districts"—*i.e.* those districts which had in 1871–80 mean annual death-rates below 17·0. Another and even more important series of calculations shows the comparative incidence upon each calling of phthisis, respiratory, nervous, circulatory, and urinary diseases, hepatic and other digestive diseases, alcoholism, gout, plumbism, accident, and suicide. It is pointed out that the influence of selection cannot be excluded. Miners, for example, are a picked class, while among cabmen and costermongers the reverse is often true, bad health being the cause rather than the effect of their adopting those particular callings.

It was found that in 1880-1-2 there was a mortality of 1,000 per 64,641 males aged from 25 to 65 years, and that of such 64,641 males 41,920 were under and 22,721 over 45 years of age. The rates are stated in this inverted form in order to facilitate the calculation of the "comparative mortality figures" (page 508). The next step was to estimate the deaths which would occur in a similar population entirely engaged in each respective occupation—for instance, in a male

population of 64,641 farmers, of whom 41,920 were aged from 25 to 45 years, and the remaining 22,721 from 45 to 65 years. The results as regards total mortality, and also certain specified causes of death, are given in the following table :—

Comparative Mortality according to Occupation.

	Phthisis.	Respiratory Diseases.	Nervous Diseases.	Urinary Diseases.	Liver Diseases.	Circulatory Diseases.	Gout.	Alcoholism.	Plumbism.	Suicide.	Accident.	Comp. Mort. Figures.
All Males England and Wales	220	182	119	41	39	120	3	10	1	14	67	1000
Farmers	103	99	81	31	41	84	2	6	0	17	30	631
Agricultural Labourers	122	156	80	22	20	97	1	1	0	9	33	701
Fishermen	108	90	81	14	32	153	0	4	0	13	152	797
Hosiery Manufacture	168	115	114	42	16	104	0	1	0	22	16	717
Grocers	167	116	107	48	52	107	2	10	0	17	14	771
Drapers	301	129	109	37	35	75	2	8	0	5	23	883
Bakers	212	186	136	40	46	131	2	15	0	26	21	958
Commercial Travellers	240	147	139	44	61	100	6	23	0	31	36	948
Coal Miners :— Notts and Derby	118	138	64	18	17	59	0	4	0	5	163	734
West Riding	111	172	60	23	21	88	0	1	0	5	161	772
Northumberland and Durham	135	122	88	26	33	105	0	4	0	5	196	873
Lancashire	125	229	83	24	18	96	0	3	0	*	198	929
Staffordshire	102	260	81	38	20	104	0	1	0	3	172	929
South Wales	166	293	60	34	24	120	0	5	0	4	229	1081
Wool Manufacture	257	205	127	36	36	142	0	4	0	15	27	1032
Cotton ,,	272	271	142	32	43	112	0	3	0	*	30	1088
Earthenware ,,	473	645	140	49	49	160	0	8	10	*	24	1742
Cornish Miners	690	458	117	38	40	111	0	2	0	4	117	1839
Tailors	285	186	144	45	48	127	4	11	0	16	18	1051
Butchers	261	208	139	55	96	132	5	23	0	23	35	1170
Printers	461	166	90	30	28	93	0	3	5	8	24	1071
Plumbers	246	185	167	100	48	140	10	12	21	21	73	1202
Cutlers	371	389	190	35	30	180	0	3	0	*	17	1309
File-Makers	433	350	262	123	41	180	0	3	41	*	6	1667
Brewers	334	236	144	55	96	165	9	25	0	11	64	1361
Innkeepers	140	217	200	83	240	140	13	55	0	26	45	1521
Drivers (cab and omnibus)	359	341	134	65	54	160	11	33	0	16	84	1482
Costermongers	475	420	207	69	47	227	3	19	0	44	53	1879

The comparative mortality figures for many other

* Deaths from suicide classed with those from nervous diseases.

occupations are also given. Among them are the following:—

Clergy	556	Law Clerks	1,150
Teachers	719	Hairdressers	1,327
Lawyers	842	Bargemen	1,305
Paper Manufacture	717	Chimney Sweeps	1,519
Lace „	755	General Labourers (London)	2,020
Silk „	845	Inn Servants*	2,205
Shopkeepers generally	877		
Medical Men	1,122		

All Males	1,000
Occupied Males	967
Unoccupied Males	2,182
Males in "selected healthy districts"	804

Phthisis and respiratory diseases cause a high mortality among debilitated persons, especially those exposed to weather, to hot or impure air, and to certain forms of organic or inorganic dust. Hence the mortality from these causes is high among costermongers, tailors and drapers, wool and cotton workers, cutlers, file-makers, potters, printers, and highest of all in Cornish miners. The comparatively low mortality from phthisis among coal-miners is difficult to explain. Perhaps the particles of coal are less irritating than stone or metallic particles, being comparatively free from sharp angles (*Hirt*). The same immunity from phthisis has been observed among coal-miners in other countries, but it must not be forgotten that the nature of the employment excludes weakly persons, and that coal-mines are well ventilated. Contrary to the popular belief, butchers are somewhat liable to phthisis.

Nervous diseases cause excessive mortality among those addicted to drinking, and apparently among

* Neison's statistics show that among "intemperate persons" the comparative mortality figure is 3,240.

persons liable to plumbism; the most fatal occupations in this respect are those of innkeepers, costermongers, cutlers, file-makers, and plumbers. The incidence of gout and of fatal kidney disease is very similar. Mortality from diseases of the liver is in the main associated with mortality from alcoholism, both being high among commercial travellers, butchers, brewers, and innkeepers, and above the average among cabmen and costermongers. Suicide also has a fairly close relation to intemperance.

Diseases of the circulatory system are most fatal among costermongers, cabmen, fishermen, brewers, publicans, potters, plumbers, file-makers, and workers in wool. Plumbism, as well as alcoholism, would, therefore, appear to be a cause of some forms of heart disease. It is possible that the intermittent violent exertions of fishermen, and rheumatism due to exposure, may account for the high mortality from this class of disease.

These figures tend to establish a relation between intemperance and diseases of the heart, liver, kidneys, and nervous system, and also phthisis, gout, and suicide. Lead poisoning, similarly, is seen to be associated with diseases of the kidney, heart, and nervous system, and also with gout, except perhaps as regards file-makers. Hirt considers plumbism to be conducive to phthisis, but this is open to question.

