MANUAL OF HYGIENE

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PREFACE.

In writing this Manual the needs of those who are seeking to obtain a Public Health Diploma have been specially considered. While following closely the lines prescribed, a short account has not been omitted of some of the more important investigations which have been made in recent years with regard to questions of interest in relation to Public Health. The requisite references have, in many instances, been given, with a view to indicating directions in which further inquiry may profitably be pursued. The reader will, I hope, in clambering up the path it has been my business to mark out for him, find, that, without unduly straying from the beaten track, he obtains, from time to time, glimpses of the prospect which opens up as the ascent is made. Allusion has been made, more particularly, to reports of the Medical Officers of the Privy Council and Local Government Board, of Medical Officers of Health, of the Registrar-General, and of various Royal Commissions and Departmental Committees. This Manual, however, of necessity only refers to a small part of the material contained in those volumes, and to that in a somewhat cursory fashion. It has not been possible to attempt more than to present a kind of bird's-eye view of the pleasant country which the student may, if he will, explore.

Several of the illustrations in Chapter IX have been placed at my disposal by Mr. Shirley Murphy. Fig. 11, on page 76, was originally given by Dr. Ballard. To Dr. F. W. Andrewes and Mr. G. H. Day thanks are due for corrections and suggestions at a stage when the Manual was approaching completion. Last, but not least, I am indebted to my wife, who has been my fellow-worker throughout.

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MANUAL OF HYGIENE.

CHAPTER I.

INTRODUCTORY: THE RISE AND PROGRESS OF PREVENTIVE MEDICINE.

"Mankind," says Sir John Simon in his "English Sanitary Institutions," "in no stage, however early, of existence, can ever have been without glimmerings of health protective purpose." These "first steps of avoidance" probably related to "the pangs of dying by hunger or thirst, the poisonousness of certain foods and waters, the fatality of certain sites, the hardships and dangers of extreme heat and cold, the destructiveness of floods, and the sterilising effects of drought,—such, in various combination, may be supposed to have been familiar conditions to the beginners of the human race: the primordial field of physical evil, where man first became conscious of inclination to escape disease, and learnt ways by which he partially could do so."

The early pioneers had, of course, no secure foundation of knowledge of the natural history of disease to build upon. Long ages elapsed before it was realised that the phenomena in question are governed by laws which can be learnt by observation. In "Caliban upon Setebos," Browning has referred to the attitude adopted by the half-savage intelligence in dealing with such problems. Caliban held that nothing was of any avail when Setebos began to plague, and that the best way to escape his ire was not to seem too happy. Again, Caliban thinks Setebos will visit with his wrath any creature whom he finds presuming to have knowledge of his ways. Hence, thinks Caliban, it is courting disaster to assume that "because he did so yesterday with me, and otherwise with such another brute, so must he do henceforth and always." In times when notions such as these were generally prevalent there was little prospect of the acquirement of knowledge concerning the prevention of disease.

The seven books known as the "Epidemics" of Hippocrates constitute the first great landmark of epidemiology. In them the influence of season and climate upon particular diseases is discussed, and the conception which was later developed into the notion of an "epidemic constitution," giving special characters to the diseases of the season or year in which it prevailed, was first framed. The growth of knowledge concerning epidemics was, however, very slow. Even Sydenham, in the seventeenth century, writes that nothing, in his opinion, "strikes the mind that contemplates the whole and open domain of medicine with greater wonder than the well-known varied and inconsistent character of those diseases which we call epidemic." Sydenham, however, continues, "I am not prepared to say that a very careful examination (such a one, however, as the brief life of a single mortal would be insufficient for) would not give us the fact of certain epidemics succeeding each other regularly and in series, forming as it were a circle."

The development of the practice of keeping statistical records has made it possible to collect and focus the observations of many observers. Dr. Farr, in the first Annual Report of the Registrar-General, pointed out the advantage of substituting numerical formulæ for loose phrases. He commented upon Sydenham's employment of such terms as, "It prevailed a little but disappeared again;" "The small-pox was more prevalent in town for the first two years of this constitution than I ever remember it to have been;" "The small-pox arose, yielded to the dysentery, returned,"—and so on; and he said it is "impossible to compare Sydenham's experience thus expressed with the experience of other writers in other places and other ages; for 'prevailed a little,' 'raged with violence,' and similar terms, may imply either that small-pox destroyed 1, or 2, or 5, or 10 per cent. of the population. The superior precision of numerical expressions is illustrated by a comparison of Sydenham's phrases with the London Bills of Mortality in the same years."

The extent to which numerical expression has been rendered more precise since Sydenham's time may be tested by comparing the list of diseases enumerated in the first London Bills of Mortality (which did not exceed some sixty or thereabouts in number) with the modern "Nomenclature of Diseases" drawn up by the Royal College of Physicians. The later scheme includes upwards of 1,000 different forms of disease, and more important than the number of terms employed is the question of accurate assignment of the statistical units to the several species of malady. The advances made in quite recent years suggest that finality in the matter of classification, and in the accuracy of death returns, has been by no means yet attained.

Considerations of this kind serve to strikingly indicate the nature of the difficulties which must have impeded the early progress of preventive medicine. The troglodyte flint-chipper may have suffered from what is now known as "silicosis," as a result of inhaling particles of flint into his lungs; the Aryan, with the adoption of the practice of domesticating animals, may have rendered himself liable to maladies such as are now known to be communicated from these animals to man; the immigrant races which from time to time peopled Europe may have brought with them forms of exotic disease, much as cholera and plague have been conveyed from continent to continent within recent years. With regard to such questions history is silent. "Pre-glacial man, the short, long-skulled Iberians, the tall, fair, long-skulled Aryans, the tall, broad-skulled Turanians, the small-boned, broad-skulled Mongolians," all these races have lived and died in Europe, but of their diseases no record survives. Even in historic times the references to epidemics are, during the earlier centuries, of the most meagre description—indeed, up to the date of appearance of the Black Death, practically nothing is known concerning the maladies which widely prevailed in this country, beyond the fact that certain extensive famines from time to time occurred, and that in particular instances outbreaks referred to as "the great fever," "pestilence and murrain," "plague and murrain," "destructive pestilence," "fever and flux," and a few others, have barely left their mark in the chronicles of the times.

Though knowledge as to methods of preventing the spread of particular diseases is of quite recent origin, there are certain principles of modern hygiene which can be traced back to comparatively remote ages. Thus the old fable of Æsop, of the wolf and the lamb, indicates some sort of recognition of risk incidental to pollution of supplies of drinking-water. It is interesting to note that it was not until Dr. John Snow's investigations, concerning the cholera outbreak of 1848–49, had been made, that water-borne infection became an established reality. Again, there is the account given in the twenty-second book of the "Odyssey" of the proceedings of Ulysses after the killing of the wooers. Sir John Simon refers to this, and points out as remarkable the fact, that the place of slaughter was cleansed and disinfected "by such washings and scrapings, and especially by such burnings of sulphur as would be prescribed by a modern nuisance authority in like circumstances." Further, it may be conjectured that "the learning of the Egyptians," in which Moses was skilled, was in part concerned with questions of health. The directions set out in Leviticus show an advanced state of knowledge with regard to such matters. The methods adopted, for example, in dealing with a house affected with a plague of "leprosy" are specially interesting. Thus there is the requirement that the fact shall be notified to the priest, and the necessary scrapings and plasterings are described in detail. There is, moreover, not only insistence upon removal of accumulations of filth, but also upon the isolation of persons suffering from contagious disease.

Cave deposits and the "kitchen middens" bear witness to the lack of appreciation, in very early times, of the evils likely to result from the collection of accumulations of refuse within or near the dwelling; but, on the other hand, the remains of extensive systems of drainage designed for dealing with flood and surface waters in ancient Nineveh, and in cities of later date but still of great antiquity, show that already, many thousands of years ago, large works were undertaken with the object of dealing with waste material.

Coming to a still less remote period of history, the Roman sewers, works of water supply, and public baths and latrines, indicate a greatly advanced stage of civilisation. In Rome there were definite laws relating to nuisances, and, in some of the cities of the Roman Empire, medical officers were appointed for public purposes, and there was a medical service for the poor, men being employed who, knowing themselves "to be paid by salary for attending to the poor, must think of them rather than of the rich."

In the centuries which succeeded the downfall of the Roman Empire there was, generally speaking, retrogression rather than progress. The Arabian physicians made, however, notable advances. Rhazes, in the ninth century, wrote in Arabic his famous "Treatise on the Small-pox and Measles"; and the saying attributed to him, "When you can cure by regimen, avoid having recourse to medicine, and when you can effect a cure by a simple medicine, avoid employing a compound one," shows how far his ideas were in advance of his own and, indeed, of far later times.

In the Middle Ages, with the development of the monastic system in Europe, influences unfavourable to sanitation became predominant. Sir John Simon observes that "while an unwashed, verminous state of body and clothing was accepted as of moral merit, there could be little hope that sewers would not be let stink, or that the qualities of public water supplies would be cared for." But the Middle Ages contributed to progress inasmuch as the lessons supplied by certain great epidemics (the Black Death in the fourteenth and the Sweating Sickness in the fifteenth and sixteenth centuries) were not altogether unheeded. The prevalence of leprosy after the time of the Crusades led to the institution of leper houses. In 1423, Venice established its first lazaretto for defence against Levantine plague, and in 1485 a permanent health magistracy was created in that city. If the monastic system is to be held responsible for neglect of cleanliness, it must also be remembered that to it was due much of the effort made in those early times to alleviate the sufferings of the poor, and in particular to it belongs the credit of the introduction of hospitals.

The state of London from the thirteenth to the fifteenth centuries was, it may be gathered, such as urgently to need an active sanitary administration. In 1283, however, "tallow-melting was no more to be allowed in Chepe"; in 1311, "flaying of dead horses in the City or suburbs was no longer to be allowed"; in 1371, the continuance of plumber's solder melting in Eastcheap was "made conditional on raising the shaft of the furnace"; and in 1388 was enacted the first English general statute (12 Rich. II., cap. 13) against nuisances near cities and towns. This Act imposed a penalty of no less than £20 upon persons who cast animal filth and refuse into rivers and ditches.

The ancient courts leet, which have now become obsolete, presumably in their day exercised a certain amount of control in sanitary matters, and it may be noted that the court rolls of Stratford-on-Avon show that Shakespeare's father was fined in 1552 for depositing filth in the public street, in violation of the by-laws of the manor, and again in 1558 for not keeping his gutter clean.

The Tudor legislation is specially noteworthy in three connections. In the first place, it regulated the practice of medicine and surgery. The charter of the Royal College of Physicians of London dates from the tenth year of Henry VIII., and that of the Mystery and Commonalty of the Barbers and Surgeons of London from the thirty-second year (1540) of that king's reign. Secondly, an Act of 1532* authorised the issue of Commissions of Sewers for "the overlooking of sea-banks and sea-walls, and the cleansing of rivers, public streams, and ditches." In the third place, a serious attempt was made, in the Act passed in the forty-third year of Elizabeth's reign, to deal with mendicants and vagrants.

* Acts relating to this subject had already been passed in the reigns of the two earlier Henrys.

At about this time it appears that considerable works of town improvement were undertaken. Thus, Plymouth obtained, in 1585, powers to provide itself with a public water supply from Dartmoor, and some thirty years later the water supply of the City of London was improved by the famous New River of Sir Hugh Myddelton. Again, the City records, relating to this period, speak of the cleansing of Fleet Ditch, and of complaints made because, during a severe frost, "no steps had been taken for the removal of ice and snow." Overcrowding began to cause uneasiness: a proclamation was issued, in 1580, to the effect that there should not be any new building in the City or within three miles of its gates; and an Act of 1593 refers to the "great mischiefs" which "daily grow and increase by reason of pestering the houses with divers families, harbouring of inmates, and converting great houses into several tenements, and the erecting of new buildings in London and Westminster."

After this, for a number of years the chief subject of concern as regards the public health was plague. In 1580 it had been raging at Lisbon; in 1584, "for the stay of infection" in London, burials in St. Paul's were restrained—there had been so many, and these "by reason of former burials so shallow, that scarcely any graves could be made without corpses being laid open." James I. passed stringent laws with a view to preventing plague; in 1625 there was a serious outbreak, and the disease prevailed from 1629-31. Infected houses were guarded, and a red cross was set upon the door; it was directed that the streets should be kept clean, and that ditches should be cleansed; "antient women" were appointed to visit houses; the dead were to be buried late at night; lazarettos were established, into which ships coming from foreign ports "might discharge their cargoes to be aired for forty days"; it was recommended that "on the arrival of any infected vessel a list should be made of all persons on board," and that no ships or vessels should "be allowed to enter the Port of London unless they brought with them a certificate from the port authorities whence they came."

The mortality caused by the great epidemic of 1665 in London in six months was estimated by Macaulay at more than 100,000. De Laune, in his "Memorials of London," records the progress of the outbreak as shown by the Bills of Mortality. In May, 1665, a few cases occurred, and "great persons began to retire into the country." In June "the bill increases to 112, next 168, next 267, next 470; then do many tradesmen go into the country, and many ministers take occasion to absent themselves from their charge."

In the last week of July the bill rises to 2,010; in the last week of August to 6,102. "Now there is dismal solitude in London streets; every day looks with the face of a Sabbath observed with greater solemnity than it used to be in the City. Shops are shut up, very few walk about, so that grass begins to spring in some places. A deep silence everywhere; no rattling of coaches, etc., no calling in customers, no London crys, no noise but dying groans and funeral knells, etc. In September the bill rises to 6,988; the next falls to 6,544, but then rises again to 7,165, which was the greatest bill." The bills show now fairly steady decline, and lessen "more and more to the end of the year." The "remarkable occurrences as well publick as private" which happened during this great visitation are set forth in Defoe's "Journal of the Plague," which has been described as a work of fiction leaving "all the impression of a genuine narrative."

In the next year the fire destroyed the old City, with its "narrow irregular passages, wherein houses of opposite sides often nearly met above the darkened and fœtid gangway," and its wood and plaster houses, with their "hereditary accumulations of ordure in vaults beneath or beside them." By compelling reconstruction the fire did far more for London than was accomplished by the measures of quarantine upon which reliance had hitherto been mainly placed. The Act of 1667 provided "that streets specially needing enlargement should be enlarged, and that in all the new houses the outside and party walls should be of brick or stone"; it further authorised the appointment of special surveyors to see that "all new constructions should be done according to rule."

The time had now come when observation of natural processes was beginning to receive a large measure of attention, and the progress made by Sydenham and his successors in connection with the study of disease could not fail to be fruitful of results in regard to preventive medicine. Sir John Simon refers especially to the advances made by certain investigators in the eighteenth and in the beginning of the nineteenth centuries, and he styles these men—Mead, Pringle, Lind, Baker, Blane, Jenner, and Thackrah—the "fathers of modern preventive medicine." A brief account may be given of the work done by them.

Mead's "Short Discourse concerning Pestilential Contagion and the Methods to be used to prevent it," published in 1720, contains suggestions, which at that time were quite novel, for the establishment of a Central Council of Health, for measures of isolation and disinfection, and for the enforcement of cleanliness and the abatement of nuisances. Pringle discussed "Diseases of the Army," and was the pioneer of hygienic reform in connection with military organisations. Lind wrote "On the Means of Preserving the Health of Seamen," and upon Scurvy and Infection. An object lesson showing the value of the new teaching was forthcoming when, in 1776, Captain Cook was able to give account to the Royal Society of his three years' voyage in the *Resolution* "with the loss of only one man by a disease" out of a company of 118. Blane was the author of "Observations on the Diseases of Seamen," and Baker of an "Essay concerning the Cause of the Endemial Colic of Devonshire." Jenner's "Inquiry into the Causes and Effects of the Variolæ Vaccinæ" dates from 1798; Thackrah's treatise on the Diseases of Occupations was not published until 1831.

Apart, however, from increase in knowledge, there were other factors tending to improvement of the condition of the masses in the eighteenth century, prominent among these being what Sir John Simon calls the "growth of humanity in British politics." As a conspicuous instance of the influence of this humanitarian spirit he refers to the work of John Howard. Howard became impressed with the iniquities of the prison system of his time, and at his own cost undertook an elaborate inquiry with a view to exposure of the abuses which prevailed. The prisons in his day were run to make a profit; the gaolers lived on their fees, and "every prisoner, whatever the way in which he became a prisoner, had to pay these fees before he could be permitted to leave the prison." It is little to be wondered at, under such circumstances, that the prisons were not merely grossly insanitary themselves, but that they should become notorious on account of the way in which infectious disease spread from them. "Gaol fever" became a byword, the "atmosphere of the prisons was the atmosphere of typhus," and they were the "forcing-houses from which the typhus contagion of those days was ever overflowing into fleets and barracks and hospitals, and was a constant terror to courts of justice and to the common population." Howard wrote concerning the atmosphere of these prisons: "My reader will judge of its malignity when I assure him that my clothes were, in my first journeys, so offensive that in a postchaise I could not bear the windows drawn up, and was therefore obliged to travel commonly on horseback. The leaves of my memorandum-book were often so tainted that I could not use it, till after spreading it an hour or two before the fire; and even my antidote, a vial of vinegar, has, after using it in a few prisons, become intolerably disagreeable." Howard was called before the House of Commons to bear witness to what he had seen in his "Winter's Journey," and as a result Acts of Parliament were passed, to provide that gaolers should no longer be paid by fees, and with the object of reforming the sanitary condition of prisons. What was done as regards improvement of the prison system was typical of much else accomplished, during the century, in connection with the amelioration of the lot of the lower grades of society, and the growth of "a sense of moral responsibility in national affairs" prepared the way for the important new developments in connection with sanitary legislation which were soon to be inaugurated.

Only a brief account of progress in public health effected during the early part of the nineteenth century can here be given, and consideration must be limited to this country; the English code of law has, however, served largely as a model for imitation elsewhere. Already in the reign of George II. the larger towns had begun to apply to Parliament for special Acts enabling them to deal with paving, lighting, cleansing, and later with matters of more special sanitary concern, but the great impetus which determined the undertaking of measures of reform of more general application was again, as it had been in the past, the dread of pestilence.

In 1831 came the first great cholera outbreak of the last century, with its death toll in Great Britain of upwards of 30,000 persons, and for dealing with the emergency a consultative Board of Health was formed. This Board was soon replaced by a new Central Board of Health, which issued regulations and advice for the guidance of Local Boards established in the large towns. It was, no doubt, largely due to the lessons learnt during the outbreak that the Municipal Corporations Act, passed in 1835, gave to certain towns general powers for dealing with nuisances; again, the sense of need of knowledge concerning mortality statistics led to the passing of the important Act of 1836, which established the General Register Office.

In 1838–9 three reports were made to the Poor Law Commissioners, which did much to direct attention to the need for further reform. These reports were—(1) A joint report by Drs. Arnott and Kay "On the prevalence of certain physical causes of fever in the metropolis which might be prevented by proper sanitary measures."

(2) A report by Dr. Southwood Smith "On some of the physical causes of sickness and mortality, to which the poor are particularly exposed, and which are capable of removal by sanitary regulations, exemplified by the present condition of the Bethnal Green and Whitechapel districts, as ascertained on a personal inspection."

(3) A second report by Dr. Southwood Smith "On the prevalence of fever in twenty metropolitan unions and parishes during the year ended the 20th March, 1838."

The first two reports were submitted by the Commissioners as evidence of the need of provision being made for charges upon the rates, arising in connection with "nuisances, by which contagion is generated and persons are reduced to destitution." They demonstrated the need for power to deal with crowding, bad ventilation of dwellings, absence of drainage, insufficiency of water supply, and so forth. The third report showed that "out of the total number of persons who received parochial relief" during the year, "more than one-fifth were the subjects of fever,"* and urged "the prevention of the evil rather than the mitigation of the consequences of it."

The teaching of these reports and the influence exerted by those of the Registrar-General, which were now beginning to appear, led to the appointment of a Select Committee of the House of Commons to inquire into the Health of the Inhabitants of Large Towns. This Committee, known as Mr. Slaney's Committee, reported in 1840. Its chief recommendations were that "Acts should be passed for the better regulation of buildings and construction of sewers, and for the appointment of Local Boards of Health and inspectors." The Committee, moreover, commented upon the several necessities, of dealing with burial-grounds, water-supply, and lodging-houses, of providing public baths and open spaces, and of effecting the clearance of certain sites. An important new departure was made, too, in the Act which, in 1840, established gratuitous public vaccination—the first recognition in the statute-book "that it may be wise economy to offer to all comers the assistance which tends to prevent future still larger expense."

In 1842, two further important reports appeared. The one, that of a Select Committee of the House of Commons on Burial in Towns, the other the report (in three volumes) of the Poor Law Commissioners on the results of a general inquiry which had been ordered, on consideration of the reports already referred to, by the House of Lords. The third of the Poor Law Commissioners' volumes contained Mr. Chadwick's famous "General Report on the Sanitary Condition of the Labouring Population of Great Britain."

Mr. Chadwick, in this report, demonstrated the serious nature of the evils existing; he pointed out especially the difficulties of refuse-removal when hand-labour and cartage had to be resorted to, and showed how great would be the advantage of adopting a system of water-carriage with improved sewers, and with geological areas as the basis of operations. He also insisted on the need of improving

* Out of 77,186 paupers, 13,972 were attacked with fever, and 1,281 died. Of the 13,972 cases, 9,228 lived in Whitechapel, Lambeth, Stepney, St. George-the-Martyr, Bethnal Green, Holborn, and St. George-in-the-East, Unions containing less than half the total metropolitan population.

water supplies, and of appointing medical officers independent of private practice and possessed of special qualifications. In the year following (1843), Mr. Chadwick supplemented his general report by a special one "On the Practice of Interments in Towns." The great interest excited by Mr. Chadwick's reports led to the appointment of a Royal Commission, with the Duke of Buccleuch as chairman, which presented two statements to Parliament, one in 1844 and the second in 1845. These reports practically endorsed Mr. Chadwick's recommendations, and led to the passing, firstly, of the Nuisances Removal and Diseases Prevention Act of 1846 (which by the introduction of Boards of Guardians as Sanitary Authorities first extended sanitary legislation to rural districts); secondly, of the various "Clauses Consolidation Acts" of 1847 (designed to be incorporated with, and thus to ensure uniformity in the provisions of, various private Acts), the Towns Improvement Clauses Act, Markets and Fairs Clauses Act, Gas Works, Commissioners, Water Works, Cemeteries, and Towns Police Clauses Acts; and, thirdly, of the Public Health Act of 1848, and of the amended Nuisances Removal and Diseases Prevention Acts of the same year.

The main provisions of the Public Health Act of 1848 were as follows:

1. A General Board of Health was constituted for five years.

2. The system of summary jurisdiction for dealing with health nuisances was established.

3. The necessary financial and administrative arrangements were made for carrying into effect the recommendations of the Health of Towns Commission with regard to sewers, water-supplies, refuse-removal, offensive trades, nuisances, paving, streets, dwelling-houses, common lodging-houses, cellars, burial-grounds, etc.* Local Boards of Health were to be formed, either upon the petition of not less than a tenth of the inhabitants of a locality, or, in places where the average death-rate, for a period of seven years, exceeded 23 per 1,000, upon the initiative of the General Board of Health.

4. Special provision was made for coping with formidable prevalences of epidemic disease.

At the moment when the new General Board of Health, of which Mr. Chadwick was a member, commenced its work, the second cholera visitation was close at hand, and the first general report of the Board dealt with quarantine, urging that reliance should not

* Baths and Washhouses Acts were passed in 1846-48. The special Common Lodging Houses Acts of 1851 and 1853, and the Labouring Classes' Lodging Houses Act of 1851, may also be here referred to.

be placed on this means of combating contagion, but on sanitary improvement. In 1850 the Board reported on a "scheme for extramural sepulture," and on the Metropolitan water-supply. The Board soon found itself in conflict with "interests," and, as Sir John Simon says, "the millions of population still under the free ravages of preventable disease had not yet the self-consciousness of an interest." In 1854 the Government proposal to renew the tenure of office of the members of the Board was defeated, and the Board was reconstituted, with a paid president eligible to sit in the House of Commons, on a changed plan, Mr. Chadwick's official career being terminated.

The new Board commenced its career coincidently with the appearance of the third cholera outbreak, and a council of members of the medical profession was at once consulted by the Board with regard to the measures to be taken. This medical council included among its members Neil Arnott, William Lawrence, John Simon, and William Farr. The outbreak of cholera naturally led to further legislation. A Bill was introduced in 1855 for amending the Act of 1848, but was subsequently dropped, save as to a clause providing for the continuance of the Board of Health, and a clause enabling that Board to appoint a Medical Officer. In the same year the Nuisances Removal and Diseases Prevention Acts were amended, and the Metropolis Management Act was passed.

Another stimulus to reform, apart from cholera prevalence, should be mentioned here. The failures of administration in connection with the Crimean War led in 1855 to the appointment of a Crimean Sanitary Commission; in 1857 a Commission on Army Regulations commenced its labours; again, in 1861 appeared the report of the Commissioners appointed to make suggestions for the improvement of the sanitary condition of barracks and hospitals. In the same year Miss Nightingale's "Notes on Hospitals" was published, and the Army Medical School at Netley was shortly afterwards established.

In 1855 a central medical officership had been constituted. This office was first held by Sir John Simon, who during the seven years prior to this appointment had been Medical Officer of the City.* In the last-named capacity he had been able to bring about many important reforms. Thus "at a time when cesspools were almost universal in the Metropolis, and while in the mansions of the West-end they were regarded as equally sacred with the

* The first Medical Officer of Health in this country was Dr. Duncan, who was installed in that office in Liverpool in 1847, a year before Mr. Simon's appointment by the City Corporation.

wine cellars, they had been abolished for rich and poor throughout all the square mile of the City." Again, in 1851, when the City Sewers Act of 1848 was renewed and made permanent, a first precedent was established for the "registration and regulation of the tenement houses of the poor."

As Medical Officer of the Board of Health, Sir John Simon prepared, in 1856, a report "On the London cholera epidemics of 1848–9 and 1853–4 as affected by the consumption of impure water," and, in 1857, a comprehensive report on vaccination. In 1858 appeared "Papers relating to the Sanitary State of the People of England," by Dr. Greenhow, with an introductory report by the Medical Officer of the Board. This inquiry may be regarded as the forerunner of the series undertaken in the years succeeding for the Privy Council. The Local Government Act of 1858 handed over the medical duties of the General Board of Health to the Privy Council, at the same time imposing new duties in connection with vaccination, authorising the making of inquiries concerning the public health in any place or places, and directing that the Medical Officer should report annually, and that his reports should be presented to Parliament. The remaining (but somewhat reduced) duties of the General Board of Health were to be carried out by the Local Government Act Office, a sub-department of the Home Office.

The newly-constituted Medical Department under the Privy Council was largely occupied with questions relating to vaccination, but special inquiries were also made, concerning certain outbreaks of disease—notably into diphtheria prevalence in 1859, into famine diseases in 1862–3, into cerebro-spinal meningitis in 1865, and into cholera in 1866. Permanent inspectors were appointed to carry out the work of the Department in 1865 and 1869. Furthermore, important reports were made, in 1862–4 on food interests of the country, in 1862–3 on dangerous industries, in 1863 on hospitals, and in 1864–5 on the dwellings of the poorer labouring classes in town and country.

The Nuisances Removal Amendment Act of 1863 empowered medical officers of health or inspectors of nuisances to seize unwholesome meat, fish, fruit, bread, etc., and in 1865 the Sewage Utilisation Act (amended in 1867) was passed. The important series of Factory Acts, which dates from as early as the year 1802, had at first been mainly concerned with limitation of the hours of labour of young working people, but direct sanitary provisions were gradually introduced, and a section of the Act of 1864 provided for the cleanliness and ventilation of workrooms.

Special attention must be called to the Sanitary Act of 1866.

This Act declared it to be the duty of Sanitary Authorities to provide for the proper inspection of their districts. "The grammar of common sanitary legislation acquired the novel virtue of an imperative mood." In default, the Chief Officer of Police, under the direction of the Secretary of State, could enforce the obligation. This Act further made reference to the regulation of tenement houses, and it extended the definition of nuisances to overcrowded houses and workshops and to smoke. It also dealt with spread of contagion and authorised the provision of hospitals and of apparatus for disinfection.

The year of cholera, and of the passing of the Sanitary Act, was also that in which Buchanan commenced his inquiry concerning the sanitary effect of town improvements hitherto made, and in 1867 his report on phthisis-distribution appeared. In 1867 the Vaccination Act, which provided "special machinery and method to promote the compulsory intentions of 1853, and instituted 'payment for results,'" was passed. Another Factory Act also dates from 1867, and the Merchant Shipping Act of the same year included provisions extending protection in matters of sanitary importance to merchant seamen.

In 1869, scarlatina was prevalent, and relapsing fever was diffused in the poorer parts of London. In the same year a system newly introduced on the Continent, that of Animal Vaccination, was reported on by Ballard and Seaton. Another Vaccination Act was passed in 1871, and this was the year of the great small-pox epidemic. In 1871 there was, moreover, a threat of cholera invasion, and port inspections were made by Netten Radcliffe and Buchanan. The principle was then accepted of "letting foreign infectious arrivals be dealt with in detail, just as dangerous infections of native origin would be dealt with in the same localities." In 1870, Auxiliary Scientific Investigations were provided for, and a new development was made, in connection with the "Quarterly Returns," expediting the publication, for the whole of England, of facts already presented in the "Weekly Returns" relating to London, and adding materially to the value of the series of reports now being issued by the Registrar-General.

Certain important advances in knowledge regarding matters of concern in relation to public health had, it may be noted, been made during the years just passed under review. The differentiation between varieties of continued fever, by Jenner and others, was already effected in 1849–52. In 1859–60, Dr. William Budd urged that enteric fever, like cholera, was a water-borne disease; in 1863, Davaine's researches on the subject of the anthrax bacillus were published; in 1865, Villemin showed that tubercle was inoculable; and in 1870 the possibility of certain germs of infectious disease being transmitted by milk was established. It may be added that the years 1848–71 were those of Pasteur's chemical investigations, of his fermentation studies, of his controversies with regard to spontaneous generation, and of his inquiries concerning wine, beer, and diseases of silkworms.

The period in which public health legislation had been, so to speak, on trial had at length come to an end, and it was with the object of framing a new and comprehensive statute that the Royal Sanitary Commission (1869–71) commenced its labours. As Sir John Simon says: "The Legislature for a quarter of a century, on the motion sometimes of one department, sometimes of another, had been proceeding tentatively, and with many renewals of attempt, in section after section of the vast subject matter; and the successive bits of piecemeal legislation, uncombinable except with gaps and overlapping, and sometimes with apparent inconsistencies of intention, made a parquetry which was unsafe to walk upon." It was not only a confusion of local jurisdictions, in each parish "the privies were under one authority, and the pigsties under another," but "two or three central departments, variously advised, might be communicating with some single locality in respect of some single sanitary subject matter."

On the recommendations of the Sanitary Commission was based the legislation which in 1871 constituted the Local Government Board; that embodied in the Public Health Act of 1872 (which created Urban, Rural, and Port Sanitary Authorities, each under obligation to appoint one or more Medical Officers of Health), and in the consolidating Public Health Act of 1875; and again that contained in the Sale of Food and Drugs Act of 1875, the Rivers Pollution Act of 1876, the Factory and Workshops Act of 1878, the consolidating Contagious Diseases (Animals) Act of the same year, the Public Health Interments Act of 1879, the Alkali, etc., Works Regulation Act of 1881, and the Artisans' Dwellings Improvements Acts of 1875–82. As a result of the work of the Sanitary Commission, in fact, the modern era was inaugurated. The enactments in force at the present time will be referred to in detail in a later chapter.

CHAPTER II.

AIR.

The importance of atmospheric pollution was early recognised; indeed it was the custom at one time to look to miasmatic influences for explanation of almost any unusual prevalence of disease. Thus, to the inhabitant of the crowded, insanitary, plague-stricken London of three hundred years ago, "this most excellent canopy the air" may well have appeared at times "no other thing than a foul and pestilent congregation of vapours." In the light of modern knowledge, having regard to the sources of atmospheric impurity, to the ill effects likely to be associated with certain kinds of pollution, and to the extent to which, even under existing conditions, the operation of purifying agencies is interfered with, there is good reason for considering the subject of the relationship of air to disease one of the most important within the scope of hygiene.

Comparatively little has hitherto been done in the direction of preventing the addition of impurity, but much stress has been laid on the importance of securing free dilution, if not complete removal, of noxious matter by an adequate supply of "fresh" air. For a right appreciation of the whole question it is necessary first to consider the nature and physical properties of the "canopy" or covering of air which envelopes the earth, and to deal with its chemical constitution, and with the characteristics and means of detecting the more commonly occurring impurities. It will then be possible to more adequately discuss the ill effects of contaminating influences, and to more fully appreciate the operation of ventilation and heating in relation to the promotion of interchange of air.

(I.) The Physical Properties of the Atmosphere.

The atmospheric covering is said to extend upwards of fifty miles beyond the earth's surface, and on this basis it may be calculated that there are some 10,000 million cubic miles of air encircling the globe. While, however, those layers of the atmosphere which adjoin the earth have the density of air as we know it, the outer layers become more and more attenuated. In order to understand how this is brought about it is necessary to refer to some of the elementary properties of gases.

A gas ever tends to expand. In solids what is called the force of cohesion comes into play, the same force is traceable in liquids, though in far less degree; but in the case of gases the constituent particles, in place of attracting, actually repel one another. Thus, if a gas be introduced into a flask, it pervades the entire space, and tending, as it does, to expand further, it exerts pressure upon the sides of the flask. If, in place of a rigid flask, an elastic enveloping surface, such as a bladder, be employed, the gas will dilate it until a sufficient counter-balancing resistance to further extension is produced by the bladder's tendency to contract. From the point of view of the gas it is under greater or less pressure from without. From the point of view of the enveloping surface an equivalent pressure is exerted upon it by the gas it contains.

In a gas, as in a liquid, the law that the pressure is equally distributed in all directions holds good. This principle, which was discovered in the first half of the seventeenth century as applying to fluids generally, is called the law of Pascal or Pascal's principle. It may be illustrated by the case of a quantity of gas in a closed receiver, fitted with tubular openings of equal size, in which pistons work in a direction at right angles to the surface of the receiver. In order to maintain equilibrium under these circumstances pressure must be applied, to the several pistons, to counteract the expansive tendency of the gas, and this pressure must, in the case of each piston, be the same. In the corresponding case, in which liquid fills such a receiver, if one piston be subjected to pressure, the like pressure must be applied to the other pistons, if they are to be maintained in position and prevented from being driven outwards by the pressure transmitted through the liquid. If the tubes in which the pistons fit have differing sectional areas, the pressure necessary to prevent any given piston being displaced must be increased in proportion to the area of that piston. The principle here involved is, of course, that of the hydraulic or Bramah's press, a machine in which the work done in displacing a piston of small sectional area, through a long distance, is transformed into work accomplished in raising a piston of large sectional area, through a small distance; thus great pressure can be exerted by the application of a small force.

In further illustration of the ditsribution of pressure in gases, may be mentioned the fact that when the hand is stretched out, say palm upwards, the pressure exerted on the palm of the hand is counterbalanced by the upward pressure of the air on the back of the hand; as result, the fact that these forces operate is apt to be lost sight of. That such pressures have a very real existence is, however, strikingly shown in the experiment of the Magdeburg hemispheres, which consist of two hollow cups fitting accurately one into the other. These cups are readily separable under ordinary circumstances, the pressure of the air upon the outside of the cups being counteracted by the pressure of the air within them, but if the air inside the cups be exhausted, and the stopcock with which one of the cups is fitted, be closed, so as to prevent re-entry of air, considerable force is needed to pull the cups apart.

Weight of Air.—The next point to be considered is that the atmosphere has weight. This discovery was also made in the first half of the seventeenth century. Galileo is said to have experimented with regard to the weight of a globe, filled at one time with ordinary air and at another with compressed air, and he is also said to have noted, in connection with certain fountains of the Grand Duke of Tuscany, that air would not rise in a pump more than eighteen cubits, *i.e.*, about thirty-two feet.

The lifting pump, in its simplest form, consists of a cylinder, fitted to a tube placed in a reservoir of water. At the junction of the tube and cylinder, and covering the opening of the tube, is a valve which opens upwards. In the cylinder a piston is worked by means of a lever (the handle of the pump), and this piston is perforated by an opening, covered above, on the upper surface of the piston, by a valve, which also opens upwards. If the piston be raised, its valve remains, owing to atmospheric pressure, closed down over the opening in the piston; the air beneath the piston, and between the two valves, tends to become rarefied as the piston ascends, and the lower valve therefore opens, and air (or water) from below is sucked into the cylinder. Inasmuch as the atmospheric pressure is continuously acting on the surface of the water in the reservoir outside, while within the pump the pressure tends to diminish when the piston ascends, the level of the water must rise in the tube. As the piston descends, however, at the end of the stroke, the upper valve opens and the lower valve closes in virtue of the pressure now transmitted through the opening in the piston. When the piston again ascends, a further rise in the water level inside the pump occurs: water, as the strokes succeed one another, enters the cylinder, then passes upwards through the perforated piston, and is ultimately raised to the level of the spout, and escapes.

The fact that water rises in a pump, was at one time explained by saying that Nature abhorred a vacuum; the question arose why this statement of the case, which is really no explanation at all, no longer applied when the height, through which the piston was raised, exceeded eighteen cubits, or thirty-two feet. Torricelli, a pupil of Galileo, seems to have argued that the water must be raised in the pump by the pressure of the atmosphere, and he concluded that as this pressure was capable of supporting a column of water about thirty-two feet in height, it could only manifest ability to support a proportionately smaller column of a more dense material, such as mercury. In fact, mercury being thirteen times as heavy as water, the column should be only one-thirteenth of thirty-two feet, *i.e.*, about thirty inches high. In the year 1643, Torricelli made his famous experiment of inserting a glass tube, more than thirty inches in length and filled with mercury, over a bowl containing this metal, and he demonstrated that the mercury fell in the tube, leaving a vacuum behind it, and coming to rest at a height of about thirty inches above the surface of the mercury in the bowl.

Pascal subsequently showed that the height of the mercurial column supported, steadily diminished at increasing distances above the earth's surface, as more and more air was left beneath, and a less and less weight of air remained above the site of the experiment. Thus at the top of the Puy de Dôme he found the mercurial column supported was about three inches less in height than it was at the bottom of the mountain.

The experiment of Torricelli demonstrated that the atmosphere has weight, and the appliance he used, *i.e.* a barometer (from the Greek words *βάρος*, weight, and *μέτρον*, a measure), has been found admirably adapted to act as a measure of that weight. The form of *mercury barometer* now commonly used for precise measurement of atmospheric pressure, is that known as Fortin's cistern barometer, shown in the annexed figure.

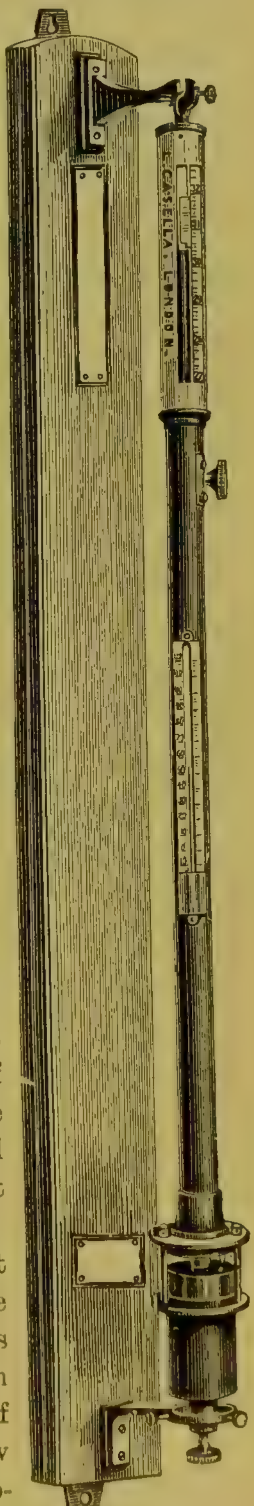

FIG. 1.
Fortin's Barometer.

Through the glass at the lower part of this instrument the surface of the mercury in the cistern can be seen. From the brass covering of the cistern (just above the glass) an ivory pin descends towards the mercury. Before taking a reading of the upper surface of the mercury in the tube, the extremity of this pin must be accurately adjusted, so that it just touches the surface of the mercury in the cistern.

The reason for taking this precaution is that the level of the mercury in the cistern fluctuates slightly with variations of atmospheric pressure, and it is therefore necessary to bring the zero of the scale, on the upper part of the barometer tube, into exact correspondence with that level. This is done by turning the screw (seen at the lower extremity of the instrument) and thus bringing pressure to bear upon the under surface of the cistern, which is made of flexible leather. By this expedient the lower extremity of the ivory point, from which the scale is measured, can be made to exactly correspond (so that with its reflection it forms a double cone) with the surface of the mercury in the cistern. It may be further noted that a piece of chamois leather is fitted round the tube containing the column of mercury, at the point where it is inserted into the case of the cistern; this means of junction, while it prevents escape of mercury, does not exclude the transmission of the atmospheric pressure, through the pores of the leather, to the surface of the mercury in the cistern.

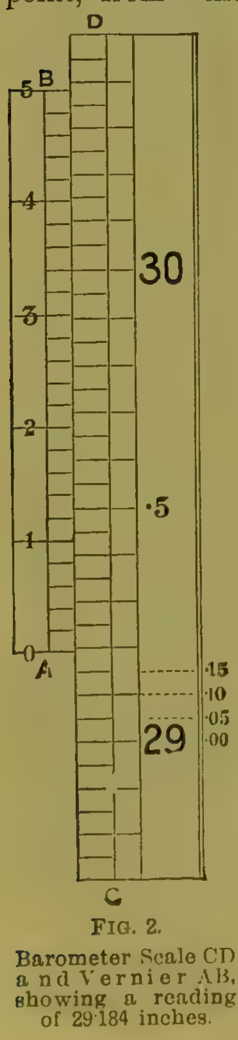

Fig. 2.
Barometer Scale CD and Vernier AB, showing a reading of 29·184 inches.

The ivory point having been adjusted, the reading of the thermometer (seen in the figure at about the middle of the barometer tube) may be taken—the object of ascertaining this reading will be seen presently. Attention should then be directed to the upper surface of the mercurial column in the barometer. Here the adjustable scale called, after its inventor, a "vernier," is situated. This must be set so that its lower margin is precisely tangential to the convex upper surface of the mercurial column. The reading is then made by noting — first, the division on the fixed scale immediately below the zero of the vernier; and, secondly, the number of divisions which have to be counted, from zero upwards, on the scale of the vernier, before one of the divisions of the latter is found to be in a straight line with a division on the fixed scale.

If the number of divisions so counted be multiplied by ·002, and the result added to the first reading exhibited on the scale, the final reading of the barometer is obtained. In the figure the first reading noted is 29·15, and seventeen divisions in the vernier scale have to be counted, therefore 29·15+·034, or 29·184, is the final reading. Or more shortly, the first line on the vernier scale, which is in a straight line with a division on the fixed scale, may be read off at once as ·034, as it is beyond the 3 on the vernier scale (supplying the figure for the second place of decimals) and is situated two-fifths, *i.e.*, *four-tenths*, of the distance between 3 and 4, above the 3 on that scale (supplying 4 as the figure for the third place of decimals).

The principle of working with the vernier will be understood if it is borne in mind that twenty-five divisions on the vernier correspond to twenty-four on the scale. Going downwards, therefore, from two divisions which are in a straight line, it is necessary to count twenty-five divisions of the vernier before again reaching two divisions in a straight line; the first division of the vernier reached will be one twenty-fifth of a scale division above the first division of the scale, the second two twenty-fifths of a division, and the seventeenth seventeen twenty-fifths of a division above the corresponding division of the scale. The distance last named is that of the height of the mercurial column above the first reading taken. Each division of the fixed scale represents one-twentieth of an inch, therefore the vernier reading to be added is clearly $\frac{17}{25} \times \frac{1}{20}$ inch, or ·034.

Certain corrections must be applied to the reading of the barometer thus ascertained. Some of these are corrections which apply to the particular barometer used—they are, so to speak, personal to the instrument; thus, *index errors* include errors in graduation, or in the position of the zero of the scale; the correction for *capacity*, *i.e.*, for change of level of the mercury in the cistern, has also to be made, unless this correction has already been allowed for in taking the reading; thirdly, the correction for *capillarity* must be applied so as to compensate for capillary depression, which causes the barometric height to be somewhat under-estimated. The corrections necessary to compensate for these three kinds of error, at every half-inch of scale, are furnished in a table which is supplied with instruments sent out from Kew Observatory.

Other corrections are those relating to *temperature*, to *reduction* *to sea level*, and to *unequal intensity of gravity.* Correction for temperature is necessary owing to the expansion of mercury under the influence of heat, and to the alterations effected in the scale of the barometer itself from a like cause; these factors must be allowed for in all precise observations. Hence the need for taking a reading of the thermometer, as described above, at the time when the reading of the barometer is made. The necessary correction for temperature is ascertained by the help of tables which give the amount of allowance to be made, for all ordinary temperatures and heights of the barometer. Reduction to sea level is also effected by means of tables. Roughly speaking, for each 100 feet above sea level, one-tenth of an inch must be added to the barometric reading. The correction for unequal intensity of gravity requires to be taken into consideration when observations are made at places in which the intensity of gravity markedly differs, as, for example, near the poles and at the equator.

A form of barometer which possesses the advantage, as compared with the mercury barometer, of far greater sensitiveness of indication, is that known as Jordan's glycerine barometer. The height of the column of glycerine supported by the atmospheric pressure is about twenty-seven feet, and the instrument has thus far greater range of variation, in correspondence with small fluctuations of pressure, than is the case with the mercurial barometer. A water barometer has, of course, even greater range than a glycerine barometer, but the vapour tension in the vacuum is so considerable a source of error, as to militate against the use of this form of instrument. The aneroid barometer (from the Greek ἀ, priv., and νηρός, wet, damp) is readily portable and sensitive, but it needs to be tested from time to time by comparing its readings with those of a mercurial instrument. This form of barometer consists of a metallic box partially exhausted of air, and the indications are afforded by the sensitively responsive movements of the walls of the box in accordance with variations of atmospheric pressure. These movements are communicated to levers and are thus made to turn an index needle which moves along a graduated scale.

The *syphon* may be here referred to, as it also strikingly illustrates the influence of atmospheric pressure. It consists of a bent tube, open at the ends, and having one arm longer than the other. When this tube is filled with liquid, and its two arms are placed, one (the shorter) in a vessel or reservoir containing liquid, and the other (the longer arm) in a vessel or reservoir placed on a somewhat lower level and also containing liquid, it is found that flow occurs, up the shorter arm and down the longer arm of the syphon, until the upper reservoir is emptied, or until the level of liquid in the two reservoirs becomes the same. The phenomenon in question may be explained as follows :—At the point where the shorter arm meets the surface of the liquid in the higher reservoir, the pressure on the column within the tube, tending to promote the flow up the short arm, must be the atmospheric pressure, less the weight of a column of liquid whose height is equal to that, of the point of junction of the long and short arms, above the level of the liquid in the higher reservoir. Similarly, at the point where the longer arm meets the surface of the liquid in the lower reservoir, the pressure on the column of liquid, tending to oppose its flow into the lower reservoir, is the atmospheric pressure, less the weight of a column of liquid whose height is equal to that, of the point of junction of the long and short arms of the syphon, above the level of the liquid in the lower reservoir. As the height of the column, determining the weight to be deducted, is greater in the latter than in the former case, the pressure tending to promote the flow, from the higher to the lower reservoir, exceeds that tending to oppose it, and thus the discharge takes place.

From what has been said concerning the weight of the atmosphere, it will now be clear that the strata of air near the earth's surface, which have to bear the weight of a considerable quantity of overlying atmosphere, must be far more dense than more outlying strata which are subjected to less pressure. The experience gained in mountain and balloon ascents may be referred to as showing the effect of breathing rarefied air. The "mountain sickness" of the higher Andes and Himalayas has been experienced at elevations of less than four miles, while in the famous balloon ascent of Messrs. Glaisher and Coxwell the furthest limit of penetration into the upper regions of the air was less than seven miles, but those observers narrowly escaped with their lives. On the other hand, the results of exposure to "compressed air" are illustrated in the so-called "Caisson disease" and in "Divers' palsy."

Boyle and Mariotte's law.—The pressure of the atmosphere due to the superincumbent weight of air is, if the air be at rest, the same for all points in the same horizontal layer, and the density is also the same for such points. On comparison of layers at different horizontal levels the pressure and density of course increase on descending or approaching the earth, and diminish on ascending. But the volume of a given amount of gas varies inversely as its density, the density of a quantity of air, occupying one cubic foot, being doubled, when the air is compressed so as to occupy half a cubic foot, *i.e.*, only half the original volume. Boyle and Mariotte nearly 250 years ago independently demonstrated the law, which governs the relationship between pressure and density on the assumption that temperature remains constant. This law may be stated, for the case of a closed receiver, as being that the pressure is proportional to the mass of the contained gas. Or, generally, the pressure exerted by a gas is proportionate to its density, and therefore inversely proportionate to its volume, temperature remaining constant. Thus, if half the mass of a quantity of air contained in a flask be removed, the pressure exerted on the sides of the flask, per unit of surface, will be found to be only half what it previously was, the volume of the air remaining in the flask, having expanded to double the original volume, while its density is now only half the original density. The law discovered by Boyle and Mariotte may be also expressed as follows:—If V and V^1 be the volumes occupied by the same mass of gas, P and P^1, D and D^1 the corresponding pressures and densities, then

$$\frac{P}{P^1} = \frac{V^1}{V}, \text{ or what comes to the same thing } \frac{P}{P^1} = \frac{D}{D^1}.$$

Experimental verification of the truth of this law may be made by means of what is called Mariotte's tube. This consists of a glass tube of uniform bore, so shaped that, when fixed to an upright support, it has two vertical arms connected below by a curved intermediate portion. One vertical arm is short and closed at the end, the other much longer, and open, so that mercury can be poured into it. Each of the arms has marked on it a graduated scale. A little mercury is poured into the tube so as to occupy its lower curved intermediate portion, and also so much of the extent of each of the vertical arms as will bring the mercury up to the two zero points on the graduated scale. The level in the two limbs is then the same, and, as the mercury rests in the curved portion of the tube, one surface, that situated at the zero of the longer vertical limb, is under the atmospheric pressure exerted through the open tube, while the other surface, that situated at the zero of the shorter limb, is also under the atmospheric pressure exerted by the imprisoned column of air. If mercury be now poured into the longer limb, the air in the shorter limb is compressed, and if the addition of mercury be continued, until the top of the column in the longer limb stands at the height indicated on a barometer above that of the shorter limb, the air in the shorter limb will be found to occupy only half the volume it originally filled. The pressure exerted on the imprisoned air is now the atmospheric pressure plus the weight of the mercury in the longer limb, this weight being itself equal to the atmospheric pressure. The imprisoned air is therefore subjected to twice the atmospheric pressure, and its volume has therefore diminished to one half its original volume. If mercury be added in the longer limb until the reading on the scale, giving the height of the top of the column of the longer above that of the shorter limb, is twice the barometric height, the imprisoned air will be subject to the atmospheric pressure plus twice the atmospheric pressure, *i.e.*, to three times the atmospheric pressure, and its volume will now be found to be one-third of its original volume.

In thus describing the relation between pressure and volume it has been assumed that the temperature remains constant. It is necessary to consider what happens if the temperature of a gas be raised or lowered. Gases, like solids and liquids, expand when they are heated, but the expansion of gases is far more marked and more regular than that of solids and liquids. The meaning of this statement will be rendered more clear when some of the simpler phenomena resulting from applying heat to bodies have been considered.

Temperature.—When two bodies are placed in contact heat passes from that which is hotter or has the higher temperature, to that which is colder or has the lower temperature; if no heat passes the bodies are said to have the same temperature. As bodies expand when they are heated, change of temperature can be measured by ascertaining the alteration of volume which occurs. In the ordinary thermometer the apparent expansion of mercury in a graduated glass tube is adopted as the standard, of change of volume, to which all questions of temperature are referred.

In constructing a *thermometer* a glass tube with a very fine and uniform bore, and having a bulb blown at one end of it, is used. Upon the fineness of the bore depends the sensitiveness of the instrument, its ability to indicate small differences of temperature; upon the uniformity of bore depends the accuracy of the correspondence observed between lengthening of the mercurial column and increase of temperature. In filling the thermometer the bulb is first heated, so as to drive air from the instrument, and the mouth of the tube is then plunged into a vessel containing pure mercury. As the air in the tube and bulb contracts, the mercury will rise into the tube, and reach the bulb. By alternately heating and cooling the bulb, more and more mercury may be drawn into it. The instrument is then placed in a furnace, in a sloping position, bulb downwards, until the mercury boils, and its vapour has expelled all air from the bulb and tube. The tube is then hermetically sealed and, on cooling, a continuous column of mercury is found filling the bulb and part of the tube, the other part being left empty.

The next proceeding is to determine the fixed points, which correspond to the temperature of melting ice and to that of the steam given off by boiling water at ordinary atmospheric pressure. The thermometer is first surrounded by melting ice, contained in a vessel from the lower part of which the water produced, as melting proceeds, can escape; when the level of the mercury ceases to fall "freezing point" has been reached; a mark is scratched with a diamond on the stem at this point, which indicates the position of zero on the Centigrade scale. Then, to determine the other fixed point, the thermometer is immersed in the steam arising from pure water boiling under ordinary atmospheric pressure, and, when the level of the mercury has again become stationary, a mark is made on the stem to indicate "boiling point," 100° C. If the atmospheric pressure is not exactly 760 m.m. a small correction requires to be made as regards "boiling point"; roughly speaking, a difference of 27 m.m. in pressure causes a difference of 1° C. in the temperature of the steam produced.

In the Centigrade system the scale between the two fixed points is divided into 100 degrees. In Réaumur's scale "freezing point" is still zero, but "boiling point" stands at 80°. Thus a degree Réaumur is five-fourths of a degree Centigrade. It is easy to calculate, therefore, to what temperature Centigrade any given temperature Réaumur corresponds, and *vice versâ*. In the case of the Fahrenheit scale freezing point is no longer zero, but 32° F.; while boiling point is 212° F. Thus the range of temperature, which in the Centigrade scale is represented by 100°, and in the Réaumur scale by 80°, is in the Fahrenheit scale represented by 212° − 32 or 180°. Hence a degree Fahrenheit is equivalent to $\frac{100}{180}$, or $\frac{5}{9}$ths of a degree Centigrade, and to $\frac{80}{180}$ths or $\frac{4}{9}$ths of a degree Réaumur. Thus $\frac{F-32}{9}=\frac{C}{5}=\frac{R}{4}$.

In converting degrees Fahrenheit into those of one of the other scales, or *vice versâ*, it is always necessary to have regard not only to the range covered by a degree, but also to the position of zero point on the Centigrade and Réaumur scales, as compared with freezing point on the Fahrenheit scale. In the case of thermometers, as has been already seen with regard to barometers, certain corrections of the observed reading require to be made. Thus, what is called displacement of the zero point occurs, from gradual contraction of the bulb, due to a molecular change in the glass; this alteration is rapid at first, but becomes negligible after a year or so. It may be almost entirely avoided, therefore, by delaying the process of graduation until some time after the thermometer has been sealed. The instruments employed for precise observations should have been carefully tested—a Kew certificate is regarded as essential in the thermometers used in scientific work.

Other liquids than mercury have been used in constructing thermometers; thus, an alcohol thermometer may be employed when very low temperatures, below the point (about $-39°$ C.) at which mercury congeals, have to be registered.

Self-registering or *maximum* and *minimum thermometers* indicate the highest and lowest temperatures recorded during any particular period. In Rutherford's minimum thermometer alcohol is the fluid used, and a small index, usually of glass, is placed in the tube, which should be kept horizontal, or nearly so. When the column of alcohol expands it flows past the index, but when it contracts it does not leave the index behind it, but draws it along by capillary attraction, so that the point at which it ultimately rests indicates the lowest temperature attained. In Rutherford's maximum thermometer, a mercurial thermometer, whose stem is horizontal, is used and a steel index is employed. This is pushed before the mercurial column as it expands, and is left behind when the mercury contracts. Thus the hinder end of the index indicates the highest temperature attained. The thermometer can be set by bringing back the index, usually by means of a magnet, into contact with the end of the column of mercury. This instrument is liable to fail completely after a few years' use, as chemical action occurs, and the index is then apt to become wetted by the mercury.