Value of statistical series and averages.—The *mean* or *average* of a series of numbers is a number which lies between the greatest and least of these, and stands in a definite dependence upon the whole of the series (*Radicke*). There are several kinds of means. Thus, if the series consists of four numbers—namely, a, b, c, and d—we have

The *arithmetic* mean, or simple average, $\frac{a+b+c+d}{4}$.

The *geometric* mean, $\sqrt[4]{a\,b\,c\,d}$.

The *harmonic* mean, $\frac{4}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}$.

The *quadratic* mean, $\sqrt{\frac{a^2+b^2+c^2+d^2}{4}}$.

When the terms of the series are equal, all kinds of means are also equal; but if otherwise, the quadratic is the highest, then the arithmetic, geometric, and harmonic, in the order stated.

The simple average, or arithmetic mean, is by far the most generally adopted, and mainly in three classes of cases :—

1. *As a pure average;* for example, the average age of a number of persons. The terms are exact, and the "mean" has no significance as regards any individual. Thus, the ages of ten persons whose deaths were attributed to diarrhœa might be 1, 1, 1, 1, 71, 71, 1, 1, 1, 71; and those of ten who died from enteric fever 17, 18, 26, 29, 25, 20, 16, 19, 24, 26. These two series have nothing in common as regards the individuals, but the average of each is 22. The mean temperature of a day or year is a simple average of the observations which are taken into account. Similarly, if we mix together equal volumes—say, an ounce of each—of four saline solutions containing respectively 10, 20, 30, and 40 grains of salt per ounce, the whole will contain 25 grains per ounce.

2. *As a probable true value of a definite quantity.* —It may be taken as an axiom that, given two conditions equally likely to occur, the frequency of the one becomes more and more certainly equal to that of the other, in proportion as the number of observations increases. If a coin be tossed 1,000 times, it is highly improbable that heads will turn up much more or much less than 500 times; but if there are only 10

trials, there is little certainty of approximate equality. If in a given series of measurements of a fixed quantity (an angle, for instance), the errors of experiment are exactly as likely to be in excess as in deficiency, these errors will neutralise each other if we take the mean of a sufficiently large number of observations. An error of magnitude x in a single observation will affect the mean to the extent $\frac{x}{10}$ in a series of ten observations, but only $\frac{x}{1{,}000}$ in a series of a thousand terms. The more extended the series, the greater the probability of accuracy, which increases as the square root of the number of observations.

If the measurements are of equal precision, a closer but less simple approximation to the probable true value sought may be obtained by adopting the principle of Least Squares : that is, by finding such a mean value that the sum of the squares of the residual errors of the observations shall be a minimum.

3. *As a probable value of a variable quantity* determined under average conditions ; for example, the average daily excretion of urea, as determined by a series of more or less exact measurements under varying conditions as to food and exercise. The terms of the series are not exact, being open to experimental errors ; and there is no fixed point of exact truth to be arrived at, so that this case differs from the first two. In the first case we had a true average ; in the second, a probable value of a fixed quantity : here we have a probable value of an average.

In vital statistics absolutely fixed points are of rare occurrence, and most of the problems ought, strictly speaking, to be classed under the third heading. In any case, it is important to be able to determine the value of a series of observations ; that is, how far the mean is a trustworthy approximation to the true

value sought. As already explained, the value of a series of observations increases with the number of observations, and with their equality. Another important test is that of "*successive means.*" For this purpose we take the mean of the first two terms $\left(\frac{a+b}{2}\right)$, of the first three $\left(\frac{a+b+c}{3}\right)$, of the first four $\left(\frac{a+b+c+d}{4}\right)$, and so on. These "successive means" may vary sharply at first; but presently the first figure becomes stationary; then the second; and finally, if the series is sufficiently extended, the later successive means cease to vary materially. If the successive means, carried to the end of the series of terms, do not attain the required degree of constancy, the series is too short.

A further criterion is the determination of the "error;" that is, the divergence of the individual terms of the series from its mean. The *mean error in excess* and the *mean error in deficiency* are simply the arithmetic means of the errors of those terms which fall respectively above and below the mean of the series. The *mean error of the series* is the average of the mean errors in excess and deficiency. The greater the mean error, the greater is the need for an extended series in order to compensate for the uncertainty of each observation. Radicke prefers to adopt the quadratic mean error rather than the arithmetic, described above, since the former increases more rapidly with the inequality of the terms.

The maximum error, whether in excess or deficiency, is useful as showing the *possible* error of a limited number of observations. Another way of estimating the error is to determine the "*error of mean square.*" In a series of n terms, Q being the quadratic mean and A the arithmetic mean, the "error of mean square" is $\frac{Q-A}{(n^2-n)}$.

Finally, by multiplying the mean error by ·6745 or $\frac{2}{3}$ we get the *probable error*, so called because it is probable that, if the series were prolonged indefinitely, the errors would as often exceed as fall short of this quantity.

Whatever mode of gauging the liability to error is adopted, the value of a series (as indicating by its mean the true value of some definite quantity) increases as the proportion of the "error" to the mean diminishes. The relative value varies inversely as the square of the "probable error."

Statistics are often presented to us in bulk, and the same question of sufficiency arises. For instance, there are 6,288 persons suffering from scarlet fever in a certain population, and 2,861 of these are of ages under five years; are these numbers sufficiently great to enable us to affirm that the proportion $\frac{2,861}{6,288}$, or 45·5 per cent., is approximately constant? Such data are really the sum or average of suppressed series, and their value is proportionate to the square root of their magnitude. Poisson proposed to measure the liability to error thus:—If of μ observations, m are in one category and n in other categories, and $m + n = \mu$, then the true proportion of the m category to the total μ lies between $\frac{m}{\mu} + 2\sqrt{\frac{2mn}{\mu^3}}$ and $\frac{m}{\mu} - 2\sqrt{\frac{2mn}{\mu^3}}$; that is, within a possible range of $4\sqrt{\frac{2mn}{\mu^3}}$, or $\sqrt{\frac{32 \times m \times n}{\mu^3}}$. Applying this test to the scarlet-fever figures given above, the formula becomes $\sqrt{\frac{32 \times 2,861 \times 3,427}{(6,288)^3}}$, which by means of logarithms is found to be equal to about $\frac{36}{1,000}$. Hence the

indicated proportion, 45·5 per cent., is liable to a range of error of 3·6 per cent., from 43·7 to 47·3.