In Phillips's maximum thermometer the column of mercury is broken by a small bubble of air. When the mercury expands it pushes the air and the detached mercury in front of it, but when the temperature is lowered the detached mercury is left behind, the air expanding as the end of the column, which stretches up to the air bubble, recedes. In Negretti's maximum thermometer a constriction exists near the bulb, which allows an expanding column of mercury to pass, but is able to offer sufficient resistance to prevent the cohesion of the mercury drawing the column back as the bulb cools.

Expansion.—In describing the expansion of bodies under the influence of heat it is customary to make use of the expression "co-efficient of expansion." The co-efficient of cubical expansion of a body is the increase, per unit of volume of the body, when its temperature is raised from zero to one degree. In the case of solids and liquids, the co-efficient of expansion has varying values for different substances. Thus mercury expands under the action of heat to a much greater extent than glass, and upon this fact the use, in the ordinary thermometer, of a column of mercury in a glass tube depends. Again, the co-efficients of expansion, in the case of solids and liquids, show some increase as the temperature is raised, though it may be noted that the co-efficient of expansion of mercury is well-nigh constant at all ordinary temperatures, another fact of importance in connection with the use of mercury in the thermometer.

In the case of gases, however, it is found that the co-efficient of expansion is practically the same in all instances. In other words, if V_0 and V_t be the volumes of a gas at zero and at t° Centigrade, respectively, then, if the pressure remain the same,

$$V_t = V_0 (1 + at),$$

where $a = \cdot 003665$ nearly, *i.e.*, approximately, $\frac{1}{273}$, and where for ordinary purposes this value may be regarded as constant, whatever the nature of the gas considered. Again, the value of a remains practically the same for all the ordinary temperatures indicated by the mercurial thermometer. It will now be seen what is meant by saying that the expansion of gases is more regular than that of solids and liquids.

In discussing the increase of volume caused by increase of temperature the pressure was assumed to remain constant; consideration of the manner in which pressure varies with increase of temperature, if the volume remains the same, may now be undertaken. If P_t and P_0 denote the pressures per unit of surface of a gas, contained in a vessel of fixed volume, at temperatures t° and zero Centigrade, respectively, it is found that

$P_t = P_0 (1 + at)$ the value of a being, as before, $\cdot 003665$ nearly.

This is sometimes called the law of Charles.

Thus, if the volume remains unaltered, the pressure increases with temperature, to the extent indicated by multiplying it by the factor $(1 + at)$, and it has been seen that, if the pressure remains constant, the volume increases with temperature to the extent indicated by multiplying it by this same factor. Boyle's law, it will be remembered, is to the effect that the product of the volume and pressure always remains the same, provided the temperature remains constant.

It may be stated generally that the product of the volume and pressure of a gas at t°, is $(1 + at)$ times the product of the volume and pressure of the gas at zero, or, as it may be expressed in signs,

$$(VP)_t = (VP)_0 (1 + at).$$

Of this general statement the two previously given are of course particular cases, for, if in the general statement the volume be supposed to remain always the same, the product of volume and pressure is proportional to the pressure only, and thus

$$P_t = P_0 (1 + at),$$

while, on the other hand, if the pressure be supposed to remain the same, the product of volume and pressure is proportional to the volume only, and

$$V_t = V_0 (1 + at).$$

As a gas increases by $\frac{1}{273}$ of its volume for each degree Centigrade, it follows that if the temperature of a given volume at 0° were raised to 273° C., the volume would be doubled, while if the temperature could be lowered to – 273° C., and the law of contraction continued to hold good, the volume would entirely disappear. The point – 273° C. is referred to as the absolute zero of temperature, and temperatures reckoned from this point are spoken of as absolute temperatures. If T denote the absolute temperature, the relation between the volume, pressure and temperature of a gas, assumes the simple form, $\frac{VP}{T}$ = constant.

The following examples of the application of these principles may be given:—

(i.) To what volume would 1000 c.c. of a gas at 15° C. expand if the temperature rose to 70° C.?

Here the pressure remains constant, and V_0, the volume at zero, must be multiplied by $(1 + 15a)$ to give V_{15} the volume at 15°, a being ·003665,

$$\text{or } V_{15} = (1 + 15a)V_0$$

and V_{70}, the volume at 70° must be given by the equation

$$V_{70} = (1 + 70a)V_0$$

From the first equation, $V_0 = \frac{V_{15}}{1 + 15a}$ and from the second equation, $V_0 = \frac{V_{70}}{1 + 70a}$

$$\therefore \quad \frac{V_{15}}{1 + 15a} = \frac{V_{70}}{1 + 70a}$$

Multiplying crosswise

$$V_{70} (1 + 15a) = V_{15} (1 + 70a) = 1000 (1 + 70a)$$

$$\therefore \quad V_{70} = \frac{1000 \times 1{\cdot}25655}{1{\cdot}054975} = 1191{\cdot}07 \text{ c.c., nearly.}$$

(ii.) Calculate the volume to which 1000 c.c. of air expand when the temperature rises from 50° F. to 90° C.

Here again the pressure remains constant, but the temperatures are now expressed in different scales. They must, if the value ·003665 is to be applied to a, be both referred to the Centigrade scale.

50° F. is 18° F. above freezing point, the zero of the Centigrade scale, and each degree Fahrenheit is $\frac{100}{180}$ or $\frac{5}{9}$ths of a degree Centigrade.

$$\therefore \ 50° \text{ F.} = \frac{5}{9}\, 18° \text{ C.} = 10° \text{ C.}$$

Proceeding as before $V_{10} = (1 + 10a)\, V_0$

and $V_{90} = (1 + 90a)\, V_0$

$$\therefore \ V_{90}\,(1 + 10a) = V_{10}\,(1 + 90a)$$

V_{10} is the volume at 10° C., *i.e.*, at 50° F., *i.e.*, 1000 c.c.

$$\therefore \ V_{90}\,(1 + \cdot 03665) = 1000\ (1 + \cdot 32985)$$

$$\therefore \ V_{90} = \frac{1329\cdot 85}{1\cdot 03665} = 1282\cdot 83 \text{ c.c., nearly.}$$

(iii.) A gas initially at volume 4500 c.c., temperature 100° C., and a pressure represented by 75 c.m. of mercury, has its pressure increased by 1 c.m. of mercury, and its temperature raised to 200° C. Find its final volume.

Supposing the temperature to remain at 100° C., an increase of 1 c.m. of pressure would cause the volume of the gas to diminish to the value V, where $V \times 76 = 4500 \times 75$, by Boyle's law as to the constancy of the product of volume and pressure, when the temperature remains the same.

If this volume of gas $\left(V = \frac{4500 \times 75}{76} \text{ c.c. at } 100° \text{ C.} \right)$ be lowered to zero temperature, the pressure now remaining constant at 76 c.m. of mercury, its volume will be further diminished in the proportion represented by dividing it by $(1 + 100 \times \cdot 003665)$, *i.e.*, by 1·3665.

Thus the new volume will be $\frac{4500 \times 75}{76 \times 1\cdot 3665}$ c.c.

If this new volume be now raised to 200° C., the pressure still remaining constant at 76 c.m. of mercury, it will increase in the proportion represented by multiplying it by $(1 + 200 \times \cdot 003665)$, *i.e.*, by 1·733.

Thus the final volume of the gas at 200° C. and 76 c.m. pressure

$$= \frac{4500 \times 75}{76 \times 1\cdot 3665} \times 1\cdot 733 = 5632 \text{ c.c. nearly.}$$

Mixtures of Gases and Vapours.—The word vapour is applied to the gaseous state of bodies usually met with in the solid or liquid condition—thus it is customary to speak of water vapour, the vapour of arsenic, and so on; while the term gas is applied more especially to bodies commonly met with in the gaseous condition. If a liquid be allowed to evaporate into an empty space, it at first rapidly assumes the form of vapour, and as the amount of the latter is augmented, the "elastic force," "pressure," or "tension," as it is called, exerted by it upon the boundaries of the space will increase. At length, however, a limit will be reached, beyond which no more liquid will pass into a state of vapour; the space is then said to be saturated, and the vapour contained in it is at maximum density and pressure, for the temperature concerned. If the temperature be raised, the maximum density and pressure increase; or, in other words, the higher the temperature, the greater the quantity of vapour required to saturate a given space.

If a liquid evaporate into a space filled with dry gas, saturation will be attained more gradually than in the case of evaporation into a vacuum, but, ultimately, the same amount of liquid will be evaporated; again, when a gas is saturated with vapour, the actual pressure of the mixture is the sum of the pressures due to the gas and vapour considered separately. These two laws, concerning mixtures of vapour and gas, are sometimes called, after the name of their discoverer, Dalton's laws. It may be noted that experiments seem to show, as regards the first law, that it is not, strictly speaking, exact, inasmuch as to a very slight extent the quantity of vapour taken up is diminished, as the density of the gas simultaneously occupying the space is increased. Again, the second law holds good whether the quantity of vapour reaches the point of saturation or falls short of it; thus it may be stated generally that in the case of a mixture of gases and vapours, the total pressure, on the walls of the containing vessel, is the sum of the pressures due to the several gases and vapours considered separately.

A mixture of air and vapour obeys the ordinary laws applicable to mixtures of gases, provided none of the vapour becomes condensed; it is because of the liability to the occurrence of condensation on the part of the vapour, as the result of changes of temperature and pressure, that the subject of mixtures of gas and vapour requires special consideration. The vapour in question in dealing with air is, of course, water vapour. If air be saturated with moisture, and while the pressure remains constant a reduction of temperature occurs, some of the aqueous vapour is condensed, forming water. If, again, a non-saturated mixture of air and vapour be cooled down, at constant pressure, the point of saturation will be at length reached, and when this is attained condensation occurs. The temperature at which saturation of the air with vapour is reached is termed the "dew point." Now, throughout this cooling process, up to the time when condensation occurs, the vapour pressure will have remained unchanged, for both the gas and vapour, in the mixture, are subject to the laws of Boyle and of Charles, and the coefficient of expansion, a, is the same for each; hence whatever change is undergone by the total pressure must be equally undergone by each of the constituent pressures. But the total pressure remains unchanged, free communication with the external atmosphere being assumed, and, therefore, each of the constituent pressures also remains unchanged. In other words, the product of the volume and pressure of the mixture, divided by T, its absolute temperature, is constant, and the product of the volume and pressure of the vapour, divided by T, is also constant.

Expressing this in signs $\frac{VP}{T}$ is constant, and $\frac{VP^1}{T}$ is also constant.

But as P is constant, $\frac{V}{T}$ must be constant, and hence P^1 is constant.

Thus the actual vapour pressure in the air which is cooled down, remains throughout that which obtains when the dew point is reached. At this point the air is saturated, and the vapour pressure is the maximum pressure for that particular temperature. Hence the actual vapour pressure, in a portion of air, may be determined by ascertaining the temperature at which condensation occurs, and finding what vapour pressure corresponds to saturation of the air with vapour at that temperature.

The maximum pressure of vapour corresponding to different temperatures was first determined by Regnault, who constructed a table showing that in the case of water vapour, the maximum pressure varied from some 4·6 m.m. of mercury at 0° C., up to some 148 m.m. at 60° C., and to 760 m.m. at 100° C. It will be noted that the maximum pressure at boiling point is the atmospheric pressure, 760 m.m.; a little consideration will make it clear why this should be so. The pressure on a rising bubble of vapour is, of course, the atmospheric pressure plus the weight of water above it; thus, if the bubble reaches the surface it must still, on arriving there, have a vapour pressure equal to the pressure of the atmosphere. In other words, in order that bubbles of vapour may escape at the surface, the vapour pressure must be equal to atmospheric pressure; hence, also, a liquid may be said to be boiling when it gives off vapour of the same pressure as the atmosphere above it. The boiling point will be somewhat higher in the deeper layers of the water than it is at the surface; for this reason, in finding the fixed point of a thermometer, the instrument is plunged into the steam evolved from the water and not into the water itself.

Again, it will be clear that, at increasing heights above sea level, the boiling point will progressively become lower and lower, and given the boiling point, the atmospheric pressure and hence the height above sea level, can be determined by reference to a table, such as that constructed by Regnault, showing the maximum pressure of aqueous vapour corresponding to different temperatures.

In studying the condition of the air, with respect to its contained water vapour, it is important to know not so much the actual amount of vapour present, as the proportion which this actual amount bears to the quantity there would be if the air were saturated. This ratio is termed the "humidity," or, sometimes, the "relative humidity." If the relative humidity be low, the air usually gives the sensation of dryness; if high, the air, as a rule, appears damp; and this remains true, although, in the former case, it may be found that the actual amount of vapour is considerable, or, in the latter case, that it is small.

Relative humidity may be defined as the ratio of the mass of vapour existing in a given space, to the amount which would saturate the space at the particular temperature under consideration. In this country the relative humidity is commonly found to be about 70 per cent.

Hygrometers (ὑγρός, moist) are instruments used for measuring the amount of moisture in the air. They belong to one of four classes—chemical hygrometers, and hygrometers of absorption, of condensation, and of evaporation. In the chemical hygrometer the amount of aqueous vapour is determined by drawing air, by means of an aspirator, through a system of U tubes containing fragments of pumice soaked in sulphuric acid, and ascertaining the increase of weight which occurs. This method is too laborious for ordinary application. The other three forms of hygrometers are as follows:

(i.) Certain organic substances readily absorb moisture from the air, and are said to be hygroscopic. Such substances undergo contraction or elongation, in correspondence with the amount of water they have absorbed, and these alterations of shape can be used to measure the condition, as regards moisture, of the atmosphere by which the hygroscopic substance is surrounded. Thus, in De Saussure's hygrometer, a hair, freed from grease, is fixed at one end, and at the other is attached to an indicating apparatus. The hair contracts and elongates with increase and diminution of humidity, and these movements are recorded by a needle, whose point moves along a scale which can be empirically graduated.

In the simple form of the instrument, the hair is attached to the short arm of a rotating needle, and by its contraction carries the index arm away from the position of zero. The longer arm returns to zero when the tension of the hair relaxes, as there is a small counterbalancing weight. In a modification of the instrument the hair, after passing round the axle on which the needle revolves, is attached to a light spring. De Saussure's hygrometer cannot, as a rule, be relied upon for exact observations, but it is not infrequently used in places where intense frosts interfere with the action of the evaporation hygrometer, to be presently referred to.

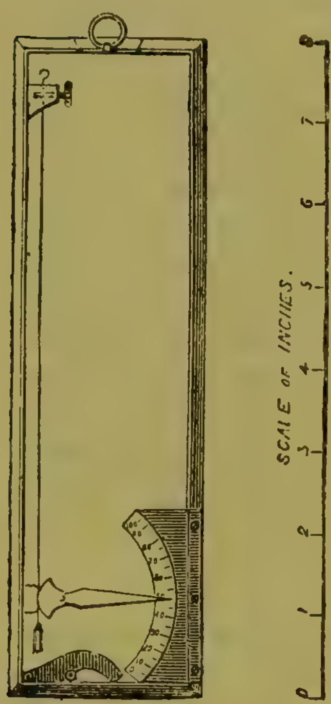

FIG. 3.
De Saussure's Hygrometer.

There are certain other materials possessed of hygroscopic property which are occasionally utilised to determine the amount of moisture in the air. Thus a piece of sea-weed is sometimes employed, inasmuch as, by reason of the salts it contains, it becomes damp in wet weather, and dry when the amount of moisture in the air undergoes decrease. Again, there is the toy weather-indicator, consisting of a house, from which the figure of a woman emerges in dry weather, and that of a man in damp weather; this phenomenon being due to the expansion and contraction of a piece of catgut, by which the figures are moved.

(ii.) Dew point hygrometers record the temperature at which condensation of vapour occurs. Dines' hygrometer has a chamber, in which cold water can be made to circulate around the bulb of a thermometer. At the upper part of the chamber is a plate of black glass; as soon as the cooling process reaches the point at which dew appears on the black glass, the thermometer is read, and the flow of cold water being then stopped, the thermometer is again read when the dew disappears. The mean of the two readings gives the dew point.

In Daniell's hygrometer cooling is effected by the evaporation of ether. The instrument consists of two globes, connected by a bent tube. One globe, made of black glass, contains a little ether and has a thermometer fixed in it; the bent tube contains, of course, ether vapour. The second globe is moistened externally with ether,

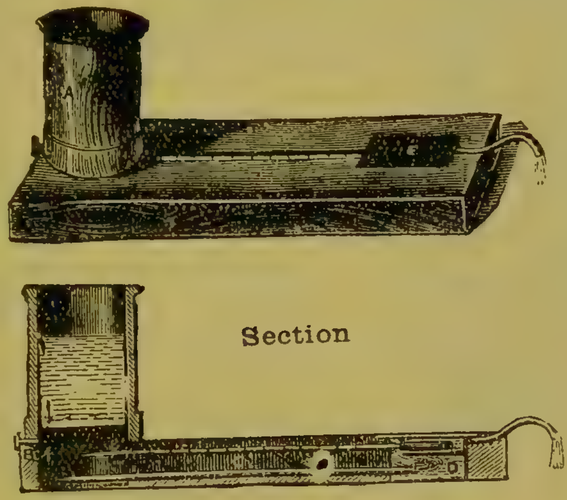

FIG. 4.
Dines' Hygrometer.

the evaporation of which, causes condensation of ether vapour in the globe, and this excites evaporation of the ether in the thermometer-containing-globe, with consequent lowering of temperature. The temperature recorded when dew is deposited on the black globe is observed, and that registered when the dew disappears is also noted; as before, the mean of these readings gives the dew point.

Regnault's hygrometer is an improved form of Daniell's hygrometer, in which evaporation of the ether is produced by drawing air through it by means of an aspirator. By this means the ether is kept in agitation, and uniformity of temperature is thus secured. Further, arrangement is made for the operator to observe the deposition of dew from a distance, and so the disturbing influence of his proximity to the instrument is eliminated. Again, a silver cap is substituted for the less sensitive black glass globe; furthermore, this hygrometer can be manipulated with alcohol, a considerable advantage when, as is the case in warm climates, the much more volatile ether can only with difficulty be employed.

(iii.) The form of hygrometer which is commonly used in temperate climates is the "wet and dry bulb," Mason's hygrometer, or August's psychrometer, as it is called abroad. This instrument consists of two ordinary thermometers, one of which has its bulb covered with muslin, which dips into, or communicates by means of a wick of cotton with, a vessel containing distilled water. The dry bulb gives the temperature of the air, the wet bulb gives a somewhat lower reading, in correspondence with the amount of evaporation, and consequent lowering of temperature which takes place. If the air be saturated no evaporation can occur, and the reading of the two bulbs is the same, though it may be noted that, under the circumstances named, the wet bulb reading may very slightly exceed that of the dry bulb, inasmuch as the former is to some extent protected from radiation by its covering of muslin. The difference in the two readings ordinarily ranges from 1° or 2° in winter, to 6° or 8° in summer. In using the instrument there should be no interference with access of air to the wet bulb, the vessel containing water should be small and placed at a little distance from the bulb, the muslin must be kept moist, and drops must not be allowed to fall from the bottom of the bulb. When frost prevails the wick no longer acts, and the bulb is then brushed over with water, which must be allowed time to freeze before the reading of the ice-covered bulb is taken.

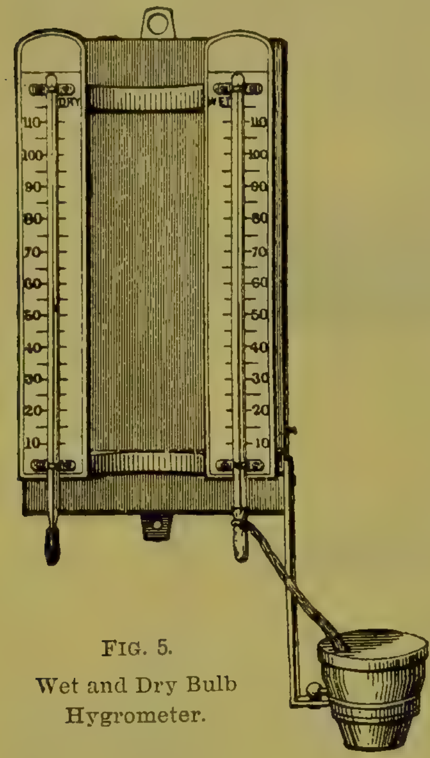

FIG. 5.
Wet and Dry Bulb Hygrometer.

Having noted the readings of the two thermometers the dew point is ascertained, either by the use of Glaisher's tables or by the following formula, known as Professor Apjohn's formula :—

$$F = f^1 - \frac{t - t^1}{87}$$

for which must be substituted when the wet bulb is frozen—

$$F = f^1 - \frac{t - t^1}{96}$$

where t and t^1 are the dry and wet bulb readings, f^1 is the vapour tension corresponding to t^1, and F is the vapour tension at the dew point.

For the application of Apjohn's formula a table of vapour tensions must in any case be used, and in practice, having ascertained the dry and wet bulb temperatures, both the dew point, and, for all ordinary readings, the relative humidity, can be obtained without calculation, by the use of Glaisher's tables. In these tables a series of factors, Glaisher's factors, is given for each reading of the dry bulb thermometer. The dew point is determined by subtracting from the dry bulb temperature, the product of the corresponding factor, and the difference of the dry and wet bulb temperatures; *i.e.*, the dew point is $t - D\ (t - t^1)$, where D is the factor and t and t^1 are the dry and wet bulb temperatures.

The dew point being determined, the weight of a cubic foot of vapour at the dew point can be read off in the tables. The relative humidity, *i.e.*,

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

can be then calculated with the aid of a table giving the weights of a cubic foot of vapour at each temperature. In practice, as has been said, it is usually taken directly from the set of tables, which supplies the relative humidities for all ordinary readings likely to be recorded.

The following example may be given of the simple calculation necessary supposing the dry and wet bulb temperatures known, while a table giving Glaisher's factors and a table of vapour tensions are alone available.

Example.—The dry and wet bulb readings are 60° F. and 55° F., what is the relative humidity?

$$\begin{aligned}\text{The dew point} &= 60 - 5\ D\\ &= 60 - 5 \times 1{\cdot}88 \text{ (from the table of factors)}\\ &= 50{\cdot}6^\circ \text{ F.}\end{aligned}$$

The weight of a given volume of vapour varies as its pressure, elastic force or tension. Hence the relative humidity, which is equal to—

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

is in this case $= \dfrac{\text{Tension at } 50{\cdot}6^\circ \text{ F.}}{\text{Tension at } 60^\circ \text{ F.}} \times 100,$ which from the table of tensions, $= \dfrac{{\cdot}369}{{\cdot}518} \times 100 = 70{\cdot}1$ per cent.

It may be required, given the necessary data, to determine the weight of a certain volume of moist air.

Example.—Find the weight of a cubic foot of moist air, containing 70 per cent. of moisture, at 60° F., under 29·92 inches barometric pressure.

The mass may be regarded as made up of two parts. A cubic foot of dry air at 60° F. under the existing pressure, less the tension of the vapour present; and a cubic foot of vapour at 60° F., and under a pressure equal to the vapour pressure at the dew point.

The pressure at the dew point will be $\frac{7}{10}$ths of the maximum tension of vapour at 60° F. This latter pressure = ·518 in. of mercury.

∴ The vapour tension of the moist air = ·362 inch.

Now a cubic foot of dry air, at 60° F. and 29·92 inches pressure, weighs 536·3 grains, therefore at pressure 29·92 – ·362, *i.e.*, 29·558 inches, it will weigh $\frac{29·558}{29·92} \times 536·3$ grains, or 529·81 grains.

The weight of a cubic foot of vapour at 60° F. is 5·77 grains if the vapour is at maximum pressure, and therefore the humidity in the present case being 70 per cent., the weight of the cubic foot of vapour = 4·039 grains.

Hence the weight of the cubic foot of moist air = 533·849.

It will be noted that this weight is less than that of a cubic foot of dry air at 60° F. and 29·92 inches pressure, and, generally, when water evaporates into dry air the resulting mixture has less weight, volume for volume, than the original dry air.

Diffusion of Gases.—If communication is made between two receivers containing different gases they diffuse one into the other. The rate of diffusion depends upon the densities, and if it be tested by allowing different gases to diffuse through a porous septum, it will be found to vary inversely as the square roots of the densities of the gases. This is called the law of Graham. Thus, if oxygen and hydrogen diffuse, one into the other, the densities being as 16 to 1, the rates of diffusion will be as 1 to 4, four parts of hydrogen diffusing into the oxygen, for each part of oxygen that diffuses into the hydrogen. The process of interchange continues as long as the mixtures remain dissimilar. Thus, if an upper glass globe containing hydrogen be placed in communication with a lower glass globe containing carbonic acid, which is twenty-two times as dense, the two gases will ultimately become uniformly mixed, the lighter hydrogen diffusing downwards and the heavier carbonic acid diffusing upwards. It is this process of diffusion which causes the atmosphere to remain of uniform composition, by leading to the distribution, throughout the general body of air, of any special constituent gas, which may be produced in excess at a given point.

Another important cause of interchange is the fact that movement is set up when constituent portions of the atmosphere, of like composition but of differing densities, come into communication with one another. Differences of temperature, by producing alterations of density, are largely operative in determining interchange of air.

If liquid escapes from an opening in the side of a vessel, the velocity becomes greater when the *head* of liquid, *i.e.*, the depth of the opening below the surface, is increased. Torricelli's theorem is to the effect that the velocity of efflux is equal to the velocity which would be attained by a body falling from the upper surface of the liquid to the opening, or, if h be the height of the surface above the orifice,

$$V = \sqrt{2gh}$$

If air flows into a vacuum its velocity will be $\sqrt{2gh}$, where h represents the height of the imaginary column of air, of the density of the effluent air, which would be required to produce the atmospheric pressure. This column would have to counterbalance 760 m.m. of mercury, and it may be therefore calculated to be about 5 miles, or 26,400 feet high. Hence V will be found to be about 1,300 feet per second. If the air diffuse, not into a vacuum, but into other air at pressure corresponding to a height h^1, the formula becomes:

$$V^2 = 2\,g\,(h - h^1).$$

This rule, the rule of Montgolfier, as it is sometimes called, may be applied to the movement of a column of air in a chimney. Within the chimney is a column of heated air, while outside there is a column of colder air of equal height; the pressure at the top of these columns, being the barometric pressure and alike in both cases, may be neglected. Air expands $\frac{1}{273}$rd of its volume for each degree Centigrade, and this proportion corresponds to $\frac{1}{491}$, or approximately ·002, for each degree Fahrenheit. If then h be taken as the height of the chimney, h^1 is determined by finding what would be the height of the column of heated air, if it were reduced to the same density as the outside air; $h - h^1$ will then give the difference of heights upon which the movement depends.

If t and t^1 be the temperatures of the inner and outer columns, $1 + (t - t^1) \times \cdot002$ represents approximately the volume to which one volume at t^1 will have expanded at t.

$$\therefore\ h^1 = \frac{h}{1 + \cdot002\,(t - t^1)}$$

and $$V = \sqrt{2gh\left[1 - \frac{1}{1 + \cdot002\,(t - t^1)}\right]}$$

Thus, if the chimney be 30 feet high and the difference of temperature 20° F.

$$V = \sqrt{2 \times 32 \times 30 \frac{\cdot 002 \times 20}{1 + \cdot 002 \times 20}}$$

$$= \sqrt{2 \times 32 \times 30 \frac{\cdot 04}{1 \cdot 04}} = \sqrt{\frac{2 \times 32 \times 30}{26}} = \begin{cases} 9 \cdot 5 \text{ ft.} \\ \text{per sec.} \\ \text{nearly.} \end{cases}$$

In practice the results obtained in the manner just indicated are much too high; allowance has to be made for friction (which varies directly as the length of the chimney and the square of the velocity, and for similar sections inversely as their diameters) and for angles, etc., to say nothing of soot and dirt.

Heat is distributed through space by conduction, by convection, and by radiation. Conduction of heat is mainly manifested in solid substances, of which some—certain metals, for example—are very good conductors of heat, while others, such as glass, are bad conductors. Wool and furs, and silk, are bad conductors, and hence their use for purposes of clothing, as they serve to prevent the heat of the body being dissipated. In the same way woollen materials may be used to keep substances cold, as for example, when a block of ice is wrapped in flannel. Moreover, wool and, to a less extent, silk possess the capacity of absorbing moisture. If a woollen garment be put on after exercise, the vapour from the surface of the body becomes condensed in the wool, imparting to it the heat rendered latent when vaporisation occurred. The garment therefore at once feels warm, and the tenacity with which it holds the moisture prevents re-evaporation and chilling. Linen and cotton are better conductors of heat than wool, and do not possess the same hygroscopic property; when they are rendered damp by perspiration, evaporation proceeds rapidly and chilling of the body results. Cellular cloth is made from cotton fibres, so woven as to leave interspaces, the air contained in which is non-conducting; hence the warmth of the material depends on its porosity.*

* Microscopically wool fibres are round on section, nearly transparent and unbranched, and they present, on the surface, imbricated scales similar to those of a hair. Silk fibres are structureless, save for occasional nodes, glass-like, and without surface markings; both wool and silk turn yellow on addition of nitric or picric acid, and are dissolved by strong boiling caustic alkali, these reactions distinguishing them from cotton and linen fibres. Silk is dissolved by hot concentrated solution of chloride of zinc, which does not affect wool. Cotton fibres are flat, ribbon-like, and twisted at intervals; linen

Liquids and gases as a rule are very bad conductors, but heat may be freely distributed in them by convection currents, which convey the heated particles from one part of the liquid or gas to another. The transmission of heat by radiation, and, of course, mainly by solar radiation, is the great cause of the maintenance of temperature at the earth's surface; some of the heat so transmitted is again radiated by the earth into space. The atmosphere (and in particular the aqueous vapour of the air) plays an important part in checking excessive loss of heat from the earth by radiation, it also absorbs and intercepts heat radiated from the sun. The heat radiated by bodies is absorbed, transmitted or reflected by other bodies just as light is; indeed, light rays constitute, as it were, a particular case of radiation, corresponding as they do to the special form of radiated energy which the eye is adapted to perceive; the rays which are invisible are sometimes called dark rays. Dry air absorbs very little of the heat radiated through it; moist air absorbs a good deal, thus becoming itself heated. The heating effects observed, during exposure to the sun's rays, in the dry air of places at high altitudes in Switzerland, illustrate on the one hand small extent of interference with solar radiation; while, on the other hand, the contrast afforded between the temperature on a clouded and on a clear night in winter, shows how large a part the aqueous vapour of the atmosphere may play in preventing loss of the earth's heat by natural radiation. Different substances require varying amounts of heat in order to produce in them increase of temperature to a like extent. Water absorbs more heat, for the same increase of temperature, than most other substances do. If the quantity of heat required to raise a kilogramme of ice-cold water one degree Centigrade be taken as the unit, the amount required to raise an equal weight of any other substance one degree Centigrade is termed the *specific heat* of that substance. As a rule the specific heat of solids is greater at a high than at a low temperature, hence the reference to ice-cold water, *i.e.*, to water at a particular temperature, as a standard.

Latent heat is the heat absorbed or rendered latent when bodies pass from the solid to the liquid, or from the liquid to the gaseous condition. If the quantity of heat required to raise one kilogramme

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fibres present many nodes, and have a ragged fibrillated appearance. Addition of sulphuric acid gelatinises cotton and linen after some minutes' exposure; the reagent slowly dissolves silk, and does not affect wool. A solution of cuprate of ammonia dissolves silk and cotton, and slowly dissolves linen; but only causes wool to swell to some extent. Cotton is a ready absorbent of odours; wool possesses the advantage of not retaining them.

of water from 0° C. to 1° C. be taken as the unit, the amount of heat required to convert a kilogramme of ice at 0° C. into a kilogramme of water at 0° C. proves to be 79, this is the latent heat of water. The latent heat of steam at 100° C. is found to be 537 units, in other words, to convert a kilogramme of water at 100° C. into steam at 100° C. requires 537 units of heat.

In connection with the subject of warming by convection, certain points should be noted. In the process of cooling, the surface particles of water, as their temperature is lowered, become more dense and descend, being replaced by particles from beneath. By convection the whole body of water is thus gradually cooled, but a remarkable fact needs to be borne in mind. The maximum density of water is attained at 4° C., and when that point is reached the water-particles cease to become more dense, as their temperature is further lowered down to 0° C. Thus, as cooling proceeds, ice is formed at the top of the water.

Convection currents in air must also be particularly referred to. Differences of temperature of masses of air, by producing differences of pressure, disturb the equilibrium of the atmosphere, and the result is wind. The force of wind is estimated by instruments called anemometers; there are two varieties of these, "pressure" and "velocity" anemometers. The simplest form of pressure anemometer consists of a sheet of metal suspended by its superior border, and a rough indication of the pressure of the wind is afforded by observing the angle through which the sheet is displaced by that pressure. In Lind's anemometer the force of the wind is measured by observing the height to which a column of water is raised in one arm of a U-shaped tube, when the water in the other arm is in communication with an opening turned to the wind. The pressure anemometers of Osler and Cator are somewhat more complicated instruments, in which resistance is furnished, in the one case by springs, in the other by a series of levers, and the pressure recorded is marked by a travelling pencil upon a sheet of paper.

The form of anemometer usually employed is Robinson's velocity anemometer. In the case of this instrument the velocity of the wind is determined by noting the rate at which four hemispherical cups rotate around a vertical axis, about which they can revolve in a horizontal plane. The wind exerts greater force upon the hollow surfaces of the cups than upon their rounded surfaces, rotation therefore occurs, and the stronger the wind the faster the rotation. It was supposed originally by Dr. Robinson that the rate of rotation was constant for varying dimensions of the parts of the instrument, and that the cups moved with about one-third of the velocity of the wind. It is now known that this is not strictly correct; roughly speaking, however, the velocity of the wind may be taken as about $2\frac{1}{2}$ times the velocity of the cups, when the instrument as ordinarily constructed, with cups 9 inches in diameter, on arms 24 inches in length, is employed. Allowance should be made for friction in the case of low velocities, and a good deal depends upon the position, in relation to neighbouring buildings, in which the instrument is placed. The degrees of intensity of wind are often expressed by reference to what is known as Beaufort's scale, *i.e.*, to certain standards laid down by Sir F. Beaufort early in the century, and based mainly upon the relation of wind pressure to the amount of sail carried by the sailing man-of-war of that time. There are 13 degrees of force on this scale beginning with 0, which corresponds to "calm," *i.e.*, to a velocity not exceeding three miles per hour: upon this follow the degrees termed 1 to 6, and referred to as light air, and light, gentle, moderate, fresh and strong breeze: then the degrees 7 to 10, moderate, fresh, strong and whole gale, and 11 "storm" (seventy-five miles per hour) supervene, and finally the degree 12 corresponds to "hurricane" (ninety miles per hour).

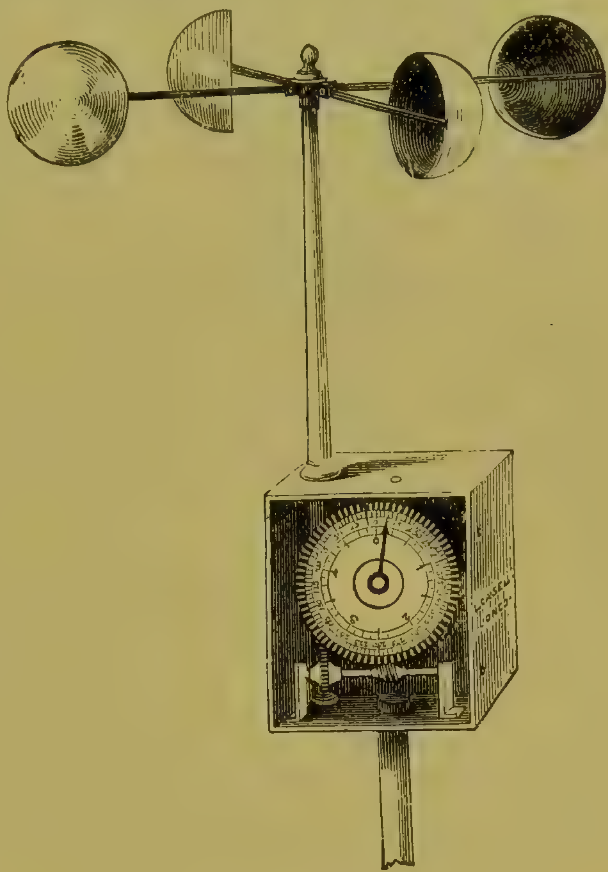

FIG. 6.
Robinson's Anemometer.

Weather Forecasts.—Of late years much attention has been directed to this subject. As long as observation was limited to the fluctuations of the barometer at a particular place but little progress was made. Certain connections between rise and fall of the barometer, and the occurrence of rain and wind were noted, and rules were formulated as to the significance of sudden and sustained alterations of barometric pressure under varying conditions. With the introduction of communication by telegraph, however, a great change was brought about, and what is called the "synoptic method" has now assumed special importance in connection with weather prognostications.

If the barometric pressures at one and the same moment of time be ascertained at various stations over a considerable area, it is possible to construct *isobars*, *i.e.*, lines connecting all the points at which the same pressure prevails; these isobars present certain characteristic shapes, and from their configuration a good deal can be learnt.

There are two primary and five secondary types of grouping of isobars which have been specially described, and which are illustrated in Fig. 7. Just below its centre there will be found

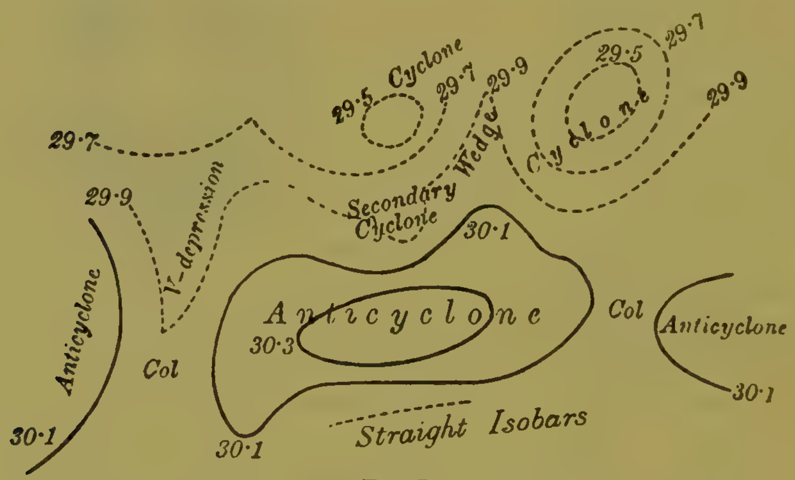

FIG. 7.

Diagrammatic representation of pressure distribution, over the North Atlantic and parts of Europe and the United States, on February 27, 1865.

an area in which the isobars form closed curves, and in which the pressure, measured in tenths of an inch, increases on proceeding from without inwards; such an arrangement of isobars constitutes an *anticyclone*.

On either side of the central anticyclone of the figure are seen the edges of two other anticyclones; the areas of comparatively low pressure intervening between the anticyclones are termed, from the analogy of a pass between two mountains, *cols*. If the isobars, instead of enclosing an area of high, enclose one of low pressure, the arrangement constitutes a *cyclone* (see the upper part of Fig. 7, on the right hand side). The cyclone and anticyclone are the two primary types already referred to: the secondary types include the *col*: the *secondary cyclone*, in which an area of low pressure is enclosed, as it were, in a loop without being completely detached; the *wedge*, in which a high pressure area projects wedge-like between two neighbouring cyclones; the *V-shaped depression*, in which a low pressure area is pushed in, so to speak, between high pressure areas; and, finally, *straight isobars*, in which the lines of equal barometric pressure form practically parallel straight lines.

Two further points require to be specially noted concerning the arrangement of the isobars. In the first place, the force of the wind varies with their closeness. If the barometric gradient be steep, *i.e.*, if the isobars, for example, corresponding to differences of pressure of $\frac{1}{10}$th inch, are comparatively close to one another, the wind will be proportionately strong, and *vice versâ*. Again, from the arrangement of the isobars the direction of the wind can be deduced by "Buys Ballot's law," which is to the effect that, on standing "back to the wind," the lowest pressure lies to the left and in front. A little consideration will make it clear therefore that, in a cyclone, the wind blows spirally inwards, towards the area of low pressure; and if wind arrows be marked all round such an area, their direction will change, on proceeding round the circle, in a manner opposed to that of the movement of the hands of a clock. In an anticyclone, on the other hand, the wind blows spirally outwards, the arrows changing in a manner corresponding to the movement of the hands of a clock.

Cyclones, as observed in this country, commonly travel from west to east with an average velocity of about twenty miles an hour. As the front of the cyclone approaches, the ordinary signs of rain usually appear, halo, watery sun, capped hills, etc.; the rain then falls in gradually increasing amount, until the "trough" or line of lowest pressure passes, when squalls of wind and what are called "clearing showers" are observed; then patches of blue sky follow, and the weather clears. The heaviest rain is experienced, as a rule, when the point of lowest pressure is situated a little to the north and west, in other words, the rain area is more marked somewhat in front and to the south of the centre of the cyclonic system. Again, differences are observed according to whether the area of lowest pressure passes directly over, or a little to the north or south of the place of observation. Broadly speaking, however, the front of the cyclone corresponds with dirty, gloomy sky, the clouds being of strato-cumulus type, and with warmth and a feeling of oppression in the air; while the rear of the cyclone corresponds with a sky of cumulus type, with cold, and a brisk feeling in the air. Anticyclones, unlike cyclones, tend to remain stationary for long periods; in summer anticyclonic weather is bright and warm, with cool, clear nights; in winter, under anticyclonic conditions, it is very cold, and fog often prevails.

The wedge, in these latitudes, usually points northwards; it is associated with a temporary period of fine weather, and is usually followed by cyclonic disturbance. On development of the col, gloomy weather prevails, and thunderstorms may occur. Straight isobars are commonly associated with hard sky and blustering wind. Secondary cyclones and V-shaped depressions correspond to weather of more or less disturbed character. As cyclones generally approach this country from the Atlantic, it is possible to forecast their occurrence with a considerable amount of success, from the phenomena observed at stations in the west of Ireland. Again, the area of lowest pressure tends to pass, as a rule, to the north of England, and this fact explains how it comes about that in this country the wind "veers," or changes with the sun, more often than it "backs," or changes in the contrary direction.

The general distribution of atmospheric pressure over the northern hemisphere is as follows:—In the tropics there is a high pressure belt which rises here and there into anticyclonic elevations. One of these elevations, the Atlantic anticyclone, is as a rule found over the central Atlantic. To the north and south of the tropical high pressure belt are regions of comparatively low pressure; an equatorial area lies to the south, while on the north low pressure generally prevails, but high pressure areas may be developed from time to time. "Trade winds" are the north-east and east winds on the southern side of the Atlantic anticyclone. There are corresponding south-east trade winds on the north side of a great anticyclone in the South Atlantic; between these regions of wind is the calm equatorial zone known to sailors as "the doldrums."

Four general types of weather have been described as occurring in Western Europe: in these the prevailing winds are from the south, west, north, and east respectively. In the first, the southerly type, an anticyclone lies to the south or south-east of Great Britain, and there is a low pressure area over the North Atlantic: from this area cyclones originate, and travel eastwards towards the high pressure area; on nearing it they die out and disappear, or they pass round it in a north-easterly direction. This southerly type is most common in winter time, but occurs at all periods of the year. In the westerly type, a high pressure area exists south of Great Britain; cyclones originate in the Atlantic, and travel mainly east and south-east.

When their areas of lowest pressure pass so far south as to travel over this country, the severe storms which usually occur in spring and autumn are experienced. In the northerly type, there is high pressure over the Atlantic to the west and north-west of Great Britain; cyclones originate on the north or east side of this anti-cyclone, and travel east or south-east. This type is rare in the autumn months. In the easterly type there is high pressure over Scandinavia, and cyclones originate in the North Atlantic and pass south-east, between the Scandinavian high pressure area and the Atlantic anticyclone, across the col which connects these two high pressure areas. These cyclones may be arrested as they approach the high pressure region, and thus fail to pass over Europe. Sometimes cyclones originate over Southern Europe, to the south of the Scandinavian anticyclone, and travel eastwards or even westwards.

Climates have been classified in five groups: warm, temperate, cold, marine, and mountain climates. In this country the climate is typically marine, being greatly influenced by the encompassing sea, and by the Gulf Stream. This last-named stream causes the lines of equal temperature, the "isotherms" of the North Atlantic to run from south-west to north-east, and thus the winter of these islands is far less severe than that of Labrador, which is in about the same latitude. The influence of the Gulf Stream is especially marked upon the winter climate of this country, when the power of the sun is least felt. In August the isotherms (the dotted lines of Fig. 8) only deviate slightly from an east-and-west direction; but in January the isotherms (the black lines of the figure), immediately over Great Britain, are markedly deflected and run from north-west to south-east, and this fact accounts for the mildness of the winter in Cornwall, or even Dublin, as compared with that of London and Edinburgh. The marine influence exerted upon the English climate accounts for the absence of extremes of heat and cold, the prevalence of moist atmospheres, and the comparative lack of sunshine. The chief diseases associated with this form of climate are lung affections and those forms of "rheumatism" which are influenced by humidity and weather changes.

In warm climates there are usually well-defined dry and wet seasons, and the rainfall during the latter may be very considerable in amount. These climates have been divided into equatorial, tropical, and sub-tropical groups. "Heat-stroke," certain forms of skin disease, cholera, yellow fever, dengue, dysentery and abscess of the liver, malaria, beri beri, sprue (psilosis, tropical diarrhœa), filariasis and other forms of parasitic disease are especially associated with warm climates. The question as to the precise geographical distribution of some of these diseases will be referred to later. As regards heat-stroke it may, however, be here noted, that the term appears to cover not merely conditions, of heat-exhaustion brought about by high

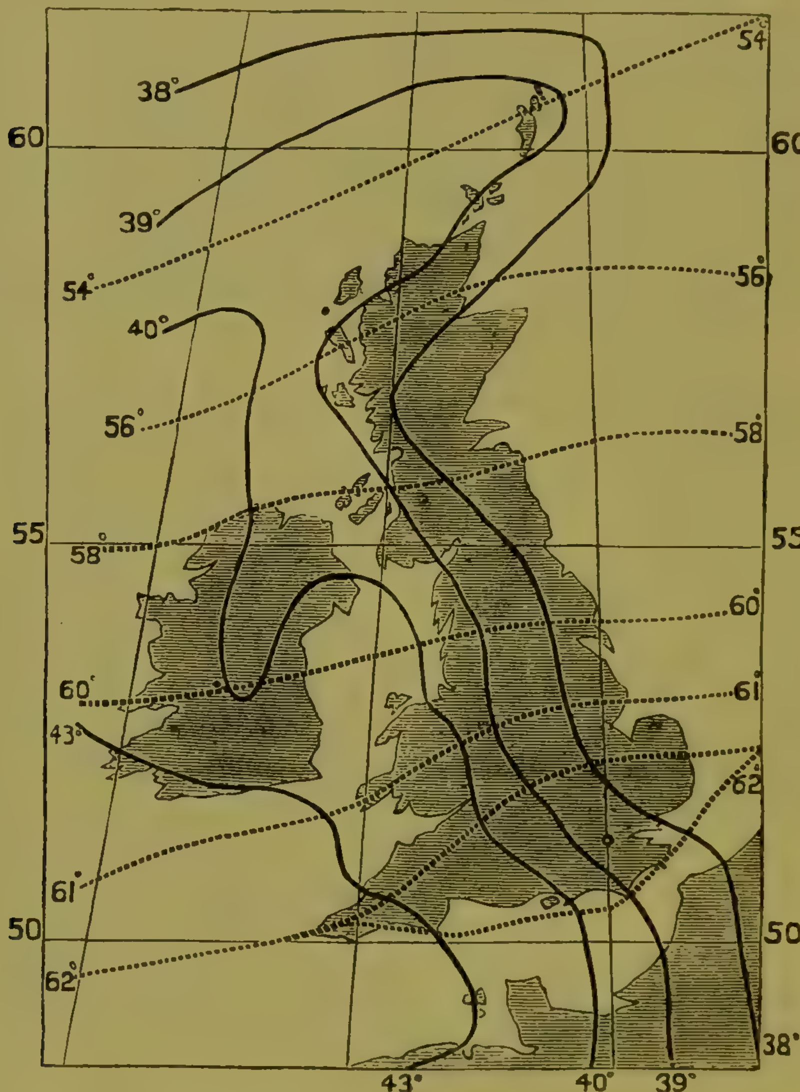

FIG. 8.

Isothermal lines of Great Britain. Dotted lines (August). Continuous black lines (January).

temperatures, and of injury directly due to exposure to the sun's rays, but also a form of fever, possibly of specific character, in which hyperpyrexia is a prominent symptom. To this last form of malady it has been proposed to apply the name *siriasis*.

Temperate climates are usually met with between 35° and 50°

of latitude, while between 50° of latitude and the poles cold climates prevail. Rheumatism, respiratory affections, phthisis, scarlet fever, diphtheria, and measles are especially destructive, as a rule, in temperate climates. In connection with cold climates scurvy, scrofula, and snow-blindness may be referred to; the two former are due to defective dietary, the latter to reflection of light from the snow. In high latitudes, the long winter stamps a marked character upon the climate. In mountain climates the main features are the lowered barometric pressure and the rarefied atmosphere, while the range of temperature is often considerable. In the Alps, and the high lands of South Africa, the air, as a rule, contains but little moisture; in the Himalayas the rainfall is excessive, and the air damp. Certain mountain climates have been found specially suited for consumptives.

Acclimatisation.—This question may be studied, as Virchow pointed out, from two points of view, those of the race and of the individual. Adaptation of races to altered climatic conditions, in the gradual process of migration, has been over and over again exemplified in past ages, and in comparatively modern times the Gipsies and the Jews have spread over wide areas of the world's surface. In cases of colonisation in which there has been abrupt exposure to altered circumstances, the colonists have as a rule only showed ability to multiply when the new conditions did not greatly differ from those of the original climate. Thus comparison may be made between the colonisation of Australasia and North America by the Anglo-Saxon race on the one hand, and on the other the inability usually manifested by that race to increase and multiply within the tropics.

The acclimatisation of the individual may be merely a process of adaptation of the body and its organs to altered physical conditions, together with acquirement of knowledge as to the regimen which is suited to the particular climate. Obviously the subjects of gout, kidney-disease, etc., are less likely to bear the strain of altered physical conditions than healthy persons are. Again, the less the amount of change experienced the better, and hence the inhabitants of southern Europe more readily withstand sub-tropical or tropical climates than the inhabitants of northern Europe.

The behaviour of yellow fever (*q.v.*) in relation to new arrivals, and the observations of Koch with regard to the presence of the malaria parasite in the blood of native children, seem to show that acclimatisation may mean something more than is indicated in the preceding paragraph. Again, negroes in temperate climates are said to be specially prone to develop phthisis. The subject, however, is by no means fully worked out as yet, and from the number of disturbing influences which have to be reckoned with, is one of peculiar difficulty. Thus there can be no doubt that, as Parkes pointed out, the high mortality of Europeans in parts of the tropics is by no means attributable to climate alone—questions of impurity of water, improper food, bad drainage, and various kinds of excess, all need to be considered. As this has been increasingly recognised, there has been manifested a striking reduction in the mortality of white men in the tropics, and the experience gained has materially modified earlier notions on the subject of acclimatisation.

In concluding this discussion of the relation of the physical properties of gases to health conditions, reference must be made to the power of absorbing gases which certain substances possess. Charcoal is a familiar instance of this, and a like property is manifested by spongy platinum. Many liquids, too, absorb gases. Bunsen found, supposing the gas, liquid, and temperature to remain the same—(*a*) that the weight of gas absorbed is proportionate to the pressure, in other words, the volume absorbed is practically the same at all pressures; (*b*) that the lower the temperature the greater is the weight of gas absorbed; and (*c*) that the quantity of gas absorbed by a liquid is independent of the nature and amount of other gases which it may hold in solution. At the ordinary temperature, and under a pressure equal to atmospheric pressure, water dissolves nearly $\frac{1}{20}$th its own volume of oxygen, but only $\frac{1}{40}$th its own volume of nitrogen; it dissolves almost exactly its own volume of carbonic acid, and more than 400 times its own volume of ammonia.

(II.)—The Composition and Examination of Air.

Atmospheric air consists, in the main, of a mixture of oxygen and of what may be provisionally termed nitrogen, in the proportion of about 20·96 volumes of the former, and 79 volumes of the latter, per 100 volumes of air. These gases are not chemically combined with one another, but form what is called a mechanical mixture. Thus the relative quantities of the gases are not those of their combining weights, or of simple multiples of those weights, and although these relative quantities are remarkably constant, for samples of air obtained under differing conditions, slight variations do occur. Further, if appropriate volumes of the two constituent gases are brought together, a mixture possessing the properties of air results, and yet no alteration will be found to have taken place in the temperature or volume of the mixture, as would have been the case had chemical combination occurred. Finally, the fact that the mixture is merely mechanical may be demonstrated by shaking air and water together: the water dissolves some of the air, and the dissolved gases can be afterwards expelled by boiling and analysed. It is found that the water contains less than two volumes of nitrogen for each volume of oxygen, whereas in the original air there were four volumes of nitrogen to each volume of oxygen. Oxygen is more soluble in water than nitrogen, and the fact that, by merely shaking air and water together, the gases are abstracted in proportions differing from those in which they exist in air, indicates that they cannot be chemically combined in the atmosphere.

The oxygen of the air is its active constituent, it possesses the property of entering into combination with most of the other chemical elements under certain conditions, and upon these interactions the support of life on the globe, and the various processes of oxidation and combustion depend. The nitrogen, on the other hand, is a very inert gas, and its most obvious function in atmospheric air appears to be to dilute the oxygen; it probably, however, also plays an important part in connection with the life, more particularly, of certain plants. It has been recently shown that about one per cent. of this inert constituent of air consists of a gas called argon, and certain other gases have, since the discovery of argon, been isolated. Argon was differentiated from nitrogen by the fact that it freezes on exposure to a somewhat less extreme degree of cold. Argon is even more inert than nitrogen, and, indeed, it has not hitherto been found capable of entering into chemical combination with any other element.

In stating the composition of 100 volumes of ordinary air, ·04 volume has not yet been accounted for. This amount is approximately that contributed to the atmosphere by carbonic acid.

Another ordinary constituent of the atmosphere, present in such considerable amount as to be readily capable of measurement, is aqueous vapour. Its quantity, however, unlike that of the gases already mentioned, is very variable. Thus a cubic foot of air, when saturated at 32° F., can only hold a little more than 2 grains of water vapour (about $\frac{1}{160}$th part of its own weight), but at 60° F. it can hold nearly 6 grains, at 100° F. 19 grains, and at 120° F. 34 grains. It has already been seen, that when water vapour is added to dry air the volume of the latter is increased, and that a cubic foot of saturated air weighs less than a cubic foot of dry air under the same temperature and pressure.

In addition to the constituents of air already named, which exist in appreciable quantity, there are others, which are so constantly found (though their amount is excessively small) as to justify their presence being practically regarded as a normal condition: such are, ammonia and other nitrogenous products of decomposition, marsh gas, common salt and other mineral substances, and organic matter, dead or living. Fresh air, moreover, is usually found to present evidence of containing what is called ozone, an allotropic form of oxygen in which three volumes are condensed into two: evidence of the kind referred to is less marked, or altogether absent, in thickly populated localities, and in them organic matter is usually present in greater quantity than in fresh air; the air of towns also shows, as compared with fresh air, slight increase in the amount of carbonic acid, with slight diminution in the amount of oxygen, furthermore, the presence of sulphur compounds can usually be detected in town air.

So slight, however, are the variations in the quantity of the constituents of air, that much difficulty is experienced in gauging the purity of any particular sample by ordinary chemical tests. The nature of the difficulty will be appreciated on consideration of the insignificance, from the point of view of weight, of impurity which none the less profoundly affects the sense of smell, or, from the same point of view, of the living micro-organism, which, when inhaled into the lungs, may produce effects of the gravest consequence.

Eudiometry (*εὔδιος*, good, *μέτρον*, a measure) is the name given to the method usually employed for the estimation of the volume of a given gas contained in the air or in a mixture of gases, The eudiometer was originally designed for estimating the amount of oxygen, the "goodness" of the air. A common form of eudiometer is that, used in the synthesis of water, which consists of a glass tube, closed at one end, and having sealed into it, near that end, two platinum wires, across which an electric spark can be passed; the tube has, moreover, a graduated scale marked upon it. Air, and hydrogen in such quantity that it will remain in excess after combination with the oxygen of the air, can be introduced into the tube, which is inverted over mercury; the spark is passed, care being taken to prevent escape of gas, and the change of volume which has occurred is then noted. If, for example, 100 c.c. of air and 50 c.c. of hydrogen were originally introduced, and the volume after explosion is found to be eighty-seven volumes, sixty-three volumes have disappeared, and one-third of this, or twenty-one volumes, represents the volume of oxygen initially present in the 100 volumes of air.