It may also be possible to divide the total μ into two or more fairly equal parts, and thus ascertain if the proportion $\frac{m}{\mu}$ is approximately constant in each. Such constancy would tend to show that the proportion was a fixed quantity, and not a mere average.

The preceding remarks have reference mainly to series that are intended to show by their mean some true fixed quantity. Very commonly, however, series are used for a totally different purpose—namely, the exhibition of progressive changes or fluctuations. In such cases the general considerations as to magnitude still apply, but the determinations of "error" have no significance except in regard of the individual terms of the series. It is often convenient, for the purpose of comparing the fluctuations of different series, to adopt **Buchan and Mitchell's method**—namely, to state each term of a series as a percentage of the arithmetic mean of the series. In this way all series, whether the terms are large or small, are reduced to the same scale, and their true differences and resemblances can be seen at a glance. The curves in Fig. 23 may serve as an example.

If the terms of a series are based upon scanty statistics, the accidental irregularities may be so great as to obscure the true curve. Some degree of this is evident in respect of diphtheria in Fig. 23. A clearer indication of the general outline may in such cases often be obtained by **Bloxam's method**—that is, by substituting for each term the mean of three adjoining terms. Thus in a series a, b, c, d, e, f, g, etc., we should substitute (a), $\frac{a+b+c}{3}$, $\frac{b+c+d}{3}$, $\frac{c+d+e}{3}$, etc. This treatment is, of course, arbitrary and curves so constructed are not to be regarded as exact in detail.

APPENDIX I.

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____ *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.* (a)	Mortality from all causes, at subjoined Ages.							Mortality					
	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)	1 Small-pox.	2 Scarlatina.	3 Diphtheria.	4 Membranous Croup.	5 Typhus.
								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

Add *								Under 5					
								5 upwards					
Deduct †								Under 5					
								5 upwards					

* Deaths occurring outside the division

† Deaths occurring within the division

in the ..... *Sanitary District of* ..... ;

FROM SUBJOINED CAUSES, DISTINGUISHING DEATHS OF CHILDREN UNDER FIVE YEARS OF AGE.

6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
FEVERS																
Enteric or Typhoid.	Continued.	Relapsing.	Puerperal.	Cholera.	Erysipelas.	Measles.	Whooping Cough.	Diarrhœa and Dysentery.	Rheumatic Fever.	Ague.	Phthisis.	Bronchitis, Pneumonia, and Pleurisy.	Heart Disease.	Injuries.	All other Diseases	TOTAL.

of the Mortality of this Division of the Sanitary District. *See Note* 5.

or district among persons belonging thereto.
or district among persons not belonging thereto.

(B)—TABLE OF POPULATION, BIRTHS, AND

to the knowledge of the Medical Officer of Health, during the 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. Census 1891. (b)	Estimated to middle of yr. 189... (c)	Registered Births. (d)	Aged under 5 or over 5. (e)	New Cases of Sickness in each Locality coming of the Medical Officer of Health. 1 Small-pox.	2 Scarlatina.	3 Diphtheria.	4 Membranous Croup.	Fevers. 5 Typhus.	6 Enteric or Typhoid.	7 Continued.	8 Relapsing.	9 Puerperal.
				Under 5									
				5 upwards									
				Under 5									
				5 upwards									
				Under 5									
				5 upwards									
				Under 5									
				5 upwards									
				Under 5									
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				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 above-mentioned Diseases, insert in the columns with blank headings the cordingly. State here the name of the Isolation Hospital used by the situated; and if not within the District, state where it is situated.....

OF NEW CASES OF INFECTIOUS SICKNESS *coming year* 18....., *in the* .....*Sanitary District of*..... ;

to the knowledge				Number of such Cases Removed from their Homes in the several Localities for Treatment in Isolation Hospital.												
10	11	12	13	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
								FEVERS.								
Cholera.	Erysipelas.			Small-pox.	Scarlatina.	Diphtheria.	Membranous Croup.	Typhus.	Enteric or Typhoid.	Continued.	Relapsing.	Puerperal.	Cholera.	Erysipelas.		

in the District..... Since when?..... Besides the names of any that are notifiable in the District, and fill the columns ac- sick of the District. Mark (H) the Locality in which such Hospital is

.....

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," "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.

   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 Col. (*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.

APPENDIX II.

Statistical Tables drawn up by the Society of Medical Officers of Health.

TABLE I.

Showing the Population, Inhabited Houses, Marriages, Births, and Deaths for the year 18 , *and* 10 *years preceding.*

GROSS NUMBERS.

The Year.*	Estimated Population.	No. of Inhabited Houses.	Marriages.	Registered Births.†	Corrected Number of Deaths.			Deaths in Public Institutions.
					Total at all ages.	Under one year.	Under five years.	
18								
18								
18								
18								
18								
18								
18								
18								
18								
18								
Average of 10 yrs. 18 —18								

NOTES.

1. Population at Census 18 .
2. Average Number of Persons in each house at Census 18 .
3. Area of District.

* For statistical purposes the Registrar-General estimates the population to the middle of the year, on the basis of the rate of increase ruling between the two preceding census periods. The estimate of the population may be checked by the known number of inhabited houses, and by the average number of inmates per house, as ascertained at the preceding census.

† Either in this Table or in the text of the Report, the births should be classified into legitimate and illegitimate, and also according to sex. —(B A.W.)

TABLE II.

Showing the Annual Birth- and Death-Rates, Death-Rates of Children, and proportion of Deaths in Public Institutions, in a thousand Deaths, for the year 18 *and* 10 *years preceding.*

In Year	Birth-Rate per 1,000 of the Population.	Corrected Death-Rate per 1,000 of the Population.	Deaths of Children under one year, per 1,000 of Registered Births.	Deaths of Children under one year, per 1,000 of Total Deaths.	Deaths of Children under five years, per 1,000 of Total Deaths.	Deaths in Public Institutions; per 1,000 of Total Deaths.
18						
18						
18						
18						
18						
18						
18						
18						
18						
18						
18						
Average of 10 yrs. 18 —18						

TABLE III.