The principle adopted is thus the measurement of the loss of volume which results from the chemical combination. Again oxygen, if that is the gas to be dealt with, may be absorbed, as in the pyrogallic acid process, or it may be made to enter into combination with nitric oxide NO, and the nitrogen tetroxide (NO_2) formed may then be absorbed by water, and the loss of volume determined. In making the observations careful regard must be paid to the fact that the

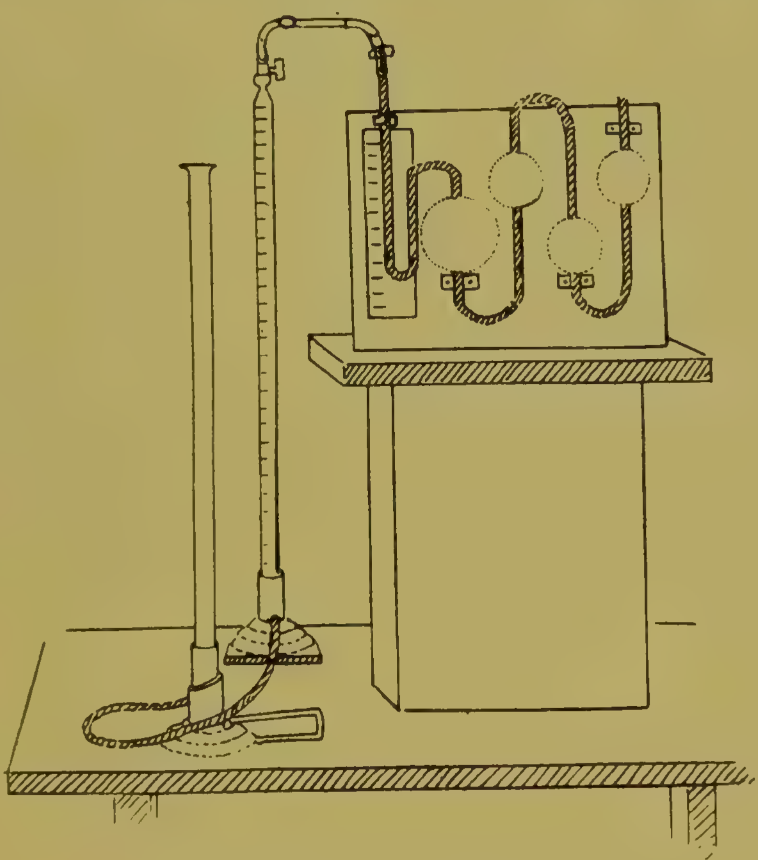

FIG. 9.
Hempel's Gas-Burette and Double Absorption Pipette.

volumes of gas measured off are materially affected by differences of temperature and pressure. The pyrogallic acid method, which is often employed, is subject to the disadvantage that the absorbing reagent affects carbonic acid and certain other gases if they are present as impurities in air; the process which will, therefore, be more particularly referred to as applicable to atmospheric air is the nitric oxide method, with employment of what is known as Hempel's burette and absorption pipette.

In this apparatus two upright glass tubes, supported on iron stands, by which they can be handled, and connected by a wide india-rubber tube, are used. One of the glass tubes is graduated in cubic centimetres, and serves for the measurement of the volume of the gas; at its upper end it narrows, and is connected with an india-rubber tube, a pinch-cock being placed on the rubber just beyond the point where the glass tube terminates. The other glass tube is the "pressure tube"; into it water is first introduced, and the level attained in the graduated tube can then be controlled by raising or lowering the pressure tube. In order to charge the graduated tube it is first filled with water by raising the pressure tube, and the sample of air is drawn into it by lowering the pressure tube; the pinch-cock is then applied, so as to prevent escape of the imprisoned air. The water used should be distilled water, previously saturated with air by thorough shaking. The sample of air taken must now be measured off at atmospheric pressure; this can be effected by raising or lowering the pressure tube until the levels of the water in it, and in the graduated tube, are the same. The india-rubber connecting tube can then be attached to the absorption pipette, which has been charged with water, and, the pinch-cocks being opened, the pressure tube is now raised, so as to pass the sample of air over, displacing some of the water, into the absorption pipette, in order that it may be submitted to the action of nitric oxide there. As soon as the air has all been passed over, the pinch-cocks are again adjusted, and the burette can be detached from the pipette, and employed to measure the volume of nitric oxide to be added to the air. The absorption pipette consists, as will be seen by reference to the figure, of a fine glass tube, having two (or preferably four) bulbs blown in it, and bent in the manner indicated. The larger and lower bulb usually holds about 150 c.c., the other bulb about 100 c.c. The volume of nitric oxide having been carefully ascertained, it, too, is passed over to the absorption pipette, the red fumes of nitrogen tetroxide at once appear, and this gas is speedily absorbed by the water in the pipette. The gas is made to move backwards and forwards until the fumes disappear; it is then taken back finally to the measuring tube, and the reading corresponding to the altered volume can be made. One-third of the contraction observed gives the volume of oxygen present in the sample; for the action which takes place is expressed by the formula $2NO + O_2 = 2NO_2$, and since the molecules of NO and NO_2 occupy the same volume as two atoms of oxygen, the oxygen originally present contributed one-third part of the three volumes which have, after conversion into NO_2, been absorbed.

Example.—50 c.c. of air and 25 c.c. of NO have been measured in the gas burette and passed over to the pipette, and after the reaction has taken place, 44·4 c.c. is found to be the volume of gas now remaining. How much oxygen was there in the sample of air? Here, the total contraction is 30·6 c.c., therefore 10·2 c.c. of oxygen were present in the original 50 c.c., or 20·4 per cent.

The pyrogallic acid and caustic potash solution is sometimes used in connection with Hempel's apparatus, but it is then essential that a double absorption pipette, with four bulbs instead of two, should be employed, inasmuch as it is necessary to avoid as far as possible exposing the absorbing reagents to the action of air, while they occupy the pipette. The bulb nearest the capillary loop contains the absorbent, which is displaced, when the sample of air is admitted, into an upper empty bulb. This last named bulb is cut off from connection with the outer air, by reason of the fact that it communicates with a second lower bulb containing water, which again communicates with a second upper bulb, into which the water can be displaced. The absorbent, under these circumstances, only comes in contact with the small amount of air originally occupying the first of the two upper bulbs.

The amount of certain other gases which may be present is sometimes estimated by eudiometry. Carbonic oxide which, under very exceptional circumstances, may be found in appreciable quantity, can be estimated by absorbing it by somewhat prolonged exposure to cuprous chloride, the oxygen and carbonic acid having been first removed. Again, nitric acid, if in considerable amount, may be estimated by measuring the loss observed, after its absorption by ferrous sulphate.

Carbonic acid under ordinary conditions is present in comparatively minute quantities, and variations in these small amounts are usually estimated in other ways than by the method of eudiometry. The importance of carbonic acid estimation arises from the fact that this gas is contained in appreciable amount in expired air; the actual quantity of carbonic acid can be fairly accurately determined, and serves as a somewhat rough indication of the extent to which other, and less readily measurable impurities have been added to air. While inspired air yields only about ·04 per cent. of carbonic acid, expired air contains about 4·41 per cent., some four volumes per cent., roughly speaking, of carbonic acid having been added, while a corresponding, though very slightly greater, amount of oxygen has been abstracted from the air. The volumes of nitrogen in expired and inspired air are practically identical, 79·19 in expired, and 79·00 in inspired air; but expired air is saturated with water vapour, while inspired air usually falls considerably short of the point of saturation; again the amount of organic matter in expired air is also increased as compared with that in the normal atmosphere. It remains to note that while the volume of the expired air will be seen, from the above statement, to be about $\frac{1}{50}$th less than that of the air inspired, this result rests upon the assumption that the volumes are calculated at the same temperature and pressure; the fact that the expired air is warmed more than compensates for the loss above referred to, and the air exhaled actually occupies a volume about $\frac{1}{9}$th greater than that of the air inspired. Roughly speaking, the amount of carbonic acid contributed to air vitiated by respiration, is assumed to indicate the extent to which impurity in the form of organic matter is added to the air. This assumption is convenient, inasmuch as the actual amount of added organic matter is so small that its variations are less easily determined than are those of the carbonic acid. It was until lately thought that the organic matter added was the more important polluting agency, and carbonic acid estimation was undertaken, principally with a view to its serving as an indication of the extent to which organic matter might be presumed to be present. Recent researches have tended to attach greater significance to the carbonic acid, itself, as the cause of the ill effects produced by breathing vitiated air. In any case, the estimation of carbonic acid is a matter of very great importance.

Estimation of Carbonic Acid by Pettenkofer's Process.—In this process the carbonic acid contained in a known amount of air is absorbed by being well shaken with a measured quantity of clear lime water or baryta water. The alkalinity of the lime or baryta, after absorbing the gas, is compared with its original alkalinity, and, from the difference observed, the amount of carbonic acid which has been taken up can be estimated. To measure the air a large wide-mouthed glass-stoppered bottle of known capacity (usually about 5 litres) is employed. This is charged by filling it with water; emptying it and allowing it to drain; then reinserting the stopper; the series of operations being carried out in the place the air from which is to be examined. Alternatively the bottle may be filled with the sample air by means of bellows. Sixty c.c. of clear lime or baryta water having been added, and the stopper or the cap adjusted, the liquid is made to roll round the sides of the bottle, so as to expose it to the contained air; it should then be left for at least an hour, to give opportunity for all the carbonic acid to be absorbed. The alkalinity of the lime or baryta water used may now be tested by titrating it with a solution, made by dissolving 2·25 grammes of crystallised oxalic acid in a litre of distilled water. The oxalic acid solution is carefully dropped from a graduated burette into a measured quantity, say 30 c.c. of clear lime or baryta water (to which a drop of phenol-phthalein has been added) the mixture being stirred the while with a stirring rod. The exact point, at which the pink colour imparted by the phenol-phthalein to the mixture disappears, is noted, and the quantity of oxalic acid solution employed gives the causticity of the lime or baryta water.

After the air in the bottle has stood for an hour, a sample of the lime or baryta water, which has been in contact with it, is similarly subjected to titration with the oxalic acid solution. From the clear liquid, 30 c.c. may now be taken—the precipitate in the bottle must not be disturbed—and the causticity of this sample ascertained. From the observed difference between the two estimations the number of milligrammes of lime or baryta, which have combined with the carbonic acid in the bottle, can be determined.

The strength of the oxalic acid solution is such that 1 c.c. just neutralises one milligramme of CaO, or 2·73 milligrammes of BaO. The problem, then, is to find how much CO_2 corresponds to the number of milligrammes of lime or baryta which have entered into combination. In the case of lime, since $CaO + CO_2 = CaCO_3$ expresses the reaction, each $40 + 16$, *i.e.*, 56, milligrammes of CaO which have disappeared, represent $12 + 16 \times 2$, *i.e.*, 44 milligrammes of CO_2.

Hence one milligramme of CaO represents $\frac{44}{56}$ milligramme of CO_2. Now, 44 milligrammes of CO_2, at 0° C. and 760 m.m. pressure, occupy 22·4 c.c.; $\therefore$ $\frac{44}{56}$ milligramme of CO_2 occupies ·4 c.c., and this volume of CO_2 corresponds to 1 milligramme of lime, and, therefore, to 1 c.c. of the oxalic acid solution.*

Example.—Let the capacity of the bottle be 4,500 c.c., and suppose 60 c.c. of lime water to be introduced. The volume of air is then

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* If baryta be used, then from the equation $BaO + CO_2 = BaCO_3$, it follows that 1 milligramme of BaO represents $\frac{44}{153}$ milligramme of CO_2 and 2·73 milligrammes of BaO represent $\frac{44}{153} \times 2·73$ milligramme of CO_2, *i.e.*, $\frac{44}{56}$ milligramme of CO_2, which corresponds to ·4 c.c. of CO_2. Thus 1 c.c. of oxalic acid solution, which neutralises 2·73 milligrammes of BaO, corresponds as before to ·4 c.c. of CO_2.

4,440 c.c. Let the causticity of the original lime water be such that 30 c.c. require 44 c.c. of acid solution for neutralisation, and let the number of c.c. required, for the neutralisation of the 30 c.c. after exposure to the air in the bottle, be 38 c.c. Then 6 c.c. of solution correspond to the lime combined with CO_2 in 30 c.c., *i.e.*, in one half of the lime water originally placed in the bottle. Therefore 12 c.c. of solution represent the total loss of lime from combination with the CO_2 in 4,440 c.c. of air. But each c.c. of solution corresponds to ·4 c.c. of CO_2. Hence the 4,440 c.c. of air contain 4·8 c.c. of CO_2, or there are 1·08 c.c. of CO_2 in each 1,000 volumes of air.

Inasmuch as in converting the 44 milligrammes weight of CO_2 into a corresponding volume of 22·4 c.c. of that gas, it has been assumed that the conditions are those of standard temperature and pressure (0° C. and 760 m.m.), it is necessary, for exact purposes, to make correction for deviations of temperature and pressure from these standard conditions. Thus suppose, in the above example, that the temperature were ascertained to be 59° F., *i.e.*, 15° C., and the pressure 740 m.m. Then the expression giving the corrected volume of the 4,440 c.c. of air dealt with, when estimated at 0° C. and 760 m.m. pressure, is

$$= \frac{4440 \times 740}{760\,(1 + \cdot 00366 \times 15)} = 4098 \text{ c.c.}$$

Thus 4,098 c.c. of air is the real volume which corresponds to 4·8 c.c. of CO_2, and the corrected amount of CO_2 present is therefore 1·174 c.c. of CO_2 in each 1,000 volumes of air.

The correction for pressure is often neglected, and that for temperature is sometimes approximately made by adding 1 per cent. to the result, for each 5° above 32°F. If the value, obtained in the above example, be corrected on these lines, it would be concluded that there were 1·138 c.c. of CO_2 in each 1,000 volumes of air.

A rapid method of determining carbonic acid in air has been devised by Haldane,* who uses a gas analysis apparatus and determines the loss of volume, in the sample, before and after absorption of the CO_2 by potash solution. A gas burette with a wide ungraduated portion, and a narrow portion graduated in divisions, each corresponding to $\frac{1}{10000}$th part of the capacity of the burette, is employed. The burette is enclosed in a water-jacket, and to correct for variations of temperature, a control tube of approximately the same size and

* *The Journal of Hygiene*, Vol. I., No. 1, January, 1901.

shape as the gas burette is used. The pressures under which the readings are made are determined to be the same, before and after absorption, by measuring the level of the potash solution in the narrow bore tubing of the absorption pipette. The difference between the two readings gives the result in volumes per 10,000; no calculations are necessary, and with proper precautions the finding is reliable to within ·5 volume per 10,000.

Angus Smith's Test.—A rough test for determining the amount of CO_2 in air is based upon the fact that it is only when CO_2 is present in a certain proportion that visible turbidity is produced by lime water. Hence, if the smallest quantity of air which will produce turbidity in a given volume of lime water be estimated, this affords an indication of the amount of CO_2 the air contains. In making the determination, half an ounce of clear lime water is shaken up with measured amounts of air, contained in stoppered bottles of varying sizes. Ten or more bottles are provided for the purposes of the test, and the amount of CO_2 corresponding to a first appearance of visible turbidity in connection with the use of each of the bottles may be estimated, and a table, giving the results obtained, constructed. The test is applied by shaking the air, in larger and larger bottles, until that in which turbidity first appears has been determined. If turbidity is already manifested when a 6-oz. bottle is used, the amount of CO_2 present is found to be about 1·1 parts per 1,000. If turbidity appears first in the $10\frac{1}{2}$-oz. bottle, the amount is about ·06 part per 1,000; if in the $15\frac{1}{4}$-oz. bottle, ·04 part per 1,000. By this method fairly accurate results can be obtained, and it is so simple as to deserve the name "Household test" which has been applied to it.

Determination of Organic Matter.—This may be effected by causing water, completely freed from ammonia by doubly distilling it, to take up the organic matter contained in a considerable volume of the sample of air to be tested. The water is then analysed by one or other of the methods to be presently described, in order to ascertain how much organic matter it contains. The volume of air used must, of course, be carefully measured, and this is generally done by slowly drawing it through the water until it fills an aspirator of known capacity. The free and albuminoid ammonia taken up by the water may then be determined by Wanklyn's process (see page 123). If the oxidisable organic matter contributed to the water by the air is to be estimated by Forchammer's process, it is necessary not to lose sight of the fact that sulphurous and nitrous acids, sulphuretted hydrogen, and chlorine compounds, if present in the air, will also affect the colour of the permanganate solution (*See* page 125). Roughly speaking, ordinary air is found to yield about ·06 of a milligramme of free ammonia, and ·08 of a milligramme of albuminoid ammonia, per cubic metre of air used. In a jar containing very impure air, ammonia may be found in such considerable amount, as to admit of its detection by inserting a strip of filter paper, moistened with Nessler's reagent, between the stopper and neck of the bottle; the paper should be allowed to hang, without, of course, touching the side of the bottle, for a sufficiently long period to enable the ammonia present to produce the discoloration in question.

Carbonic Oxide.—The detection of this impurity in air is a very important matter, inasmuch as the gas, if breathed into the lungs, combines with the hæmoglobin of the blood, and, preventing its continuing to perform its function as an oxygen-carrier, produces asphyxiation. If only one or two volumes per 1,000 are present in air, poisonous symptoms are produced after about half an hour's exposure, and an atmosphere containing 1 per cent. of the gas proves rapidly fatal. Carbonic oxide is itself inodorous, but one of the most common means by which it is introduced into the air is by an escape of ordinary coal gas, which contains some 7 per cent. of it, and under such circumstances, the smell of other constituents of the coal gas usually excites attention. Carbonic oxide is contained, however, in much larger quantity, 25 to 40 per cent., in "water gas," and as this form of illuminant, unless it be specially prepared with the object of rendering any escape noticeable, is inodorous, its use is attended with considerable danger. Carbonic oxide is also introduced under circumstances in which products of combustion from furnaces or flues have access to the air of rooms, and it is evolved from stoves, particularly from cast-iron stoves in which coke is used; the heated cast-iron probably permits the gas to pass through it from the fire, and it may also effect reduction of carbonic acid to carbonic oxide; possibly, too, the carbon contained in the cast-iron becomes to some extent oxidised.

The quantitative determination of carbonic oxide has already been dealt with under the heading Eudiometry; the delicate qualitative test, known as Vogel's test, is that commonly used for detecting its presence in air. The sample of air to be examined is shaken up with a small quantity of water, and a drop or two of blood is then added to and thoroughly shaken up with it. If the mixture be then examined in a spectroscope, two absorption bands, the bands of carbonic oxide hæmoglobin, will be seen lying between the lines D and E of the spectrum. These bands occupy almost the same position as those of ordinary oxyhæmoglobin; on the addition, however, of a few drops of ammonium sulphide, the presence or absence of carbonic oxide is at once determined by the behaviour of the absorption bands. If no carbonic oxide be present, the oxyhæmoglobin is reduced, and its characteristic bands are replaced by the single broad band of reduced hæmoglobin; if, however, carbonic ~~acid~~ oxide be present, the reduction is not effected, and the bands undergo no change.

Ozone.—When sparks from a good electrical machine are passed through moist air, a chlorine-like odour is developed, and some diminution of volume occurs. These phenomena are ascribed to the conversion of some of the oxygen into an allotropic form of that element called ozone (the Greek word ὄζω signifying to smell). Ozone is capable of liberating iodine from iodide of potassium, and in certain states of the atmosphere, particularly after thunder storms, the air is found capable of producing this result. Upon this fact is based the ordinary test for ozone, originally devised by Schönbein, who first drew attention to the importance of detecting the presence of this gas in air. ***Schönbein's test*** consists in exposing to the action of the atmosphere a prepared strip of paper, soaked in a solution of potassium iodide and starch, and then dried. If ozone be present free iodine is liberated ($O_3 + 2KI + H_2O = 2KHO + I_2 + O_2$) and combines with the starch, forming blue iodide of starch. Schönbein, regarding the intensity of the reaction as an important indication of the purity of the atmosphere, pro posed to carefully estimate it by observing the amount of blueing, as compared with a standard scale of tints, and expressing the result by a number (the scale of tints ranging from 1 to 10). It appears, however, that other substances, particularly nitrous acid and peroxide of hydrogen, also blue the starch paper; moreover, some of the freed iodine becomes volatilised and some is oxidised; thus portions of the iodine never act on the paper. A second test, ***Houzeau's test***, has been devised, which obviates difficulty so far as nitrous acid is concerned. In this test faintly red litmus paper is soaked in very dilute iodide of potassium, and dried. The blue coloration of the litmus observed, when air is tested with this paper, is attributed to liberation of iodine by the ozone, which enables the potash, formerly combined with the iodine, to produce the change of colour in question. Hydrogen peroxide gives a similar reaction, but it is said to only do so after comparatively prolonged exposure. The presence of ammonia may also lead to difficulty, but this may be obviated by simultaneously experimenting with a piece of litmus paper, similarly tinted to the first piece, but not soaked in potassium iodide. The difference in the colour change observed in the two pieces of litmus paper may be ascribed to ozone. While the precise importance to be attributed to these tests for the presence of ozone is not clearly made out, it may be accepted as a fact that the phenomena are more marked—in country air than in that of towns, at high than at low levels, near the sea than at places inland, and (in this country) at times when the wind is in the south and west, as opposed to those when it is in the east.

Sulphur compounds are present in the atmosphere in traces in places where much coal, particularly coal containing appreciable quantity of sulphides, is used. The presence of sulphurous acid in considerable amount is readily detected by its characteristic smell and action upon litmus paper. Sulphuretted hydrogen and sulphide of ammonium also possess distinctive odours, and they may be detected by their power of darkening lead acetate paper. Ammonium sulphide may be distinguished from sulphuretted hydrogen by its alkaline reaction, and by its giving a violet colour with sodium nitro-prusside. These gases are produced in processes of decomposition as well as in those of combustion.

Other gases which may be met with as impurities in a sample of air, are chlorine, which has a characteristic smell, and which first reddens and ultimately bleaches litmus paper; hydrochloric acid, which markedly reddens blue litmus paper, and gives a white precipitate (soluble in ammonia) on being shaken up with silver nitrate; and nitric and nitrous acids, which also redden litmus paper, (the presence of the two last-named gases may be tested for by shaking the air up with a little water and applying the tests for nitrates and nitrites, to be presently described). Carbon bisulphide may occur as a product of combustion, and is said to be produced in connection with the manufacture of vulcanised india-rubber; this gas possesses a very characteristic odour, like that of garlic. In particular processes in the manufacture of bone manure arsenic is given off. Some of the effluvia evolved in carrying on certain offensive businesses, to be presently referred to, produce eminently characteristic impressions on the olfactory sense; such are, for example, the effluvia resulting from gut scraping, blood boiling, and tallow melting.

Suspended matter.—The sunbeam reveals the extent to which visible suspended particles exist in air, and the contrast between the ordinary appearance of the lungs (as seen post mortem) and that observed in the case of an individual who has been but little exposed to town atmospheres, shows the considerable advantage, over persons compelled to inhale a dust and smoke-laden atmosphere, enjoyed by those who breathe pure air. The pigmentation of the town dweller's lungs is mainly attributable to particles of carbon; as Arlidge points out, "soot and coal dust have remarkable powers of diffusion throughout the parenchyma, far exceeding that of the dust of metals and stone." Particles of mineral matter assume importance mainly as a result of their physical characters of shape, density, and capacity generally of acting as irritants; to this subject it will be necessary to return in connection with special trade processes.

Dust of animal and vegetable origin does not, as a rule, affect the lung substance so injuriously as certain mineral dusts do, and the discovery, in air, of wool, cotton, etc., fibres, epithelial scales, pus cells, starch grains, woody fibres and fragments of animal and vegetable tissue, is mainly of interest as serving to indicate the kind of surroundings from which the air was taken, and as suggesting what is likely to be the character of the much more minute, but far more important, living organisms contained in it. The most valuable methods of examination of the suspended matter in air, therefore, are those which relate to the cultivation in or upon appropriate nutrient media of its contained micro-organisms, with a view to their isolation and the determination of their specific characters.

Various devices have been employed with a view to collecting suspended particles. Thus, in Pouchet's aeroscope, air is drawn by aspiration through a tube terminating in a fine point, which is directed upon a glass plate smeared over with glycerine. The particles contained in a given volume of air can thus be sprayed upon and intercepted by the glycerine, and subsequently submitted to examination. Or a known volume of air may be slowly drawn through a filter of pure sugar, and when the filter has intercepted the suspended matter, the sugar can be dissolved in a little pure water, and the material thus collected in the water may be examined as before.

In order to study further the micro-organisms contained in air, it is necessary to cultivate them in or upon the surface of sterilised nutrient media. In Hesse's apparatus (Fig. 10) air, in measured quantity, is drawn through a cylinder coated with such sterile nutrient material, the organisms are deposited upon the surface of the medium, and from the colonies which develop pure cultivations can be obtained.

As the use of the cylinder is attended with several disadvantages, it is more usual to employ a sterile filter to collect the germs, or to cause the air to pass through sterilised broth, and to afterwards examine the material intercepted by making plate cultivations with it, in such degrees of dilution as will ensure its being practicable to separate the individual colonies which appear.

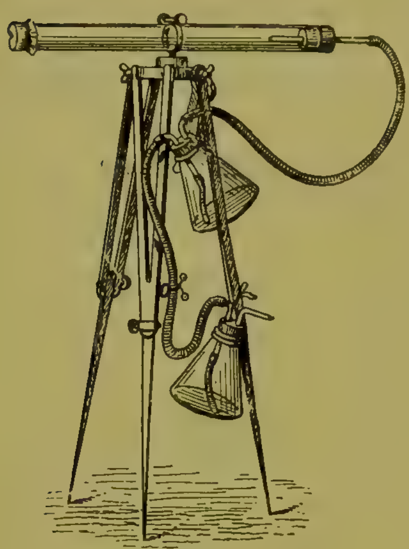

FIG. 10.
Hesse's Apparatus.

A simpler method consists in exposing, to the air to be examined, for varying intervals of time, nutrient material in ordinary Petri dishes. The number of colonies which develop, after a definite number of seconds' or minutes' exposure, can then be counted, and a means of comparison between the number of organisms present in different localities, and capable of growing upon the material used, can thus be instituted. Moreover, particular colonies can, if this be considered desirable, be isolated and grown in sub-culture and submitted to further examination. It is, of course, important to bear in mind that only those species of organisms develop which are able to grow under the conditions of the experiment. Thus the colonies which appear on the surface and in the depth of nutrient gelatine, kept at ordinary temperatures, do not represent all the forms of living organisms present in the air. It is desirable, therefore, in particular cases, to work also with agar plates, which can be incubated at higher temperatures, and if it is thought necessary, the number and character of the anaerobic forms present may be also ascertained. This can be done by exhausting air from, and then sealing, the vessel in which incubation is carried on; by absorbing the oxygen by means of pyrogallic acid and potash solution; or by replacing the air of the vessel by an atmosphere of some other gas, such as hydrogen.

Bacteria are practically non-existent in the air at the summit of high mountains and in that at sea, provided the nearest land be a hundred miles or more away. Miquel found, as the average of six years' observations, about 450 organisms per cubic metre in the air of the park at Montsouris, near Paris, while in the Rue de Rivoli the corresponding average was nearly 4,000. In a hospital ward he found nearly 80,000 per cubic metre. The number observed attained a maximum at Montsouris in July, and was at its minimum in February. There was, it may be noted, marked diminution after rain.

Carnelley, Haldane, and Anderson made experiments at Dundee, as a result of which they were led to attach importance to the proportion in which moulds, as contrasted with bacteria, are found in various atmospheres.

In the open air they found only 2 moulds and 6 bacteria per 10 litres of air.

In houses of 4 or more rooms, there were 4 moulds and 85 bacteria per 10 litres of air.

In houses of 2 rooms, there were 22 moulds and 430 bacteria per 10 litres of air.

And in houses of 1 room, there were 12 moulds and 580 bacteria per 10 litres of air.

(III.)—Atmospheric Impurities.

The impurities met with in the atmosphere may be considered under the following heads:—Suspended matter and dust; gases and effluvia generated in connection with various trade processes; emanations from putrefying organic matter; and finally, there are the various substances added to the air by the processes of combustion and respiration.

Suspended Matter.—The dust particles in air have been counted by Aitken; his method consists in diluting the air to be examined, to a suitable extent, with dust-free air and then, by addition of water vapour, causing each particle of dust, in a measured quantity of the mixture, to have attached to it a minute droplet of water; these droplets are then allowed to fall upon a surface of known area, and the number so deposited is counted. Aitken found that the number of particles per cubic inch of fresh air, varies from about 2,000 in the open country, to upwards of 3,000,000 in towns, while in inhabited rooms the number may be ten times as great as that last mentioned.

Dust as a Mechanical Irritant.—The dust produced in some trade processes produces deleterious effects in the persons who are compelled to inhale it: as has been noted, the physical characters of the dust exercise important influence in this connection, and, according to the various degrees of irritation produced, cough, the expectoration of material betraying the presence of the particular dust inhaled, and dyspnœa, are likely to be sooner or later developed. In contradistinction to the phenomena of tubercular disease, it may be stated, that in the dust-diseased lung the appearance of expectoration is usually delayed, hæmoptysis is uncommon, fever is but little marked, and diarrhœa and loss of voice do not, as a rule, occur. The symptoms specified are, no doubt, caused by the setting up of chronic catarrh, which causes degeneration of epithelial cells, and favours penetration of foreign matter into deeper tissues, with induration and ultimate transformation of the lung substance into a hard, solid, fibrous mass. These changes preferentially, though not exclusively, affect the apices of the lungs, and, as they progress, emphysema, in greater or less degree, is produced, with the formation of pleural adhesions, and sometimes with the development of pleural effusion. In cases in which tubercular mischief is not engrafted upon the damaged tissues, cavities do not, as a rule, exist.

The trades in which these dust diseases are most common are the various occupations in which metallic and mineral dusts are inhaled. Among miners great differences are observed; in the colliers of the north of England, who work in well-ventilated mines, and who are mainly exposed to particles of carbon, the mortality from pulmonary disease is not particularly high; indeed, these men seem to suffer to a less extent from phthisis than might have been anticipated, and this has been held to be due to some property of coal dust which renders it antagonistic to tubercle. It appears, however, that there is little to be said in favour of this contention, for miners are, for the most part, picked men, and their freedom from tubercular phthisis does not seem to be more pronounced, than might be expected to be the case on this ground alone. At the other end of the scale from the colliers stand the Cornish or tin miners; these last-named workers inhale a mineral dust of very irritating character, and their mortality from phthisis is exceptionally high.

Again, quarrymen, cutlers, and file makers usually show high mortality from lung diseases, and the frequency of occurrence of lung-mischief among earthenware manufacturers is indicated by the common application of the term "potters' asthma" to the malady which contributes largely to the high mortality observed in the potteries. The irritating elements at work, in the occupation last referred to, appear to be the angular particles of silex derived from the potter's clay. In the process of "china scouring," in which the flint dust is brushed by women off the china ware after it has been baked, clouds of dust particles are produced, and this particular branch of the earthenware manufacture is especially associated with damage to the tissue of the lung.

In 1899 Dr. Birmingham drew attention to what he termed "ganister disease," a malady which affects workers engaged in the ganister industry in the valley of the Don, between Penistone and Sheffield. Ganister is a hard silicious stone which is obtained by blasting with dynamite, and is then crushed. The material is subsequently ground wet, and moulded into bricks, which, being pre-eminently fire-resisting, are used for lining the bottoms of Bessemer converters and crucibles for moulding steel. Inquiry concerning the disease was made by Dr. Legge, whose report appears in the Annual Report for 1900 of H.M. Chief Inspector of Factories. Among ganister miners the incidence of phthisis was found to be ten times as great as in the general male population at corresponding ages. Among workers in the material, at the surface, the mortality was excessive, but to nothing like the extent observed in the miners. Dr. Andrewes, who examined the lungs of two fatal cases of ganister disease, found that the primary changes were dependent upon the irritation of the inhaled dust, which had given rise to a fibrosis, lymphatic in its distribution in its earlier stages, but subsequently extending to large areas of lung tissue. Upon this fibrosis a secondary tuberculosis was later grafted.

The metallic dust produced in some of the Sheffield trades is, if anything, more injurious than the silicious dust of the potteries, and according to Arlidge can only be compared with the worst kinds of stone dust. In button making, and particularly in connection with the cutting and polishing of mother-of-pearl buttons carried on at Birmingham, a heavy dust is produced which is especially liable to cause fibrosis of the lungs. Again, in association with pin pointing and with the needle-making industry at Redditch, lung diseases are commonly observed; moreover, in certain finishing departments in electro-plate manufactories, in which articles are rubbed with a polishing powder, dust which possesses irritating properties is evolved.

As regards vegetable dusts, those derived from cotton and flax are most frequently associated with the production of disease. In the manufacture of cotton, moreover, the china clay which has of recent years been used for sizing the warp, gives rise to a dust which produces disease, and its ill effects appear to be aggravated by the fact that the clay is manipulated in a moist atmosphere. Flour dust seems to be comparatively innocuous, but the dust of some hard woods possesses irritating properties.

Other Dusts and Vapours.—The above-mentioned dusts act mainly as mechanical irritants; there are certain other dusts and vapours evolved in various trade processes which produce special characteristic symptoms and which must now be referred to. Lead poisoning occurs in plumbers and painters; in persons engaged in the glazing of pottery; in file makers and type setters; in makers of glazed playing cards and of artificial flowers; and in connection with the manufacture of lace, in which industry white lead is used "to throw up the pattern." The manufacture of white lead is especially attended by danger, when the process is conducted by what is known as the Dutch method, in which thin sheets of lead are exposed to the vapour of acetic acid; the subacetate of lead which is thus formed is afterwards exposed to carbonic acid, evolved from tan, and so converted into carbonate of lead. The women who remove the white lead, and who grind and pack it, suffer much from plumbism. Wet grinding and the enforcement of absolute cleanliness tend to reduce the mischief to a minimum.

Copper poisoning is said to occur in a few industries. Somewhat contradictory opinions have, however, been expressed on this subject. Arlidge believes that under certain circumstances "copper colic" is undoubtedly met with. "Brassfounders' ague" which occurs among persons who inhale the metallic dust produced in particular operations carried on in brass foundries, has been attributed to fumes of zinc oxide, but it is probably really in the main due to chronic copper poisoning. The symptoms of this peculiar malady simulate ague, but are not truly periodic. Mercurial poisoning occurs in "water gilders," who use an amalgam of mercury and gold, and in silverers of mirrors. Workmen employed in the manufacture of arsenical wall papers, and the makers of artificial flowers, suffer from arsenical poisoning, and this malady has also been produced from time to time in persons who have merely inhaled the dust of rooms, papered with wall paper coloured with certain compounds of arsenic.*

Fumes of phosphorus produce necrosis of the jaw, but fortunately the red amorphous phosphorus has replaced, to a considerable extent, the yellow phosphorus which formerly caused so much harm to those who worked with it.† In the manufacture of bichromate of potash, dust is evolved which causes irritation and ulceration of the lining membrane of the nose. Portland cement manufacturers suffer from lung diseases as a result of inhaling dust, and traces of

* See the report by Dr. Guy published in the Fifth Report of the Medical Officer of the Privy Council.

† The subject of the match-making industry was elaborately dealt with by Dr. Bristowe, whose report appeared in the Fifth Report of the Medical Officer of the Privy Council.

cyanogen compounds are said to be given off during the "burning process." Other specially injurious fumes, evolved in trade processes, are the vapours of silicon fluoride produced in the manufacture of superphosphate manure, the carbon bisulphide of vulcanised india-rubber works, the sulphurous acid evolved in bleaching works, the sulphuretted hydrogen of certain chemical works, and the hydrochloric acid vapours of alkali works.

Workmen exposed to the fumes of naphtha, which is used in rubber works as a solvent, are apt to suffer from headache, giddiness, digestive disturbances, and in some cases from nervous excitement. Nitro-benzene is another substance which produces distinctive symptoms; drowsiness, passing in extreme cases into coma, being especially met with. In connection with the use of roburite—an explosive much employed in mines—symptoms of this kind have been developed, and they are probably to be attributed to nitrobenzene poisoning. Similar symptoms have resulted from use of the "Sicherheit explosive." The symptoms observed in workers in melinite are said to be due to picric acid.

In some weaving sheds, and in connection with other trade processes, the air is steamed, and excessive humidity together with heightened temperature is produced. Ventilation is often imperfectly carried out, and impurities accumulate under such conditions (*See* p. 555).

Micro-organisms.—The atmosphere undoubtedly at times contains living particles which are capable of producing specific disease. The spores of fungi causing skin diseases may spread from person to person in this way. The pollen of some kinds of grass is held accountable for the production of what is called "hay fever"; little is known concerning the mode of action of the exciting cause in this malady, but personal idiosyncrasy on the part of the patient is particularly marked. Bacteria capable of causing disease are not infrequently air borne. The infection of tubercle, small-pox, measles, typhus, whooping-cough, influenza, scarlet fever and diphtheria, and, possibly, that of enteric fever and of plague may be communicated in this way. Granular ophthalmia, puerperal fever, erysipelas, some forms of throat affection, and hospital gangrene may be similarly spread.

The occurrence of anthrax in workers in certain trades has special interest in connection with diseases of occupation. It had been recognised from 1846 onwards that wool-sorting was associated with the production of symptoms of lung disease, and that these symptoms were attributable to the inhalation of dust. After the introduction of particular wools into the Yorkshire mills, notably mohair and alpaca, a number of deaths from "wool-sorters' disease" occurred, and the illness was studied by J. H. Bell, of Bradford, who arrived at the conclusion in 1879 that the mischief was caused by the anthrax germ. The subject was fully investigated in 1880 by Spear, and the fact that "wool-sorters' disease" was really "internal anthrax" became established. Of late years, from time to time, various measures of precaution have been suggested and carried out by Bradford manufacturers with a view to preventing spread of the malady. Cases of illness have, moreover, been met with among persons who manipulate hair, and in 1878 an outbreak of anthrax was observed in some hair factories in Glasgow, and was reported on by the Medical Officer of Health of that city.* The occurrence of anthrax in workers in horsehair, and in brush manufacturers, has since been observed in several instances in London, and considerable outbreaks of the disease have been recorded by German investigators, particularly in connection with the paint-brush manufactories of Nuremburg. In the case of both the trades mentioned, anthrax commonly assumes what is known as the internal form.

As long ago as 1883 Spear collected a number of cases, mainly of malignant pustule, *i.e.*, of the external form of the disease, which had occurred among persons engaged in the London hide and skin trades. A considerable outbreak in Bermondsey in 1882 was traced to the manipulation of a consignment of dry hides from China, and it was found that many of these hides were "dead" hides, that is, they had been removed from animals which had presumably died from the effects of disease, possibly anthrax, and had not been slaughtered in the ordinary way. Since the date of this outbreak a number of cases of anthrax have been met with in London, and in some other English towns in which hides and skins are manipulated, and infection appears to have been transmitted in these cases, as a rule, by "dry" hides or skins, as opposed to those cured by the wet process. In cases of malignant pustule, provided the patient is seen at an early stage of the malady, and the pustule is excised, recovery generally ensues.

Dr. Bell recorded in 1901 (*British Medical Journal*, July 20) six cases of what he terms "Œdematous and erysipelatous anthrax." This form of the disease is, he says, identical with what was described by Bourgeois in 1843 as "œdème malin." Extensive œdema develops; in slight cases there is no redness, vesication or

* Glasgow remained for long after this free from the disease, but a case occurred in a woman who had handled hair from Russia, which is reported by Dr. Scott in the *British Medical Journal* of July 20, 1901.

eschar; in the more severe forms much redness, and later vesication and eschar, or gangrenous appearance of the skin, develop. Three of the six cases recorded by Bell were fatal; in all of them wool was the source of infection. It may be noted that the Factory and Workshop Act of 1895 made cases of anthrax, as well as of lead, phosphorus or arsenical poisoning, contracted in any factory or workshop, compulsorily notifiable to H.M. Chief Inspector of Factories.

Offensive Trades.—The occupation diseases which have hitherto been referred to mainly affect persons actually employed in the several processes of manufacture; there are, however, a number of trade processes in which offensive effluvia are produced, the ill effects of which are not limited to the factory; the surrounding atmosphere becomes contaminated and nuisance results, which may affect persons living at some distance from the particular trade premises concerned. Certain of these "noxious" or "offensive" trades, as they are called, may be regulated by by-laws. Thus, the Public Health Act of 1875, prohibits the establishment, without the consent of the local authority, of the businesses of a blood boiler, bone boiler, fellmonger, soap boiler, tallow melter or tripe boiler, or "any other noxious or offensive trade," and provides for the making of by-laws regulating these trades, if they are once established.

Model by-laws, dealing with the trades specified, and also with those of a blood drier, leather dresser and tanner, fat melter and fat extractor, glue and size maker, and gut scraper, have been framed by the Local Government Board. The question has arisen, from time to time, as to whether certain trades can or cannot be scheduled as offensive trades and regulated by by-laws. It would have to be proved, in the case of any particular trade, intended to be so controlled, that it was *ejusdem generis* with the trades specified. All these trades, it will be noted, deal with animal matter; presumably, therefore, varnish making, the manufacture of chemicals, etc., could not be regulated in this way. It has been held that the business of a bone and rag merchant (*Passey v. Oxford Local Board*) could be scheduled, but that a particular case of brick burning which came before the courts could not.

Dr. Ballard investigated the subject of effluvium nuisances in 1876 78, and his very comprehensive report is printed in the Sixth, Seventh, and Eighth Reports of the Medical Officer of the Local Government Board. He found, speaking generally, that the symptoms commonly attributable to the inhalation of noxious effluvia of the kind investigated were, loss of appetite, headache, and digestive disturbance. These symptoms are likely to be particularly marked in persons in a poor state of health, or suffering from chronic disease, and are naturally of more serious import in children, and in old and feeble persons, than in strong, healthy adults.

Dr. Ballard classified the offensive trades investigated under the following heads :—

(i) The keeping of animals; (ii) the slaughtering of animals; (iii), (iv) and (v) branches of industry in which animal, or vegetable, or mineral substances are principally dealt with; and (vi) branches of industry in which substances of mixed origin are manipulated. In connection with the keeping of animals he studied the source of, and means of minimising, nuisance arising from keeping pigs, cows, horses, and poultry. With regard to the slaughtering of animals, the businesses of a knacker and a butcher were especially considered; the term knacker meant originally "saddler"—it is generally employed to designate a person whose business it is to slaughter horses and to utilise the skin, flesh, bones, etc. Thus, on a knacker's premises a number of processes, bone boiling, boiling of flesh for the purposes of making cat's meat, fat extracting, etc., are usually carried on. In addition to the ordinary sources of nuisance associated with the keeping of animals, effluvia may be produced in connection with the slaughtering of horses and cattle, from want of care in regard to the conduct of the special processes of the business, and from the retention on the premises of putrefiable materials. On the premises of knackers large numbers of dead horses are sometimes allowed to accumulate, giving rise to serious nuisance. In this business, moreover, smell is likely to be complained of in connection with various boiling processes, unless proper means for consuming the noxious vapours, and preventing their escape into the outer air, are adopted.

Dr. Ballard's third group includes a number of important noxious trades. The *blood drier* allows blood to settle with a view to separating the serum from the clot, and then dries the former in shallow pans, in a room heated to about 120° F. Serum-albumen is thus produced, while the discarded clot is generally used for manure making. In this business the blood manipulated must be comparatively fresh. The *blood boiler* boils blood, usually with admixture of common sulphuric acid, and then dries it, and in these processes an extremely sickening smell is usually produced. Blood is also used in Turkey-red dyeing for the purpose of fixing alizarin, the dye employed, on the cotton.

The *bone boiler* boils bones with a view to extracting the contained fat and gelatine. The bones after boiling are dried, and the long bones are used for handles of knives, forks, etc., while the other bones are generally converted into manure. It is a common practice in this trade to allow large heaps of bones to accumulate in what is called a "bone hole," and when this is done there is risk of the production of great nuisance.

The *tallow melter* "renders" butchers' fat, in order to extract the tallow, the residue consisting of muscular and connective tissue is pressed, in hydraulic presses, to form the "greaves" which were, at one time, sold as dogs' food, but are nowadays, as a rule, merely fit to be made into manure. The boiling process was formerly largely conducted in pans heated by direct fire heat, and unless these pans were constantly stirred, the fat was likely to burn, producing a very offensive odour; considerable improvement has resulted since steam-jacketed pans, or pans in which the fat is heated by free steam, have been substituted for fire-heated pans; though smell is produced, even under the improved conditions, if the material is at all tainted, as it usually is, at any rate in warm weather.

The *fat melter*, or *fat extractor*, carries on a business similar to that just described, but deals with fat already once rendered; fat extracting in large towns, mainly has concern with the utilisation of hotel and restaurant waste, the fat contained in which is abstracted, while the residue is commonly devoted to pig-feeding purposes.

The *glue and size maker* boils down bones, horns, hoofs, clippings of skins, and the like, with the object of extracting the gelatine. The liquid glue is poured out into shallow pans to solidify, and then sliced and dried. The residue left in the pans after drawing off the glue, is termed "scutch"; it is used in making manure.

The *tripe boiler* converts the first stomach, or "paunch," of oxen or sheep into "tripes." The material manipulated in this business must be fresh, hence the smell which results is merely that of cooking on a large scale, and the effluvia produced are not, as a rule, so offensive as in the other trades which have been referred to. The tripe boiler often also prepares cowheels and sheep's trotters for food, and he occasionally manufactures neats-foot oil. Sometimes waste material too putrid to be used for food is manipulated on the premises upon which the food is prepared, with a view to extracting size and fat; when this is done, there is great liability to the production of nuisance.

Soap boiling consists in boiling together tallow and alkali. The neutral fats are composed of a combination of glycerine with fatty acids, and in the process of saponification the alkali (soda or potash, as the case may be) replaces the glycerine, forming alkaline stearates, palmitates and oleates; in other words, soap. In the case of soft soap potash is used as the base; in that of hard soap, soda is employed. The "lye," as the alkali is called, is run into the boiling pans which contain the melted fat, and the soap formed is caused to float, on the surface of the liquor in the pan, by the addition of common salt, soap being insoluble in strong saline solutions. The soap is then poured into frames in which it sets, and it is afterwards cut, by means of wires, into bars of appropriate size. This trade was associated with the production of serious nuisance years ago, when soap makers commonly rendered fat, and manufactured the alkali which they used, upon the soap-making premises. At the present time the altered custom of the trade causes the process of manufacture to be comparatively free from offence.

Gut scraping is a particularly offensive business. The gut scraper cleans the small intestines of pigs and sheep, and the gut, after soaking it for a while in brine, is scraped on a bench with wooden scrapers, the object being to remove the contents and internal lining, leaving only the peritoneum and a portion of the muscular wall behind. The gut thus prepared is either cut into lengths to be used for sausage-casings, or if the scraped gut is to be converted into catgut, lengths of it are sewn together, steeped in carbonate of sodium, spun by means of a spinning wheel, and then bleached by exposure to sulphurous acid, and finally dried.

The *fellmonger* prepares skins for the leather dresser; the fresh sheep skins are cleansed, soaked and then "limed" on the internal surface; after a while the wool can readily be detached, and the skin freed from wool is now called a "pelt." The pelts are soaked in pits containing milk of lime, and are then ready to go to the leather dresser, who subjects them to the processes of tanning and currying for the purpose of converting them into leather.

The *tanner* deals with raw hides from the outset, and carries out the entire series of operations necessary in leather making. It is thus not the practice to subdivide the manufacturing processes, in the case of hides, as is usual in that of sheep skins. The hides are "limed" and subjected to the process of unhairing, they are then washed and "fleshed," *i.e.*, the loose tissues on the inner surface of the hide are removed with a sharp knife. The hide is now "rounded," and becomes what is known as a "butt." The butts are treated with "puer," or "grainers," the former material consisting of dogs' dung, and the latter of pigeons' dung. The process renders the leather supple, and it is one which is particularly likely to give rise to offensive odours. Then follows what is called "scudding," which consists in removing superfluous water, etc., and the hides are, moreover, in some instances split. The next process consists in subjecting the butts to the action of tanning materials, bark, etc., in pits.

In all these trades nuisance is likely to result, from the storage of offensive substances, unless these be kept under proper conditions (for example, in suitably covered receptacles of non-absorbent material), and from accumulations of dirt and filth, splashings on walls, collection of pools in badly-paved floors, and similar causes. Nuisance experienced at a considerable distance from the premises mainly results from failure to consume the offensive vapours produced in the process of manufacture. These vapours should either be condensed, or burnt by being passed through a furnace fire.

In Fig. 11 the method commonly adopted for the consumption of offensive effluvia evolved from fat-melting pans is indicated. A similar method is applicable in connection with many of the other boiling processes which have been referred to. The draught in the chimney draws the vapours which traverse the pipes G through the ashpit C and the fire B, and they escape to the flue along the channel marked H. The fire is thus fed by air sucked through the narrow opening beneath the hinged portion attached to the lid of the pan F, and this air carries with it all the vapour produced in the process of boiling, so that the offensive gases are subjected to the heat of the furnace before they escape through the chimney into the outer air. If the door of the fireplace D, or that of the ashpit E, is

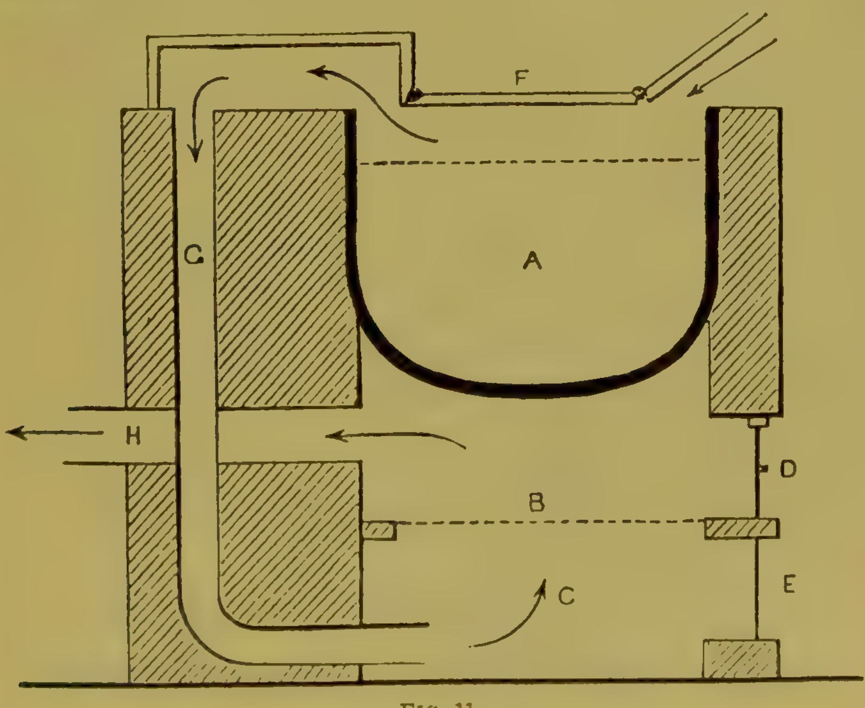

FIG. 11.
Method of Consuming Vapours from Boiling-pans.
(*After Ballard.*)

allowed to remain open, the suction of the vapours from the boiling pans is of course interfered with.

A certain amount of vapour, however, is sure to escape into the chamber in which the boiling pans are fixed, and indeed such escape must occur in connection with stoking operations, or when the lids of the pans are thrown open for the purpose of ladling out contained materials. It is a common practice, therefore, to convert the boiling house into a "closed chamber," and to arrange for propelling the vapours which accumulate in it by means of a fan or fans along a shaft, thus leading them to a point immediately beneath a furnace, in which they are consumed. The vapours from bone holes, etc., may be similarly treated. Provision for the access of fresh air to such closed chambers must, of course, be made; sometimes this is done by merely leaving a space at the lower part of one of the doors, but under such circumstances, what is intended to be an inlet is apt at times to become an outlet, and far better results are obtained by propelling fresh air into the closed chamber by means of a fan.

The various sources of nuisance which have been referred to require to be borne in mind in connection with framing codes of by-laws. The Public Health (London) Act, 1891, gives power, it may be noted, to regulate not only the conduct of the business, but also the structure of the premises on which the business is carried on.

Dr. Ballard's fourth group of trades includes certain industries involving manipulation of material of vegetable origin. He especially drew attention to the distillation of wood, in which process very disagreeable vapours escape; and, further, to the manufacture of oxalic acid by treating sawdust with an alkali and subsequently boiling with lime, the oxalate formed being finally decomposed with sulphuric acid, as irritating fumes are produced in all these processes. In paper making, the boiling of esparto grass with alkali yields very offensive effluvia. Again the process of retting flax, which consists in steeping the flax plant in pits, is a source of disagreeable smell. Other trades studied by Dr. Ballard were the making of india-rubber, of floorcloth and linoleum, the manufacture of oil varnishes, and the distillation of certain vegetable oils.

It remains to consider the industries included in Dr. Ballard's two remaining groups. Among those in which mineral substances are principally dealt with, cement making, which has already been referred to, is a process which sometimes causes nuisance at a considerable distance from the works. Brick - burning, when it is conducted in "clamps," and particularly if dustbin refuse is used in making the bricks, is almost always a source of considerable offence. When the bricks are fired in close "kilns," there is much less likelihood of nuisance being produced. In the salt glazing of earthenware, the process of "salting" gives rise to copious white vapours, which contain hydrochloric acid and cause much annoyance to those who inhale them. In the manufacture of gas for illuminating purposes, nuisance sometimes arises in connection with emptying the purifiers, and with disposing of accumulations of "blue billy," as the lime which has absorbed carbonic acid and sulphuretted hydrogen is termed.

The final group of trades includes general chemical works, rag and bone collecting, the manipulation of the refuse of towns, and the manufacture of manure. Manure making is a comprehensive term which includes many kinds of industry. "Superphosphate manure" is made by treating ground bones with sulphuric acid. The vapours evolved contain arsenic, small quantities of antimony, and fluoride of silicon; the manure after mixing is usually placed in what is called the "hot den," in which it is allowed to remain until it cools. "Poudrette" is a manure prepared by adding sulphuric acid to night-soil. Fish manure is prepared on a large scale in the neighbourhood of large towns, from fish offal. Blood, "scutch" from glue works, shoddy waste, sawdust from hair manufactories, and many other materials, are used in the preparation of various manures.

Under the "Alkali, etc., Works Regulation Act," alkali works and allied trades, such as chemical manure, nitric acid, bleaching, and gas-liquor works, are made subject to special regulations and to inspection by inspectors appointed by the Local Government Board. The Act provides that 95 per cent. of the hydrochloric acid gas given off must be condensed, and that not more than one-fifth of a grain of hydrochloric acid, or more of the acid gases of sulphur and nitrogen, than the equivalent of four grains of SO_3 per cubic foot of air, gas or smoke, must escape into the atmosphere.

The *air of mines* is liable to possess certain special characters which may be here referred to. In deep coal mines the amount of carbon dioxide may exceed two parts per 1,000; the air is usually, moreover, almost saturated with moisture, and it may contain excess of organic matter. In mines in which gunpowder or explosives are used, special products of combustion are also likely to be present. The terms "fire-damp" and "after-damp" are employed by miners, to distinguish gas which is liable to cause explosion, from the gas which collects after an explosion, and as a result of it. "Black-damp," or "choke-damp," which in the main consists of nitrogen, with about one-seventh of its volume of carbonic acid, is liable to occur under ordinary conditions and apart from any explosion. Haldane has shown that death after explosions is, as a rule, due to suffocation caused by deficiency of oxygen consequent upon the accumulation of after-damp.

Effluvia from Putrefying Organic Matter.—Emanations of the sort now in question have already been incidentally referred to, but it remains to make particular mention of certain special cases. Decomposing sewage is one of these. In ill-ventilated and badly laid sewers cases of death from time to time occur; they are due as a rule either to inhalation of sulphuretted hydrogen, or to the presence of excess of carbon dioxide or other gases, with corresponding diminution of the amount of oxygen. In connection with cleansing old privies and cesspools, acute symptoms have been produced in persons exposed to the effluvia evolved. Such cases are fortunately, however, quite exceptional, and the main question to be considered with regard to sewage emanations is their effect upon health, when inhaled in a less concentrated form than has sufficed in the rare instances above mentioned to produce acute poisoning; further, there is the possibility of the transmission of particular forms of infectious disease by sewer gas.