Showing Deaths registered from All Causes during the year 18...

Note.—The deaths of Non-Residents occurring in Public Institutions situated in the District are excluded, and the deaths of Residents occurring in Public Institutions situated beyond the limits of the District are included.

	Ages.											Totals.	
	0 to 1	1 to 5	5 to 15	15 to 25	25 to 35	35 to 45	45 to 55	55 to 65	65 to 75	75 to 85	85 and upwds.		55 to 60*
I.—Specific Febrile or Zymotic Diseases ...													
II.—Parasitic Diseases													
III.—Dietetic Diseases													
IV.—Constitutional Diseases													
V.—Developmental Diseases													
VI.—Local Diseases													
VII.—Deaths from Violence													
VIII.—Deaths from ill-defined and not specified causes													
Totals													
I.—Specific Febrile or Zymotic Diseases:													
1.—*Miasmatic Diseases.*													
Small-pox { Vaccinated													
Small-pox { Unvaccinated													
Small-pox { No Statement													

* By filling in this Column, the Statistics of Table III. will be made comparable with those of the Weekly and Quarterly Returns of the Registrar-General, and also available for the Reports required by the Local Government Board.

TABLE III. * (*continued.*)

1.—*Miasmatic Diseases* * (*continued*).
- Measles ... ...
- Scarlet-Fever ... ...
- Typhus ... ...
- Whooping Cough ... ...
- Diphtheria ... ...
- Simple Continued and Ill-defined Fever ... ...
- Enteric or Typhoid Fever ... ...
- Other Miasmatic Diseases ... ...

2.—*Diarrhœal Diseases.*
- Simple Cholera ... ...
- Diarrhœa, Dysentery ... ...

3.—*Malarial Diseases.*
- Remittent Fever ... ...
- Ague ... ...

4.—*Zoogenous Diseases.*
- Cow-pox and Effects of Vaccination ... ...
- Other Diseases (*e.g.* Hydrophobia, Glanders, and Splenic Fever) ... ...

5.—*Venereal Diseases.*
- Syphilis ... ...
- Gonorrhœa, Stricture of Urethra ... ...

6.—*Septic Diseases.*
- Erysipelas ... ...
- Pyæmia, Septicæmia ... ...
- Puerperal Fever ... ...

II.—Parasitic Diseases:
- Thrush and other Vegetable Parasitic Diseases ...
- Worms, Hydatids, and other Animal Parasitic Diseases ... ...

III.—Dietetic Diseases:
- Want of Breast Milk—Starvation ... ...
- Scurvy ... ...
- Chronic Alcoholism ... ...
- Delirium Tremens ... ...

IV.—Constitutional Diseases:
- Rheumatic Fever, Rheumatism of the Heart ...
- Rheumatism ... ...
- Gout ... ...
- Rickets ... ...
- Cancer, Malignant Disease ... ...
- Tabes Mesenterica ... ...
- Tubercular Meningitis, Hydrocephalus ... ...
- Phthisis ... ...
- Other forms of Tuberculosis, Scrofula ... ...
- Purpura, Hæmorrhagic Diathesis ... ...
- Anæmia, Chlorosis, Leucocythæmia ... ...
- Glycosuria, Diabetes Mellitus ... ...
- Other Constitutional Diseases ... ...

V.—Developmental Diseases:
- Premature Birth ... ...

* The age-columns are omitted here to avoid unnecessary repetition. They are of course the same throughout the Table.

TABLE III. (*continued*).

V.—DEVELOPMENTAL DISEASES (*continued*):
- Atelectasis ... ...
- Congenital Malformations ... ...
- Old Age ... ...

VI.—LOCAL DISEASES:

1.—*Diseases of the Nervous System.*
- Inflammation of the Brain or Membranes ...
- Apoplexy, Softening of Brain, Hemiplegia, Brain Paralysis ... ...
- Insanity, General Paralysis of the Insane ...
- Epilepsy ... ...
- Convulsions ... ...
- Laryngismus Stridulus (Spasm of Glottis) ...
- Disease of Spinal Cord, Paraplegia, Paralysis Agitans ... ...
- Other Diseases of Nervous System ... ...

2.—*Diseases of Organs of Special Sense* (*e.g.* of Ear, Eye, Nose) ... ...

3.—*Diseases of the Circulatory System.*
- Pericarditis ... ...
- Acute Endocarditis ... ...
- Valvular Diseases of Heart ... ...
- Other Diseases of Heart ... ...
- Aneurism ... ...
- Embolism, Thrombosis ... ...
- Other Diseases of Blood-vessels ... ...

4.—*Diseases of Respiratory System.*
- Laryngitis ... ...
- Croup ... ...
- Emphysema, Asthma ... ...
- Bronchitis ... ...
- Pneumonia ... ...
- Pleurisy ... ...
- Other Diseases of Respiratory System ... ...

5.—*Diseases of Digestive System.*
- Dentition ... ...
- Sore Throat, Quinsy ... ...
- Diseases of Stomach ... ...
- Enteritis ... ...
- Obstructive Diseases of Intestine ... ...
- Peritonitis ... ...
- Ascites ... ...
- Cirrhosis of Liver ... ...
- Jaundice and other Diseases of Liver ... ...
- Other Diseases of Digestive System ... ...

6.—*Diseases of Lymphatic System* (*e.g.* of Lymphatics and Spleen) ... ...

7.—*Diseases of Gland-like Organs of Uncertain Use* (*e.g.* Bronchocele, Addison's Disease) ... ...

8.—*Diseases of Urinary System.*
- Nephritis ... ...
- Bright's Disease, Albuminuria ... ...
- Disease of Bladder or of Prostate ... ...
- Other Diseases of the Urinary System ... ...

TABLE III. (*continued*).

9.—*Diseases of Reproductive System.*
(A Of Organs of Generation.
Male Organs ... ...
Female Organs ... ...
(B) Of Parturition.
Abortion, Miscarriage ... ...
Puerperal Convulsions ... ...
Placenta prævia, Flooding ... ...
Other Accidents of Childbirth ... ...

10.—*Diseases of Bones and Joints.*
Caries, Necrosis ... ...
Arthritis, Ostitis, Periostitis ... ...
Other Diseases of Bones and Joints ... ...

11.—*Diseases of Integumentary System.*
Carbuncle, Phlegmon ... ...
Other Diseases of Integumentary System ...

VII.—DEATHS FROM VIOLENCE:

1.—*Accident or Negligence.*
Fractures and Contusions ... ...
Gunshot Wounds ... ...
Cut, Stab ... ...
Burn, Scald ... ...
Poison ... ...
Drowning ... ...

1.—*Accident or Negligence* (*continued*).
Suffocation ... ...
Otherwise ... ...

2.—*Homicide.*
Manslaughter ... ...
Murder ... ...

3.—*Suicide.*
Gunshot Wounds ... ...
Cut, Stab ... ...
Poison ... ...
Drowning ... ...
Hanging ... ...
Otherwise ... ...

4.—*Execution.*
Hanging ... ...

VIII.—DEATHS FROM ILL-DEFINED AND NOT SPECIFIED CAUSES:
Dropsy ... ...
Debility, Atrophy, Inanition ... ...
Mortification ... ...
Tumour ... ...
Abscess ... ...
Hæmorrhage ... ...
Sudden Death (cause not ascertained) ... ...
Causes Not Specified or Ill-defined* ... ...

* Uncertified Deaths should be distinguished. (B.A.W.)

SUMMARY OF TABLE III.

	No. of Deaths.
I.—Specific Febrile or Zymotic Diseases ...	
1.—Miasmatic Diseases	
2.—Diarrhœal Diseases	
3.—Malarial Diseases	
4.—Zoogenous Diseases	
5.—Venereal Diseases	
6.—Septic Diseases	
II.—Parasitic Diseases	
III.—Dietetic Diseases	
IV.—Constitutional Diseases	
V.—Developmental Diseases	
VI.—Local Diseases	
1.—Diseases of Nervous System	
2.—Diseases of Organs of Special Sense ...	
3.—Diseases of Circulatory System	
4.—Diseases of Respiratory System	
5.—Diseases of Digestive System	
6.—Diseases of Lymphatic System	
7.—Diseases of Gland-like Organs of Uncertain Use	
8.—Diseases of Urinary System	
9.—Diseases of Reproductive System ...	
(A) Diseases of Organs of Generation ...	
(B) Diseases of Parturition	
10.—Diseases of Bones and Joints	
11.—Diseases of Integumentary System ...	
VII.—Deaths from Violence	
1.—Accident or Negligence	
2.—Homicide	
3.—Suicide	
4.—Execution	
VIII.—Deaths from Ill-Defined and Not Specified Causes	
TOTAL	

TABLE IV.

Showing the number of Deaths at all ages in 18 *from certain groups of diseases, and proportions to* 1,000 *of Population, and to* 1,000 *Deaths from all causes; also the number of Deaths of Infants under one year of age from other groups of diseases, and proportions to* 1,000 *Births and to* 1,000 *Deaths from all causes under* 1 *year.*

Division I. All Ages.	Total Deaths.	Deaths per 1,000 of Population at all ages.	Deaths per 1,000 of Total Deaths at all ages.
1. Principal Zymotic Diseases			
2. Pulmonary Diseases			
3. Principal Tubercular Diseases			
Division II. Infants under One Year.	**Total Deaths.**	**Deaths per 1,000 Births**	**Deaths per 1,000 of Total Deaths under 1 year.**
4. Wasting Diseases ...			
5. Convulsive Diseases .			

NOTES.

1. Includes Small-pox, Measles, Scarlet-Fever, Diphtheria, Whooping Cough, Typhus, Enteric (or Typhoid), and Simple Continued Fevers and Diarrhœa . . . of the deaths occurred in Hospitals situated beyond the limits of the District.
3. Includes Phthisis, Scrofula, Tuberculosis, Rickets, and Tabes.
4. Includes Marasmus, Atrophy, Debility, Want of Breast Milk, and Premature Birth.
5. Includes Hydrocephalus, Infantile Meningitis, Convulsions, and Teething.

TABLE V.