The composition of the air of sewers has been investigated on numerous occasions, and it has been generally found, in the case of fairly well constructed main sewers, that carbonic acid is not greatly in excess, and that there are the merest traces of sulphuretted hydrogen and of offensive organic matter. The air of main sewers does not, therefore, as a rule, show very marked difference in chemical composition from the ordinary atmosphere; but, of course, a great deal depends upon the construction, and condition as regards ventilation, of the particular sewer in question. Again, the state of the air in a large sewer cannot be regarded as indicating the chemical composition of the air in all the drains connected with it. Inquiries as to the health of workers in sewers have led to the general conclusion that these men are not particularly unhealthy, but such investigations have never been carried out on a very comprehensive scale.

The micro-organisms of sewer air have also been made the subject of study, and it has been shown that the total number of germs present is not specially great, and that as regards their character, they appear to correspond much more closely with forms occurring in the atmosphere in the neighbourhood of the sewer, than with varieties present in the sewage itself. There seems to be no question, however, that persons who are habitually subjected to the influence of air from drains and sewers, which has obtained access to houses, are liable to suffer from headache, febrile disturbance, anæmia, and a tendency to the development of sore throat. Puerperal fever has, in numerous instances, been found to occur in connection with faulty drains, and erysipelas and hospital gangrene are, at any rate, likely to be aggravated in severity should they develop under like conditions. Diarrhœa has also been attributed, from time to time, to drainage defects.

Two diseases must be especially considered in relation to drain emanations. *Enteric fever* has been repeatedly ascribed to this cause, but the evidence adduced is not altogether conclusive, and for the most part, the supposed causal relationship was noted years ago, before certain other possible means of spread of the malady had become well recognised. Against such an hypothesis it has been urged that enteric fever is not common among men who work in sewers, and sewage does not appear to be a particularly favourable medium for the growth of the enteric fever bacillus. Again, there has clearly been misconception as to the likelihood of this organism gaining access to sewer air. Recent experiments, however, made by Alessi show that animals exposed to drain air appear to acquire a predisposition to suffer from the specific infection. Thus, of forty-nine rats which were inoculated with the enteric fever bacillus, and made to inhale sewer air, thirty-seven died with symptoms described as being characteristic; while of forty-one rats similarly inoculated, but not exposed to sewer air, only three died. *Diphtheria* is another disease which has been repeatedly attributed to drainage effluvia. Here again the evidence is inconclusive; while it seems to be clear that sore throat may result from such exposure, and that under like circumstances a person may be rendered more liable to contract diphtheria, it does not appear to be proved that drainage emanations are commonly concerned in transmitting the diphtheria bacillus.

Accumulations of fæcal matter have been held accountable for the production of disease. One of the most striking cases in point is that of an outbreak of dysentery in an asylum, which was attributed to the effluvia from sewage matter spread over the soil. On the other hand, experience of well-managed sewage farms, so far as the matter has been made the subject of inquiry, seems to negative the view that serious risk to health is incurred by living in their neighbourhood. Emanations from polluted streams have apparently produced illness in some instances, an often quoted example of this being that afforded when the Royal Commissioners on Metropolitan Sewage Discharge made a tour of inspection of the Thames immediately below London, in 1884.

The air of graveyards has also been held to menace the health of people residing in the near neighbourhood. The overcrowded graveyards situated in close proximity to houses, which were in common use fifty years ago, probably influenced prejudicially the health of persons living near them; cholera, in 1849, was, it is said, found to be specially prevalent in the neighbourhood of graveyards, but there is no evidence that injurious effects are produced under the conditions which now ordinarily exist. Exposure to concentrated effluvia in connection with exhumations has, in some instances, been followed by diarrhœa and vomiting, and ill effects undoubtedly result in consequence of inhaling air, grossly contaminated by products of decomposition from the bodies of men and horses, on battlefields.

Vitiation of Air by Combustion.—The burning of coal for heating or manufacturing purposes is an important source of atmospheric impurity. It has been estimated that each ton of coal burnt represents nearly three tons of carbonic acid added to the atmosphere. Carbon monoxide is also produced in considerable though very varying amounts, according to the degree of completeness of oxidation of the carbon of the coal. In addition to these gases, the burning of coal contributes to the atmosphere aqueous vapour, sulphur compounds, soot and organic matter.

The quantity of sulphur compounds yielded largely depends upon the character of the coal used. The sulphur existing, in one or another form, in ordinary coal, varies from less than 1 per cent. to more than 5 per cent. It becomes converted, on burning, into sulphurous and sulphuric acids, carbon bisulphide, ammonium sulphide, and, exceptionally, into sulphuretted hydrogen; while a certain amount of free sulphur may escape. The presence of sulphur compounds appreciably contributes to the pollution of the atmosphere of districts in which much coal is burnt.

The particles of unconsumed carbon given off from numerous chimneys, interfere, more or less, at all times, with the comfort of dwellers in towns, but they make their presence especially felt under circumstances in which there is little movement of air, while coincidently the atmosphere becomes misty from excess of moisture, a condition of things which is, of course, especially likely to be developed during fair weather with low temperatures. When these factors coexist, the droplets of moisture, as they condense, tend to attach themselves to the floating particles of carbon, and there results an opaque medium which shuts out the light of the sun; in fact, what is known, from the place of its typical development, as a London fog. In such an atmosphere sulphurous acid often makes its existence distinctly felt, producing irritation of the conjunctiva, and of the mucous membrane of the lungs. In the continued absence of wind, and in the presence of the other favouring atmospheric conditions, such fogs may last for days, and, under these circumstances, the death-rate, more particularly from diseases of the organs of respiration, is usually materially affected. In the burning of wood, a far smaller amount of sulphur compounds is produced than in the combustion of coal. Charcoal fires yield, however, considerable quantities of carbon monoxide.

Smoke production in manufacturing districts can be largely controlled by regulation of stoking operations in factory furnaces. The addition of coal in small quantities at short intervals and the use of mechanical stokers tend to obviate the production of dense black smoke. In some appliances the object aimed at is to spread the fuel evenly over the fire; in others, the fresh fuel is heated before being gradually delivered to the fire bars, and the smoke arising from the newly added material has to pass the hottest part of the fire before it escapes to the flue. The use of forced draught is also an important means of promoting smoke consumption, by rendering combustion more complete. Excellent results are obtained by employing the steam blast. When the chimneys of private houses constitute the main source of smoke production, as is the case in many large centres of population, the difficulty of dealing with the evil is far greater than when there are a limited number of sources of pollution which, none the less, by their magnitude, make up a considerable sum total of offence.

Impurity is largely contributed to the air by artificial lights. Coal gas is produced by the destructive distillation of coal, in retorts, in the absence of air. The residue is called coke; the volatilised products are collected and passed through condensers in which the tarry matters, and some of the ammonia, are deposited on cooling, then through scrubbers, in which the products are thoroughly exposed to the action of water, and ultimately into purifiers, containing lime and oxide of iron, for the purpose of removing sulphur compounds and carbonic acid. The gas so produced contains about 50 per cent. of hydrogen, some 33 to 36 per cent. of marsh gas, 6 to 7 per cent. of carbon monoxide, about 6 per cent. of olefiant gas and other illuminants, a little nitrogen, and traces of sulphur compounds. The Metropolitan Gas

Referees prescribe that no sulphuretted hydrogen shall be present, and that the maximum of sulphur compounds, other than H_2S, shall not be such as to yield more than 17 grains—in winter 22 grains—of sulphur per 100 cubic feet of gas, on an average of three days. The permissible amount of ammonia is 4 grains per 100 cubic feet.

The gases to which the illuminating properties of coal gas are principally due are olefiant gas, and other non-saturated hydro-carbons. The main volume of gases is constituted by what are termed diluents, while nitrogen, carbonic acid, and the sulphur compounds are spoken of as impurities. When gas is burnt, the hydrogen and hydrocarbons are consumed, and the main impurities added to the atmosphere are carbonic acid and water vapour; there are, moreover, traces of sulphurous acid and ammonia, and, if the combustion is not perfect, appreciable amounts of carbon monoxide.

Escape of gas within dwelling-houses, apart from risk of explosion, is attended by danger, by reason, mainly, of the contained carbon monoxide, though it has been suggested by Corfield that cases of relaxed sore throat, observed in association with slight escapes of coal gas from defective fittings, are attributable to sulphur compounds contained in the gas. The main impurities which have to be reckoned with when gas is burnt in rooms, under ordinary conditions, are carbonic acid and aqueous vapour, the amount of carbon monoxide being insignificant with fairly perfect combustion, and the quantity of sulphurous acid very minute.

The illuminating power of gas is gauged by comparison with the lighting capacity of a sperm candle burning 120 grains per hour. An ordinary bat's-wing burner, of 16 candle power, consumes $5\frac{1}{2}$ cubic feet of gas per hour, and has been estimated to produce, in that time, 2·8 cubic feet of CO_2, and 7·3 cubic feet of moisture, thus rendering the air impure to about the extent to which it would be vitiated by the processes of respiration of five adults. With improved forms of burners, and notably with the Welsbach burner, in which incandescence is produced by placing a mantle composed of a network of certain oxides over an ordinary Bunsen flame, it is possible, while reducing the quantity of gas consumed, and the amount of impurity added by the combustion processes, to materially increase the lighting effect.

An ordinary sperm candle of "one candle power" yields, on complete combustion of its 120 grains, about ·4 cubic foot of carbonic acid, and nearly the same amount of water. In the case of oil lamps burning paraffin, the quantity of oil used per candle power ranges from about 62 grains per hour upwards, according to the class of lamp employed, with production of about ·28 cubic foot of carbonic acid, and ·22 cubic foot of aqueous vapour, these amounts being proportionately increased, in the poorer sorts of lamps, according to the quantity of oil consumed. From the data given above, it may be calculated that to produce a 16 candle power light, $\frac{1}{4}$ lb. of sperm candles (equivalent to rather less than $\frac{1}{3}$ lb. of ordinary tallow candles), rather more than 2 oz. of paraffin, or $5\frac{1}{2}$ cubic feet of gas, must be consumed per hour; the amounts of CO_2 produced would be 6·4 (about 7·3 in the case of tallow candles), 4·5 and 2·8 cubic feet respectively; the vitiation of air would correspond to that caused by 11 or 12 adults in the case of sperm and tallow candles, $7\frac{1}{2}$ adults in the case of paraffin, and 5 adults in the case of gas. In the combustion of candles and oil no sulphur compounds are produced; oil lamps yield, however, an appreciable amount of organic matter to the air of the room in which they are used.

By employment of the electric incandescent light the addition of impurity is altogether obviated, and no oxygen is abstracted from the atmosphere; the heating effect with this form of light is only about $\frac{1}{30}$th of that produced for equal degrees of illumination with candles, oil, or gas. This variety of artificial light is obviously far superior to other forms, from the points of view both of preventing contamination of the atmosphere, and of minimising the discomfort arising from the heat and impurity generated. The electric arc light is said to cause addition of a small amount of nitric acid.

The injuries to health likely to result from impurities communicated to the air by processes of combustion may be summarised as follows:—The irritating effects produced upon the respiratory mucous membrane by inhalation of sooty particles, and by sulphurous acid, have to be considered; these effects are clearly manifested in connection with fogs, but that they are ever potent for mischief, in crowded localities, is made clear by the fact that persons with certain forms of chronic lung disease usually find their symptoms aggravated in town atmospheres. Other ill effects produced by air contaminated by the gases evolved in processes of combustion, are the headache, lassitude, and anæmia, which affect those who habitually breathe such air; these symptoms are equally produced by breathing air vitiated by respiration, and the impurities yielded in the two cases are, to some extent, identical.

Vitiation of Air by Respiration.—It has been already seen in what respects expired air differs in composition from the ordinary atmosphere. In ordinary quiet respiration, some 22 cubic inches of air, containing 4·4 per cent. of CO_2, are exhaled eighteen times, or thereabouts, per minute. This would yield ·6 cubic foot per hour. Much depends upon the size and activity of the individual, but the amount given is usually taken as indicating the quantity contributed to the atmosphere per hour by the average unit of population.

Now, the atmosphere normally contains ·4 part of carbonic acid in 1,000 parts. If, therefore, the average individual breathed into a space containing only 1,000 cubic feet of fresh air, the amount of CO_2 present would, at the end of an hour, be ·4 + ·6 cubic foot, *i.e.*, ·1 per cent. If he breathed into a space containing 2,000 cubic feet, the amount would be ·4 + ·3 cubic foot in each 1,000 cubic feet, or ·07 per cent.; and if the space contained 3,000 cubic feet, the amount would be ·4 + ·2 cubic foot in each 1,000 cubic feet, or ·06 per cent. The amount of CO_2 over and above that present under normal conditions in the atmosphere, is spoken of as the "respiratory impurity," and this, in the three cases just mentioned, is seen to be ·06 per cent., ·03 per cent., and ·02 per cent. respectively. It was found by De Chaumont that if the respiratory impurity in a room was allowed to exceed ·02 per cent., a person entering the room, from the outside air, was able to detect by the sense of smell that the air of the room was of different quality from that outside. He therefore fixed the amount ·02 per cent. as that of the "permissible respiratory impurity." To secure this amount not being exceeded, it is necessary to supply 3,000 cubic feet of air per head per hour, and as, in this country, the air of a room can, with ordinary means of ventilation, be renewed about three times an hour without producing draught, compliance with the standard indicated implies the provision of 1,000 cubic feet of air space per head.

De Chaumont made a number of analyses of the air of sleeping-rooms in barracks, in which 600 cubic feet of space per head was provided, and with various degrees of efficiency of ventilation, and found the largest amounts of CO_2 recorded varied between ·1 and ·2 per cent.; with twice, or more than twice as much cubic space, in hospitals, he found, as a rule, proportionately improved conditions; in a number of prisons, the circumstances of which he investigated, the results were far worse, the amount of CO_2 recorded reaching, in one instance, ·34 per cent.

More recent observations show that in crowded school rooms and assembly rooms, and in badly ventilated and crowded dwelling rooms, the amount of CO_2 not infrequently exceeds ·3 per cent. That such considerable quantities of CO_2 should be found is not surprising, having in view the limited amount of cubic space per head provided in such places. In infant schools the standard recognised by the Education Department is only 80 cubic feet of space; in many schools for older children not more than 120 to 130 cubic feet of space per child is provided. In the dormitories of workhouses 300 cubic feet per head has been prescribed; this amount is that usually required in registered common lodging houses, and is also that generally specified for adults in rooms used exclusively for sleeping purposes, in by-laws regulating cubic space provision in tenement houses. In barracks, 600 cubic feet is the minimum quantity of space allowed, and 850 cubic feet and upwards are required by the Local Government Board in Poor Law Infirmaries. With none of these amounts is it practicable, under ordinary conditions, to keep the percentage of CO_2 within De Chaumont's limit.

Carnelley, Haldane and Anderson were led, as the result of their experiments, to conclude that in no case should the quantity of CO_2 exceed 1 per 1,000 in dwellings, or 1·3 per 1,000 in schools; that not more than two volumes of oxygen should be required for oxidation per million volumes of air; and that the micro-organisms should not exceed 560 per cubic foot of air. These standards are considerably lower than De Chaumont's, and would allow of a permissible respiratory impurity of ·6 in dwellings, and ·9 in schools, as against De Chaumont's ·2 per 1,000. They imply the provision of only 1,000 cubic feet of fresh air per person per hour in dwellings, and only 560 cubic feet in schools. It remains to be seen how far it will be possible to prevent ill effects resulting in cases in which these lowered standards are adopted.

Some animals contribute more CO_2 to the atmosphere than human beings, and it might perhaps be anticipated that in crowded stables and cow-sheds the worst results, as regards carbonic acid, would be recorded. Oxen and horses give off about three times as much CO_2 as a man does, and, in many cases, no more than 600 to 800 cubic feet per animal are provided, hence the extent to which CO_2 might be expected to accumulate is considerable. Carbonic acid determinations for stables require, however, to be carried out with due correction for the amount of ammonia present, otherwise a less degree of pollution may be estimated than that which really exists, and in practice this source of error does not as a rule appear to have been allowed for.

The production of CO_2 and absorption of oxygen in animal respiration, is compensated for by the fact that vegetable tissues, and particularly green leaves exposed to sunlight, take up carbonic acid from the air, assimilating the carbon, and giving off oxygen. Thus the tendency to accumulation of CO_2 and diminution in amount of oxygen which results from the existence of one form of life, is corrected by the carrying on of processes of an opposed character by other living tissues.

The quantity of water given off from the lungs of an individual in twenty-four hours amounts roughly to some 10 ozs., and about twice this quantity is given off by the skin. The increased temperature and excessive amount of moisture, in air vitiated by respiration, are factors which are largely responsible for the feeling of discomfort experienced in crowded rooms. The removal of heat from the body is materially interfered with under conditions of the kind in question, and an atmosphere polluted by respiration is likely to prove oppressive from this cause alone. The organic matter of the air of much-occupied rooms has a peculiarly unpleasant odour; this smell is, possibly, more largely attributable to emanations from the skin than to products derived from the lungs. If expired air be passed through water, the liquid takes up an appreciable amount of the organic matter exhaled. The characteristic properties exhibited by the material absorbed by the water are—that it is precipitated by argentic nitrate, blackened on ignition, yields ammonia on distillation, and reduces alkaline solution of potassium permanganate. The organic matter is supposed, in the condition in which it is exhaled, to be in combination with water, inasmuch as hygroscopic substances—wool, blotting paper, and the like, which take up water with facility—possess the property of readily absorbing it. To a certain extent the amount of organic matter, added to air vitiated by respiration, is found to vary with the excess of CO_2 above the normal quantity; but its increase is less marked than that observed in the number of bacteria in the air of crowded dwelling rooms. One reason why the excess of organic matter does not more closely correspond with the increase of CO_2 is, no doubt, the fact that the organic matter does not readily diffuse, but tends to hang, as it were, in clouds about a room, and also to attach itself to damp objects. The relation between organic matter and CO_2 is found to be more close than that between the CO_2 and the number of bacteria present.

Many attempts have been made to isolate from the expired organic matter the specially harmful substance which it has been supposed to contain. Animals have been injected with the liquid condensed from air vitiated by respiration, and the symptoms thus produced have been attributed to the hypothetical organic poisonous substance. Similar experiments have, however, been conducted without any symptoms being observed. Again, animals have been placed in receivers from which the CO_2 exhaled has been removed, as fast as it was breathed into the atmosphere of the receiver, while oxygen to replace the oxygen consumed has been regularly supplied. None the less the animals have died, and this kind of experiment was long regarded as conclusive. It has, on the other hand, been shown that animals, compelled to breathe air which has percolated through liquid obtained by condensing the vapour of expired air, suffer no ill effects.

Experiments made a few years ago by Haldane and Smith, with a view to clearing up this much-disputed question, led them to the conclusion that no special organic poison was accountable for the symptoms produced by breathing air vitiated by respiration, that the headache was due merely to excess of CO_2, and that hyperpnœa resulted when the amount of that gas present was as considerable as 3 or 4 per cent. The cases of well sinkers and of workers in soda-water manufactories, have been quoted as evidence that an atmosphere containing considerable quantities of CO_2 can be breathed without inconvenience; as regards the former, however, exact determination of the CO_2 present, in the wells, does not appear to have been made; with respect to the latter, the amount of CO_2 in the air of the work rooms in question does not seem to substantially exceed that credited with being likely to produce only slight symptoms. Moreover, excess of moisture, raised temperature, and the accompanying smell of vitiated air, were presumably not associated in these instances with increased amount of CO_2 as would have been the case in the air of crowded living rooms. These last named conditions must be regarded as factors likely to aggravate the ill effects of breathing air charged with excess of CO_2.

It appears to be undoubted that when the CO_2 reaches 5 or 10 per cent. fatal results may be produced, and, this being the case, prolonged breathing of air containing much smaller quantities is clearly likely to cause serious discomfort. In catastrophes, such as that of the Black Hole of Calcutta, or that which befell the steerage passengers of the *Londonderry*, who were shut down in the cabin, in 1848, during a storm, the victims were apparently packed almost as closely as standing room would permit. The symptoms in these cases are said not to have been those of simple asphyxia, inasmuch as among persons recovering from the immediate ill effects, fever, accompanied by evidence of affected nutrition, was observed. In instances in which less extreme crowding occurs, but in which vitiated air is breathed for some time, headache, a sense of oppression and discomfort, slowing of the heart's action, quickening of respiration, and in some cases nausea are apt to supervene. If the exposure to the polluted atmosphere be habitual, anæmia, loss of appetite, impairment of nutrition, and pulmonary disease, particularly phthisis, may possibly be developed.

In such cases the question of the influence of the vitiated air is complicated by the fact that other causes likely to aggravate, if not to produce, the observed effects are often coincidently at work. Thus persons who breathe day after day polluted atmospheres such as those now in question, are usually engaged in sedentary employment, and often work long hours and inhale not only the products of respiration, but also products of combustion (their work frequently necessitating the use of artificial light), and in addition, it may be, certain dusts or vapours evolved in connection with the particular work upon which they are engaged. As to the dependence of the symptoms exhibited, in large part, upon the inhalation of impurity produced in the process of respiration, there can, however, be no question. The evidence, for example, of the relation of phthisis to the breathing of the air of crowded rooms is of quite unmistakable import.

Observations in Dundee made by Carnelley, Haldane, and Anderson, show that phthisis tends to prevail where overcrowding exists, and somewhat similar results have been recorded with reference to crowding of population upon area in various parts of London and other large cities. Again, the excessive incidence of phthisis in correspondence with prevalence of the back-to-back system of house construction has important bearing in this connection, inasmuch as purity of air in the dwelling room is much influenced by ventilation as well as by the amount of cubic space provided. This question will later be further referred to.

In such instances it might, however, be argued that other influences, such as poverty, intemperance, and the like, were really the important factors at work. In the case of prisons and of barracks, some of these suggested disturbing influences can be eliminated. The reduction of the phthisis rate in the Army has been especially appealed to as an instance in point. As early as 1858 the Royal Commissioners on the Organisation of Military Hospitals were led to attach special importance to the subject of overcrowding, and the improvements inaugurated at about that time, as regards cubic space in barracks, have been succeeded by a diminution of the phthisis rate in the Army, markedly exceeding the diminution which has occurred in the civil population. Overcrowding had been specially marked among the footguards, and in them the phthisis mortality during the years 1837–46 reached the excessive amount of 11·9 per 1,000 of strength. In the seven years 1864–70, it is interesting to note that it had fallen to 2·3 per 1,000. The mortality from phthisis in the Army at the present time is slightly below that of the male civil population at the same ages, whereas fifty years ago it was in notable excess of that amount.

A very striking instance of the power of disseminating infection displayed by the virus of tubercle under circumstances favourable to the spread of the disease, is afforded by the researches made by Cornet concerning the Catholic nursing institutions of Prussia. Dealing with the twenty-five years preceding 1888, Cornet found that in these institutions the deaths, from tubercle alone, amounted to 62·88 per cent. of the total deaths, a percentage considerably in excess of that which might have been anticipated in women of the ages under consideration. He found, moreover, that tuberculosis was most deadly in the third year of cloister life, and he concluded that "a healthy person of twenty-five years of age, who then begins cloister life, and the work of a nurse, has an expectation of life equal to that of a healthy woman of the general population who is fifty-eight years of age."

Again, Niven investigated the prevalence of phthisis in seventy-seven Manchester common lodging houses, with a population of about 1,825 persons; he found the phthisis death-rate in these persons exceeded 20 per 1,000, while the mortality, at ages 25—45, for the whole of Manchester amounted to only 3·95 per 1,000. As further instances of the relationship between phthisis and the breathing of a vitiated atmosphere, may be mentioned the frequent occurrence of the disease in animals kept in confinement. In particular, reference may be made to the case of cows crowded together in cowsheds, as in these animals, under such conditions, the ravages caused by tubercular disease are specially remarkable.

Lastly, mention must be made of the way in which the spread of other forms of specific disease is favoured by close aggregation of persons. Typhus has often prevailed in association with overcrowding, and measles, small-pox and plague may also manifest a like ability. The evidence which has accumulated in recent years as to dissemination of certain diseases, particularly diphtheria, scarlet fever and measles, in school class rooms, is quite conclusive as to the risk incurred, by bringing a number of children together within a confined space, unless the most thorough precautionary measures are undertaken with a view to the detection and exclusion of sufferers from the maladies referred to. The diseases which spread in hospital wards must also be mentioned; hospital gangrene and erysipelas outbreaks are for the most part things of the past, now that the importance of preventing their occurrence is recognised; various sorts of sore throat are still, however, of common occurrence as a result of exposure to the atmosphere of hospital wards.

(IV.)—Ventilation and Heating.

The great problem of ventilation is to secure as far as practicable—and usually the main difficulty is the limited amount of cubic space per head available—sufficient interchange of air without production of draught. A great deal depends upon the original plan of construction of the particular building in question; if a house has ample open space about it, and if regard has been paid, in planning the arrangement of rooms, to the need for preventing stagnation of air, the problem is a comparatively simple one. This aspect of the question may be best considered in connection with the subject of the dwelling in its relation to health, to be presently dealt with. If the rooms to be ventilated are those of a house constructed at a time prior to the coming into force of adequate building regulations, or of one situated in a locality where no such regulations are in force, the matter becomes one of exceptional difficulty. If, again, the rooms, the ventilation of which has to be provided for, are to be occupied in such a way as to only allow a very limited amount of cubic space per individual occupier, special effort will be needed to combat, as far as possible, the defects of original design, and the result at best is likely to be far from satisfactory.

Mechanism of Ventilation.—The diffusion of gases, the action of winds, and variations of barometric pressure, all tend to cause interchange of air, and removal of impurity; in the case of rooms provided with suitable inlets and outlets, advantage may be taken of these natural agencies in promoting efficiency of ventilation; and still more effectually, the movement of the air caused by difference of temperature, or that induced by the aspirating effect of a current of air blowing across an opening, may be utilised to good effect in replacing contaminated by pure air. When ventilation is promoted in this way, by utilising forces existing in nature to the best advantage, reliance is said to be placed upon natural ventilation. When the difficulties to be dealt with are formidable, however, and natural ventilation will not suffice, ventilating fans, blowing machines, steam jets, and the like, may need to be employed to secure adequate interchange of air, and when such appliances are used, the ventilation is said to be artificial. The part played by diffusion of gases in ventilation is most important, but reliance cannot be placed upon diffusion alone, even for securing the free dilution of gaseous impurity, and for promoting the removal of solid particles it is inoperative.

The action of wind is of importance not only as regards the space about dwellings, but, owing to the influence exerted even through solid containing walls, in connection also with the movement of the air of rooms; but winds are so variable in force, as to make their action as aids to ventilation unreliable under any circumstances, and great difficulty is experienced in regulating their influence so as to prevent draught. Cowls turned towards the wind are sometimes used, and such means are especially adopted in the ventilation of ships. As instances of the utilisation of wind as an agency for ventilating houses, reference may be made to the extraction ventilator (for example Boyle's ventilator), in which the wind effects extraction of air by blowing over the mouth of a ventilating shaft, and to Banner's cowl (shown in section in Fig. 12), in which the opening of the ventilating shaft is caused, by means of a vane, to face away from the wind.

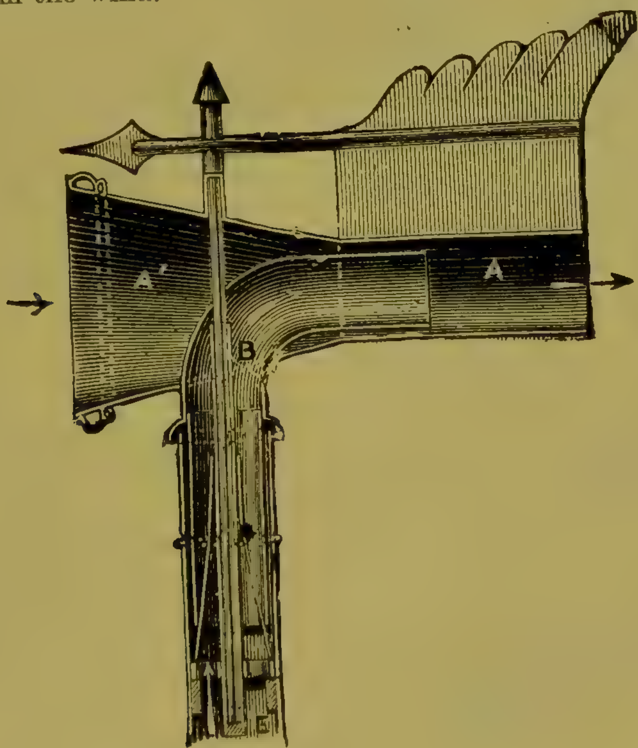

FIG. 12.
Banner's Cowl.