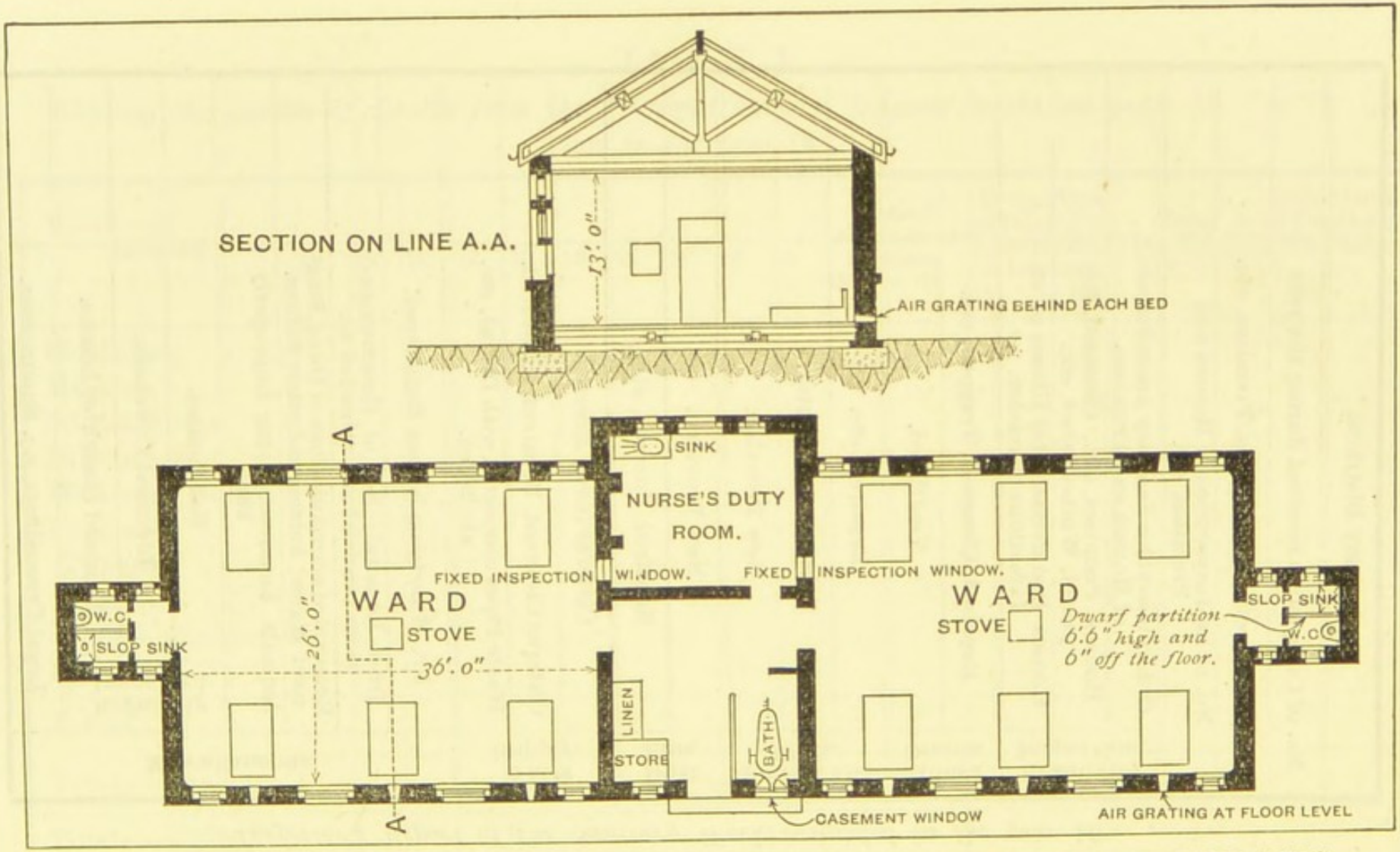
Showing the number of Deaths from the Principal Zymotic Diseases in the ten years 18 *to* 18 , *and in the year* 18 .

DISEASE.	18	18	18	18	18	18	18	18	18	18	Annual Average of 10 years, 18 —18	Proportion of Deaths to 1,000 Deaths in 10 years, 18 —18	Total Deaths in 18	Proportion of Deaths to 1,000 Deaths in 18
Small-pox														
Measles														
Scarlet-Fever ...														
Diphtheria														
Whooping Cough .														
Fevers—														
Typhus														
Enteric														
Simple Continued														
Diarrhœa														
Totals														
Totals—London ...														
Totals—England and Wales														

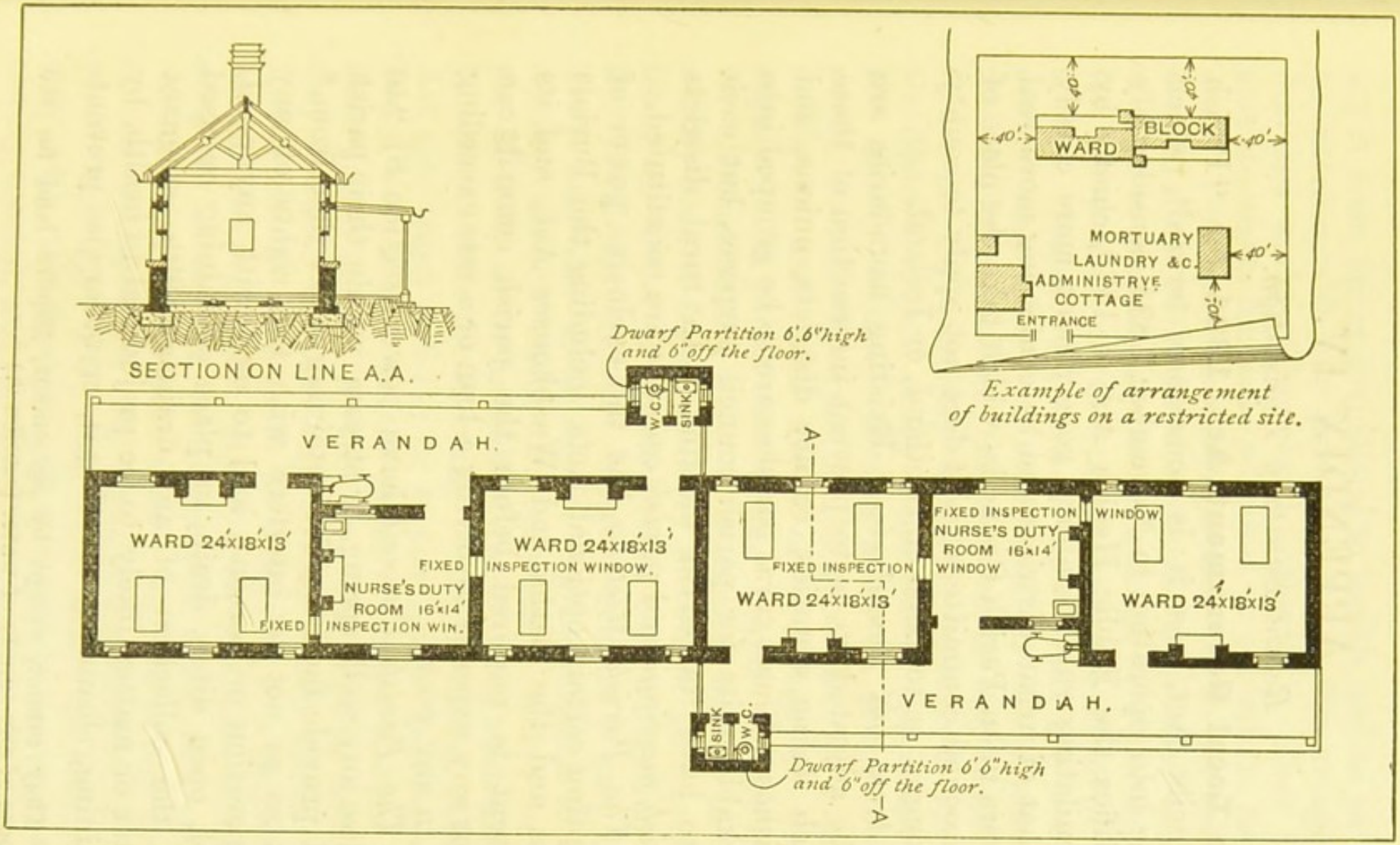
TABLE VI.

Inspector's Report of the Sanitary Work completed in the year 18 .

Sanitary Districts.		
No. of Complaints received during the year.		
No. of Inspections of Houses, Premises, etc.		
No. of Re-Inspections of Houses and Premises, etc.		
Results of Inspection.	Orders issued for Sanitary Amendments of Houses and Premises.	
	Houses, Premises, etc., Cleansed, Repaired, Whitewashed, etc.	
	Houses Disinfected after Illness of an Infectious character.	
House Drains.	Repaired, Cleansed, Trapped, etc.	
	Ventilated.	
Privies and W.Cs.	Repaired, etc.	
	Supplied with Water.	
	New Provided.	
Dust Bins.	New Provided.	
	Repaired, Covered, etc.	
Water Supply.	Cisterns (new) Erected.	
	Cisterns Cleansed, Repaired, & Covered.	
	Waste Pipes connected with Drains, etc. abolished.	
Miscellaneous	No. of Lodging-houses Registered.	
	Dust Removal—No. of Communications received and attended to.	
	Removal of accumulations of Dung, Stagnant Water, Animal and other Refuse.	
	Animals Removed, being improperly kept.	
	Regularly Inspected — Bakehouses.	
	Regularly Inspected — Licensed Cowsheds.	
	Regularly Inspected — Licensed Slaughter-houses.	
	Legal Proceedings, *e.g.* Summonses.	



APPENDIX III. ISOLATION HOSPITALS.—PLAN OF A WARD PAVILION FOR TWELVE BEDS.
(L.G.B. MODEL.)



APPENDIX III. (*concluded*). ISOLATION HOSPITALS.—PLAN OF AN "ISOLATION" BLOCK FOR EIGHT BEDS. (L.G.B. MODEL.

APPENDIX IV.

Recent Sanitary Legislation.

The Local Government Act, 1894 (or "Parish Councils Act," as it is sometimes termed), which came into operation in November, 1894, considerably modifies the Public Health Act of 1875, chiefly by assimilating rural sanitary government more closely to that of urban districts and by conferring more real powers upon Parish Councils, which take the place of "parochial committees." It does not apply to county boroughs, or to London, Scotland, or Ireland.

Area and Boundaries.—Existing boundaries are to be adjusted so as to prevent intersection of those which define counties, county districts, unions, and parishes. Small rural parishes are to be grouped into workable units for parish council purposes, but each is to have its parish meeting. In rural districts *parish meetings* and *parish councils* are constituted.

The Parish Meeting has the exclusive power of adopting certain optional Acts, including the Burials Acts and the Baths and Washhouses Act, and its consent is required before the parish council can incur any expense involving a loan or a rate exceeding 3d. in any year.

The Parish Council have power (section 8) "to utilise any well, spring, or stream within their parish and provide facilities for obtaining water therefrom,* but so as not to interfere with the rights of any corporation or person; and to deal with any pond, pool, open ditch, drain, or place containing or used for the collection of any drainage, filth, stagnant water or matter likely to be prejudicial to health, by draining, cleansing, covering it, or otherwise prevent-

* They cannot, except by agreement, acquire land for the purpose of any supply of water (section 9.)

ing it from being prejudicial to health, but so as not to interfere with any private right or the sewage or drainage works of any local authority." They may execute works for these purposes, or contribute to the cost. They 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. Notice must be given to the parish council concerned if the rural district council decide to undertake works of sewerage or water supply. The parish council may acquire or hire land for allotments, and may, if necessary, appeal to the county council for compulsory powers of purchase or hire; the Order if granted requires confirmation by the Local Government Board (sections 9 and 10). They may also make official representations to the district council under the Allotments Acts; or to the **M.O.H.** as to unhealthy dwellings or obstructive buildings under the Housing of the Working Classes Act (*see* pages 456-7); or to the Local Government Board with a view to the grant of urban powers for their parish or any part of it. The district council may delegate to them any powers which under the Public Health Acts could be delegated to a parochial committee (page 433). Apart from expenditure under adoptive Acts, the 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.

Rural District Councils take the place of rural sanitary authorities, and have the same powers and duties, with few changes beyond those noted above. Notwithstanding the limited initiative possessed by the parish council, the district council are the responsible executive sanitary authority as before, and must carry out all necessary works, giving notice to the parish council. The Local Government Board may by General Order confer upon rural district councils such urban powers as they think fit; this is in addition to their right under the Public Health Act of 1875 (*see* page 433) to grant urban powers for particular areas, which right may under the 1894 Act be exercised by the Board on the application of the county or parish council concerned.

Urban District Councils take the place of urban sanitary authorities, with the same powers and responsibilities in sanitary matters. Boroughs, however, still retain their "corporation" or "town council," but are included in the new term "county district," which comprises all urban and rural districts.

All district councils have the charge of highways. Among other powers transferred to them are the administration of the Acts relating to petroleum and infant life protection, and the licensing of knackers' yards, a duty hitherto nominally carried out by Quarter Sessions. A district or parish council may delegate their powers to a committee of their number, or to a joint committee representing other councils also.

County Councils obtain under the 1894 Act certain powers of supervision and control, specified in the foregoing summary.

The Isolation Hospitals Act, 1893, known also as Lord Thring's Act, gives 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 **L.G.B.,** if the population be less than 10,000 (according to the latest 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" (page 433). It is constituted by Order of the county council.

Procedure.—The county council may take the initiative by directing their medical officer of health to report as to the hospital requirement 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 **S.A.,** unless the county council are satisfied that the **S.A.** 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."

The county council have the power of inspecting any such hospital, and of raising money by loan for the purposes of the hospital.

Expenses.—"Structural" (*e.g.* site, building, furnishing, extensions, etc.) and "Establishment" (*e.g.* maintenance of hospital, salaries, etc.) expenses are borne by the several local rates of the constituent local areas, in proportions to be fixed by the Order. The costs 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 a fortnight of the time of admission. Patients desiring exceptional accommodation are themselves responsible for the cost of maintenance, etc., on such terms ("special patients' expenses") as the committee may appoint.

Note.—The following extract from a recent memorandum of the L.G.B. is important. "It may be laid down, with a view of lessening the risk of infection, that a local authority should not contemplate the erection of a small-pox hospital—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 to 200 persons. 2nd, On any site where it would have within half a mile of it as a centre a population of 500 to 600 persons, whether in one or more institutions or in dwelling houses."

APPENDIX V.

England and Wales.—Summary of Census Data, 1801–1891.

Year.	Enumerated Population.	Rate of Decennial Increase per cent.	Females per 100 Males.	Density of Population.	
				Per Square Mile.	Per Inhabited House.
1801	8,892,536	?	108·7	153	5·6
1811	10,164,256	14·0	108·6	174	5·7
1821	12,000,236	18·1	105·1	206	5·8
1831	13,896,797	15·8	105·2	238	5·6
1841	15,914,148	14·5	104·6	273	5·4
1851	17,927,609	12·9	104·2	307	5·5
1861	20,066,224	11·9	105·3	344	5·4
1871	22,712,266	13·2	105·4	390	5·3
1881	25,974,439	14·4	105·5	445	5·4
1891	29,002,525	11·7	106·4	497	5·3

APPENDIX VI.

ENGLAND AND WALES.—MEAN ANNUAL DEATH-RATES, AT DIFFERENT AGE-PERIODS, DURING THE FIVE DECENNIA, 1841–1890.

Age.	Males.					Females.				
	1841-50.	1851-60.	1861-70.	1871-80.	1881-90.	1841-50.	1851-60.	1861-70.	1871-80.	1881-90.
0-5	71·2	72·7	73·5	68·5	61·6	61·1	63·0	63·7	58·4	52·0
5-10	9·2	8·5	8·2	6·7	5·4	8·9	8·4	7·8	6·3	5·3
10-15	5·1	4·9	4·5	3·7	3·0	5·4	5·1	4·5	3·7	3·1
15-20	7·1	6·7	6·2	5·3	4·3	7·9	7·4	6·7	5·5	4·4
20-25	9·5	8·8	8·5	7·4	5·7	9·1	8·6	8·0	6·8	5·5
25-35	9·9	9·6	9·9	9·4	7·8	10·6	10·0	9·7	8·6	7·4
35-45	12·9	12·5	13·5	13·8	12·4	12·9	12·2	12·1	11·6	10·6
45-55	18·2	18·0	19·2	20·1	19·4	16·1	15·3	15·6	15·6	15·1
55-65	31·8	31·0	33·1	34·9	34·7	28·4	27·1	27·9	28·7	28·5
65-75	67·5	65·5	67·1	69·7	70·4	60·9	58·9	59·1	61·0	60·4
75-85	148·3	146·7	147·2	150·8	146·6	135·9	134·5	134·9	135·4	130·6
Over 85	312·3	308·2	315·0	327·4	305·8	293·3	288·9	285·1	296·4	270·8
All Ages	23·1	23·1	23·7	22·7	20·3	21·6	21·4	21·4	20·1	18·1

APPENDIX VII.

Industrial Processes scheduled by the Home Secretary as dangerous. ("Factory and Workshop Act, 1891," sect. 8. *See* page 447.)

PROCESSES IN—

The manufacture of White Lead.

The manufacture of 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.

The manufacture of Explosives in which di-nitro-benzole is used.

Chemical Works.

Quarries.

The manufacture of Red, Orange, or Yellow Lead.

Lead Smelting.

The tinning and enamelling of Iron Hollow Ware.

Electric Accumulator Works.

Flax Mills and Linen Factories.

APPENDIX VIII.

CONVERSION OF WEIGHTS AND MEASURES.

1 metre = 100 centimetres = $\frac{1}{1000}$ kilometre = 39·37 inches = 1·094 yards.

1 hectare = 10,000 square metres = 2·471 acres.

1 litre = 1,000 c.c. (cubic centimetres) = 1 cubic decimetre = $\frac{1}{1000}$ cubic metre = 67·027 cubic inches = 1·76 pint = 0·22 gallon.

1 gramme = the weight of 1 c.c. of distilled water at 4° C. or 39·2° F. = 1,000 milligrammes = $\frac{1}{1000}$ kilogramme = 15·43 grains = 0·035 ounce averdupois.

1 yard = 3 feet = 36 inches = $\frac{1}{1760}$ mile = 0·914 metre.

1 geographical or nautical mile = 6,080 feet = 1·151 statute miles = $\frac{1}{60}$ degree.

1 acre = 4,840 square yards = 4 roods = 160 rods, poles or perches = $\frac{1}{640}$ square mile = 0·4 hectare = a square of 70 yards (or more precisely 208·7 feet) = a circle with diameter 235·5 feet.

1 cubic foot = 1,728 cubic inches = $\frac{1}{27}$ cubic yard = 6·232 gallons = 28·3 litres.

1 pint = 4 gills = 20 fluid ounces = $\frac{1}{2}$ quart = $\frac{1}{8}$ gallon = 34·66 cubic inches = 0·568 litre.

1 ounce averdupois = 437·5 grains = $\frac{1}{16}$ pound = 28·57 grammes.

1 ton = 20 cwt. = 2,240 lbs. = 1023·95 kilogrammes.

WATER. 1 cubic inch = 0·036 lb.
1 cubic foot = 62·3 lbs. = 997 oz. = 6·23 gallons.
1 gallon = 10 lbs. = 70,000 grains = 277·25 cubic inches = 0·16 cubic foot.
1 ton = 210 gallons = 35·943 cubic feet.

A ton of coal measures about 40 cubic feet, earth 20, chalk 14.

THERMOMETRIC SCALES.

	WATER.	
	Freezing Point.	Boiling Point.
Centigrade (C.)	0°	100°
Fahrenheit (F.)	32°	212°
Réaumur (R.)	0°	80°

$$\text{F.} - 32 = \frac{9\text{ C.}}{5} = \frac{9\text{ R.}}{4}.$$

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