Natural Ventilation.—In rooms reliance is mainly placed, as a rule, upon the movement caused by differences of temperature of the internal and external air. The way in which the ordinary chimney comes to act as an outlet for foul air, by reason of the differing weights of columns of air at different temperatures, has been already considered. In summer time, when fires are not lighted, the air in the chimney may be actually colder than the air outside, and the chimney will then act as an inlet, a fact which accounts for the "flue smell" sometimes observed in dwellings under such circumstances. Assuming that the external air is colder than that in the room, it is obvious that, apart from the action of wind, interchange of air will take place through any window or other opening, the denser outer air tending to descend into the room, and the lighter internal air to ascend, and in part escape into the outer atmosphere. It is a common practice to establish openings in the wall of a room at suitable points in order to give opportunity for such interchange of air to take place.

Air bricks, *i.e.*, bricks perforated with numerous conical holes, having a smaller diameter externally than internally, are often used, the object of the air being made to pass through a channel, the sectional area of which increases on proceeding from without inwards, being to cause the current of incoming air to slacken, and so to obviate draught. In Fig. 13 such an arrangement is shown, the inlet to the room is fitted with louvres so as to give the incoming air an upward direction, and, in addition, an intermediate space, between these louvres and the externally placed air brick, is provided, this contrivance being designed with the object of intercepting dust.

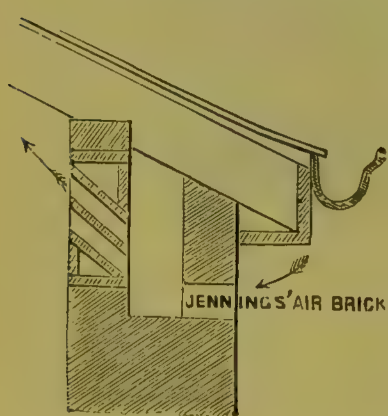

FIG. 13.
Ventilating Air-Brick.

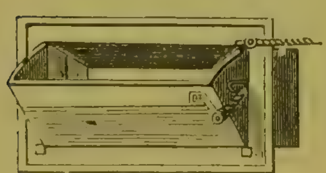

FIG. 14.
Sheringham Valve.

In the Sheringham valve a flap, usually about nine inches by three in area, falls forward towards the room, and it is sometimes balanced by a weight, so that it closes if the air tends to pass from within outwards, but remains open when the current is from without inwards. It will be seen from Fig. 14 that the arrangement of the aperture is such as to deflect upwards the incoming air, and with a view to minimising the risk of draught the opening communicating with the outside air may be made somewhat smaller than the aperture giving access to the interior of the room.

Tobin's tubes are intended to serve for the introduction of air from outside at a level, usually of some six feet or thereabouts, above the floor of the room. The inflowing air, as will be seen from Fig. 15, is caused to flow upwards, and as it gradually mixes with the air of the room, and is diffused over an area considerably greater than the area of the inlet before it descends, draught is obviated. The action of this form of inlet largely depends upon the direction and force of the wind.

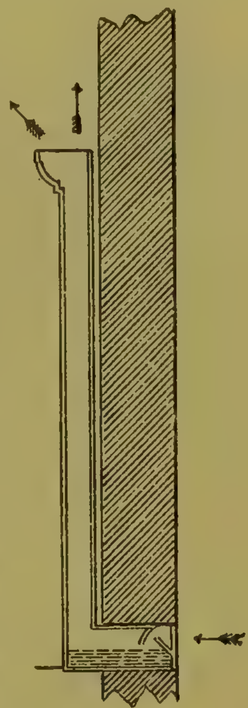

FIG. 15.
Tobin's Tube.

McKinnell's ventilator is sometimes used in rooms at the top of a house; it consists of a double tube carried through the ceiling; the inner tube is intended to provide means of exit for the impure air of the room; the fresh air enters through the space between the two tubes, which has about the same sectional area as that of the exit tube. In Fig. 16 this and other forms of ventilating opening are diagrammatically shown, in the position in which any one of them might be placed with a view to affording means of permanent ventilation. It is important in rooms which are extensively used, and in which the cubic space provision per person is limited, that some such means of permanent ventilation should be provided. If this is not done, and windows are kept closed, no sufficient means of promoting interchange of air oftentimes exists.

Hinckes Bird devised a simple plan for providing permanent means of ventilation, by introducing a block of wood beneath the lower sash of the window. With this arrangement, when the lower sash is shut down as far as it will go, an aperture is still left between the two sashes, and the air entering through this opening is directed upwards, and enters the room without, save under exceptional circumstances, causing draught. In crowded dormitories it is a common practice to replace one of the panes, of one or more windows, by a perforated piece of zinc; again, louvred glass ventilators are sometimes used. Double windows serve a useful purpose in aiding ventilation in bedrooms, inasmuch as the outer window can be left open at the bottom, and the inner one at the top, and interchange of air is thus secured without any risk of draught.

In ordinary living rooms the chimney generally constitutes the most important means of escape for impure air. The mode of circulation of air commonly observed in such a room is indicated in Fig. 17. In this case no special inlets are assumed to be in use; if they existed, modification of air currents, particularly in their immediate neighbourhood, would, of course, be produced.

Inlets, as a rule, should be smaller, but more numerous, than outlets, and they should be distributed in differents parts of a large room, in order to prevent stagnation of impure air; the current of entering air should be given such a direction, or be so dealt with, as to prevent draught. *Primâ facie*, inlets should be near the lower, outlets at the upper part of a room, but where artificial heat is in

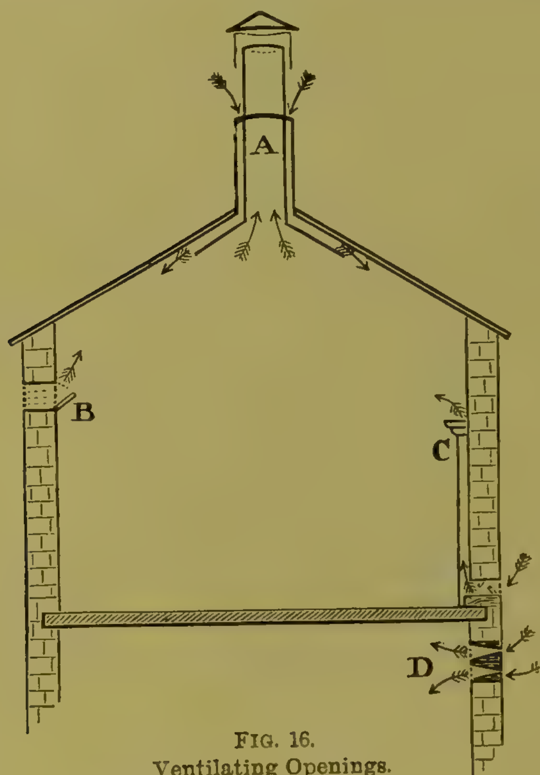

FIG. 16.
Ventilating Openings.

A.—McKinnell's Ventilator.
B.—Sheringham Valve.
C.—Tobin's Tube with Water-Trap.
D.—Ellison's Conical Brick Ventilators.

use, and under other special circumstances, considerable modification of this principle is necessary. The air exhaled is driven downwards in expiration, and its natural tendency to rise may be advantageously combated, in some instances, by the promotion of the downward movement, the impure air being then drawn off at a low level; this system is sometimes adopted in places of assembly where people are congregated in groups at one and the same level. In hospitals, on the other hand, where people are lying in bed, and the expired air is directed upwards, there is advantage in encouraging this upward movement by arranging for the provision of inlets, for warmed air, at a low level. In theatres the impure air is commonly extracted

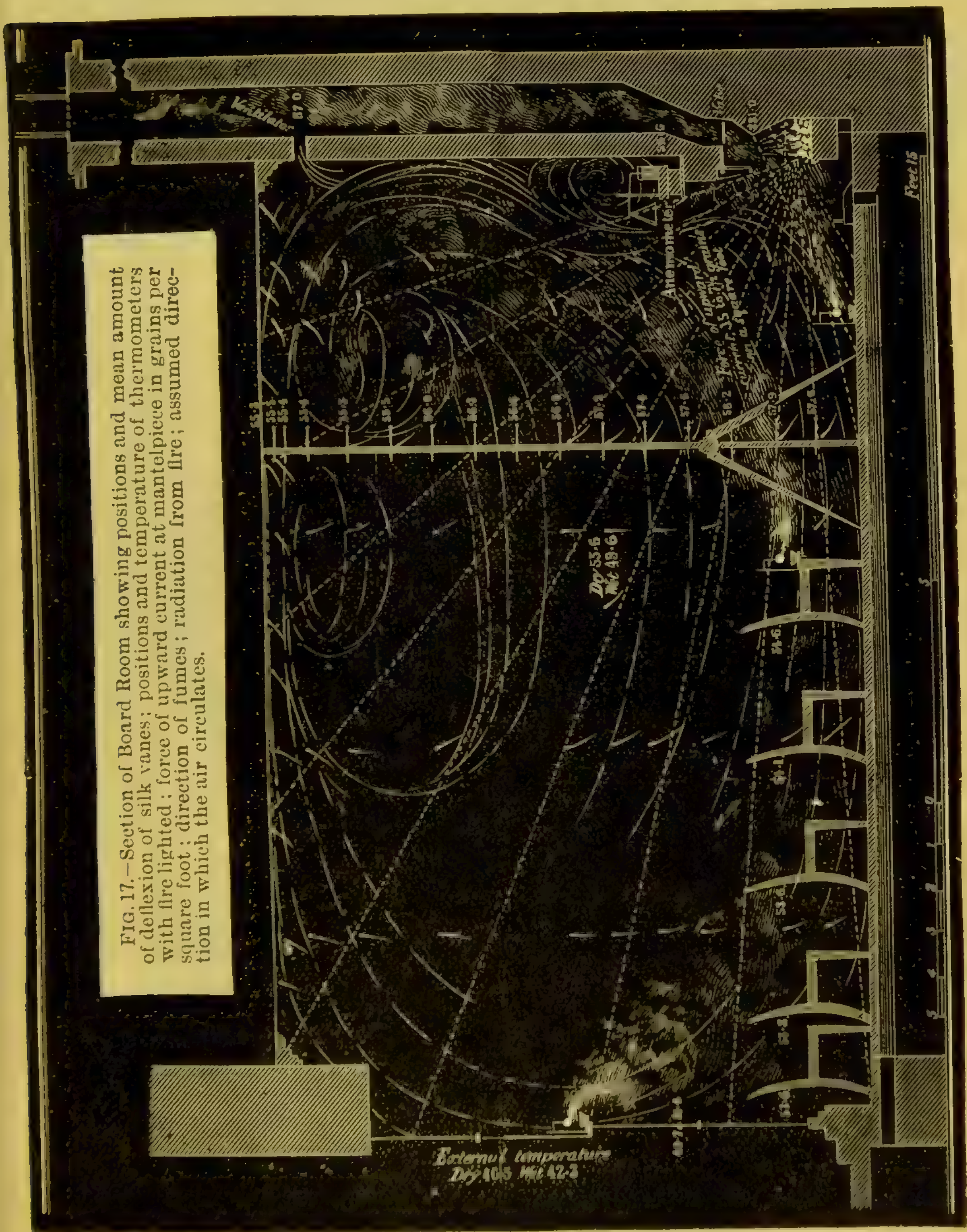

FIG. 17.—Section of Board Room showing positions and mean amount of deflexion of silk vanes; positions and temperature of thermometers with fire lighted; force of upward current at mantelpiece in grains per square foot; direction of fumes; radiation from fire; assumed direction in which the air circulates.

through an aperture in the roof above the "sunlight." The principle of McKinnell's ventilator is here often used, the heat from the gas favouring extraction of air through an inner tube, while air enters through an outer encasing tube. This use of the ventilating gaslight is also common on a smaller scale, as, for instance, under low galleries. With disuse of gas for illuminating purposes in theatres, and with the devotion of increasing attention to the need of properly securing interchange of air in such crowded places of assembly, resort is likely to be increasingly made to more elaborate means of ventilation than have hitherto been adopted. Inlets and outlets should not be so situated that the incoming air is enabled to immediately escape without mixing with the air of the room. The cooling effect of windows is a factor which requires to be reckoned with in assembly rooms with ample window space; it has been suggested that having regard to the influence exerted in this way upon circulation of air, inlets for warm air should be inserted just beneath each window.

Determination of the relative sizes of inlets and outlets mainly depends upon the rate of flow desirable in the case of the several currents of air. The fact that the impure air, being warmer, will occupy more space really has but little influence in the matter, as the increase of volume corresponding to the higher temperature is not, generally, so great as to exert material effect. As a rule the inflowing current should have less velocity than that of the outgoing air, unless the pure air from without is warmed before it enters the building; if, therefore, cold air is introduced, it would follow that the area of the inlets should, if anything, exceed that of the outlets. It has been suggested that the total inlet area should be fixed so as to provide about twenty-four inches per person, and that each individual inlet should be adapted to the air requirements of two or three persons, while the total outlet area should be equivalent to the total inlet area, but made up of somewhat larger individual outlets, each adapted to the air requirements of about six persons.

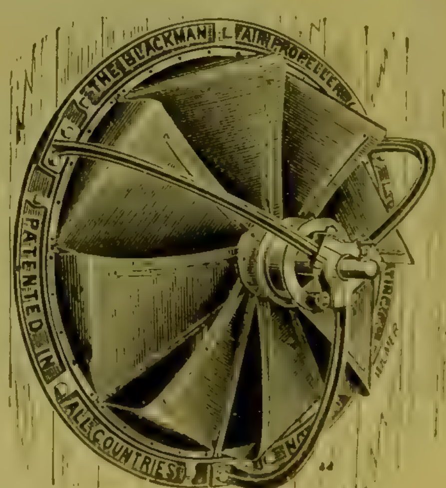

FIG. 18.
Blackman Fan.

Artificial Ventilation.—In artificial ventilation, extraction of air is usually effected by heat (as in the case of the ventilating furnaces of mines, or in that of the steam jet sometimes employed in factories); by withdrawing air by pumps; or by extracting or driving in air by means of fans. The Blackman fan, shown in Fig. 18, represents a form of appliance now frequently used for the ventilation of crowded rooms. Another kind of apparatus employed for the propulsion of air is that known as Roots' blower. In this machine two rotating pistons revolve inside a box, with two openings, and by their action draw air into one opening and drive it out at the other. By means of such appliances, fitted with due regard to all the special circumstances of each particular case, ventilation can be regulated to a nicety, and the air supplied can, if necessary, be warmed, cooled, or purified by filtration, before being delivered.

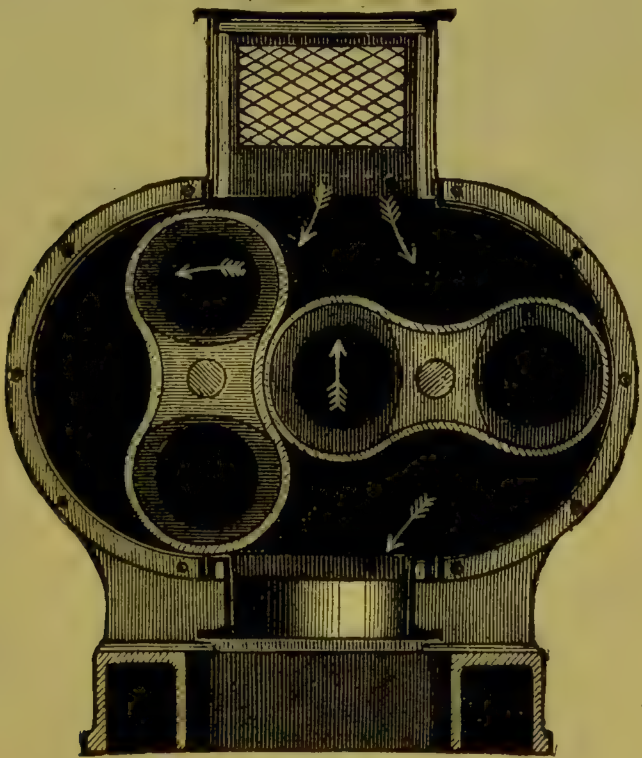

FIG. 19.
Roots' Blower.

The standard of purity of the air in crowded rooms, or in work rooms in which impurity is caused by the carrying on of special trade processes, can, by means of artificial ventilation, be maintained at a level which would be quite unattainable under ordinary conditions. In rooms in which dusty occupations are carried on, and in places in which offensive effluvia are necessarily evolved, artificial ventilation has proved invaluable. Recent researches, conducted by Carnelley, Haldane, and Anderson, concerning the ventilation of schools in Dundee, have shown how advantageously mechanically ventilated schools compare with those in which mere natural ventilation is relied upon. In the Dundee schools, the air was propelled over hot pipes, and entered the schoolrooms about five feet above the floor, the outgoing air escaping through apertures some two feet above the floor into a chamber in the roof, and passing thence through louvred exits into the outer air. The air of the schoolrooms thus ventilated was found somewhat purer, on an average, than the air of naturally ventilated schools, both as regards CO_2 (1·23 as against 1·86 per 1,000 volumes), and, as regards organic matter (10·1 as against 16·2 volumes of oxygen required per 1,000,000 volumes of air). The most striking difference under the two sets of conditions was, however, that observed in the number of micro-organisms, which amounted to 152 per litre in the naturally ventilated, and to only 16·6 per litre in the mechanically ventilated schools. It is clear that, by the adoption of improved means of artificial ventilation, the risk of danger to health, from the aggregation of considerable numbers of persons in a confined atmosphere, can be materially diminished, and it is likely that a very much larger amount of attention will be devoted in the future to this subject than has been given to it hitherto, in relation not only to schools but also to rooms of assembly of all kinds.

The Heating of Buildings.—In this country the warming of rooms is mainly effected by open fireplaces; they possess the great advantage of providing an excellent means of ventilation, but they do not secure anything like uniformity of heating effect in different parts of the room, and they are open to the objection that much of the heat generated escapes up the chimney, and does not warm the room at all. The older forms of fireplace were particularly wasteful; in modern grates attention is usually given to certain points with a view to limiting, as far as possible, the loss of heat. Thus, in the old form of grate, iron was largely used. It is now recognised that radiation must be mainly relied upon for heating a room. The heat of iron surfaces imparts warmth by conduction to the adjacent air, which, in turn, by convection, conveys heat to distant parts of the room, but, in practice, most of the heat communicated to the iron of a grate escapes up the chimney. Hence, in modern grates, iron is, as far as possible, discarded, and firebrick is used in its place, with the object of insulating the heat produced. The shape of the stove, is, moreover, important from the point of view of increasing radiation; the back of the stove should lean forwards over the fire, the bottom of the grate being made deep from before backwards, and the "throat" of the chimney should be contracted. The slits in the grating beneath the fire, and the bars in front of it, should be made narrow, and, with the object of promoting complete combustion, cold air may be excluded from beneath the fire by the use of what Pridgin Teale called an "economiser," a close fitting shield placed in front of the space into which the ashes fall.

Another improvement (now often taken advantage of in modern grates) may be effected by surrounding the stove with an air chamber, communicating on the one hand with the outer air, and on the other

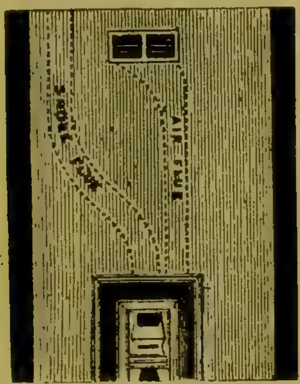

FIG. 20.
Elevation showing air and smoke flues.

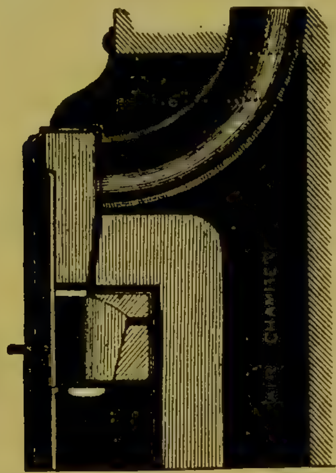

FIG. 21.
Section of Grate.

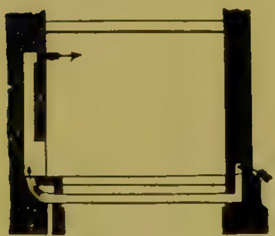

FIG. 22.
Section of a room showing air-duct and flues.

FIG. 23.
Plan of Grate and air-chamber.

Ventilating Fireplace.
(*After Galton.*)

with the room. In such "ventilating stoves" the waste heat of the fire is used to warm the air, which is then admitted into the room for ventilating purposes. Fresh air from without enters the air-chamber, is warmed by contact with its heated sides, and rising, is delivered into the room through openings, situated between the fireplace and the ceiling, or, alternatively, placed just beneath the mantelshelf. This form of stove is sometimes called Galton's stove, as the late Sir D. Galton strongly advocated its use.

Close stoves are much less wasteful of heat than fires, as the sides of the stove, and part of the flue, communicate heat by conduction and convection to the air of the room. In what are known as "cockle stoves" the apparatus is enveloped in a chamber, the air of which becomes heated and can be distributed to various parts of a house. This principle is in common use on the Continent; the heated air should be fresh air, and not merely that obtained from the chamber in which the stove is situated. The close stove does not secure ventilation so satisfactorily as does an open fire; moreover, close stoves sometimes render the air of rooms unpleasantly dry, and there is risk, under certain conditions, of pollution of the atmosphere with carbonic oxide, a question which has been already referred to.

Gas fires are cleanly, producing no ashes or smoke, they can be lighted at a moment's notice, and can be made attractive in appearance. On the other hand, they are costly; they do not, as a rule, act so efficiently in promoting ventilation as open fires; they render the air dry; and their use may be associated with escape of carbonic oxide into the air of the room.

The employment of hot air in warming schoolrooms has already been referred to; hot water at low pressure or at high pressure, and steam, may also be used for heating purposes. In the case of water at low pressure the arrangement usually adopted is that shown in Fig. 24.

Cast-iron pipes are used for distributing the heat, the highest point of the system is placed, by means of the air-vent A, in communication with the atmosphere, so that air cannot collect in the pipes; if it did, it would prevent the circulation of the water. There is, moreover, a cistern C which receives the water as it expands, thus preventing overflow, and which automatically replaces, through its ball tap, any loss of water which may occur. The system is diagrammatically represented as consisting of two vertical tubes, H B, H′ L, connected at the top by a horizontal tube, H H′. The pipe H B communicates at B with the upper part of the boiler, and in it the heated water ascends; the other termination of the system of pipes, which conveys water cooled after its passage through them, joins the boiler at its lowest point, L.*

* The circulation of the water is due to difference of density of hot and cold water. If the portions of the two vertical tubes contained between two horizontal planes h c, h' c', one foot apart, be considered, and if the density ρ of the water between h and h' be less than the density ρ' of the water between c and c', then the difference of pressure for that portion of the vertical height of the circulation between the two planes is $(c\ c')\ \rho' - (h\ h')\ \rho$. It may be shown ("A Treatise on Hygiene and Public Health," Stevenson & Murphy, vol. i. p. 133) that the head per foot per unit difference of temperature is equal to α, and hence the head for any circula-

The pressure in the boiler, since the system is in communication with the outer air, is, of course, the atmospheric pressure, plus the pressure due to the weight of a column of water measured vertically from the boiler to the highest point of the system of pipes. The temperature of the water cannot exceed 212° F. at the highest point, as the furnace must not be heated to such an extent as to produce steam, and the pressure increases by only ·43 lb. per square inch for each foot of distance vertically below this point, so that

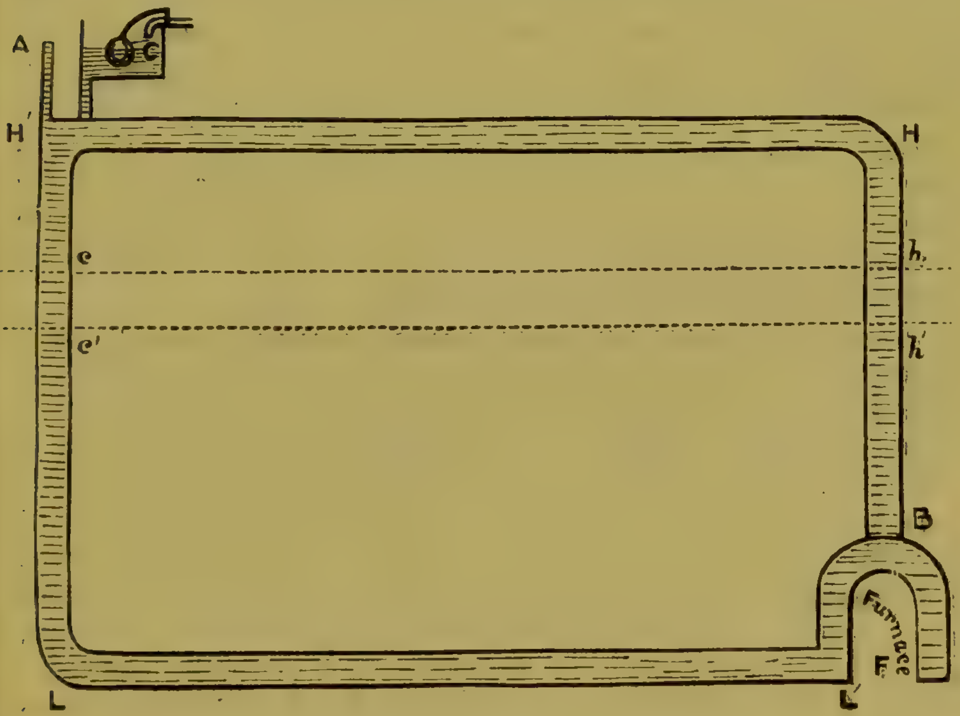

FIG. 24.
Distribution of Heat by water at low pressure.

even in lofty buildings the temperature is not likely to greatly exceed 212° F. at any part of the system. Roughly speaking, it is found that some 12 feet of 4-inch pipe are required, per 1,000 cubic feet of space in dwelling rooms, to give a temperature of about 65°; of course, much depends, however, upon the external temperature. In the case of conservatories exposed to the outer air, quite three times this allowance, of length of 4-inch pipe, must be

tion may be determined by dividing it into sections, by horizontal lines one foot apart, measuring the temperature at each section of the flow and return-pipes, adding together the differences of temperature of corresponding sections, and multiplying the total sum by a, the coefficient of expansion of water.

made, in winter time, to secure a temperature of about 55° F. In drying rooms filled with wet linen, some 150 to 200 cubic feet of 4-inch pipe, per 1,000 cubic feet of space, are needed to raise the temperature to about 80° F.

Hot water under pressure, at temperatures considerably higher than 212° F., is employed in what is called Perkins' system. A complete circuit of wrought-iron pipes, usually about $\frac{7}{8}$ inch internal and $1\frac{5}{16}$ inch external diameter, is constructed, and part of the circuit is exposed to the heat of a furnace. Expansion tubes, of comparatively large diameter and partly filled with air, are placed at the top of the system, and these allow for the expansion of the water, but the air does not extend into the smaller pipes so as to interfere with the water circulation. Water requires to be added from time to time through the tubes at the upper part of the system, to replace waste. In the event of a stoppage occurring, the weakest part of the system is that in the fire, and if a pipe bursts there no serious damage is likely to result.

In heating by steam the vapour is usually carried by pipes of small diameter to the point at which it is to be condensed, and there, in the act of condensation, it imparts heat to condensing pipes of considerably greater diameter; the condensed water is then returned to the boiler.

In contrasting the advantages and disadvantages of these several methods of heating rooms, it must be borne in mind that where heat is imparted by radiation, the air remains comparatively cool, whereas when heat is transmitted by convection the air itself becomes hot, and is thus rendered dry. On the other hand, under the conditions of the Dundee experiments, the air was found to be much more highly charged with micro-organisms in the former case than in the latter. Carnelley, Haldane, and Anderson point out that, in addition to being more cheerful, and keeping the air fresher, the open fire system involves less initial outlay than hot pipe systems; but, on the other hand, the annual cost of open fires is greater than in the case of stoves, steam pipes, or large hot water pipes, the heat is unequally distributed, and the air becomes more highly charged with micro-organisms. Stoves they found to be particularly economical, but liable to smoke and get out of repair. With respect to the relative merits of small high pressure and large low pressure pipes, they conclude that the former are cheaper, less obtrusive, more speedily set in action, and give better results as regards the condition of the air.

CHAPTER III.

WATER.

I.—Sources of Water Supply and Methods of Purification of Water.

Reference has been made in the previous chapter to some of the elementary properties of water and of the aqueous vapour given off by it. The fact that the density of water is greatest at 4° C. has been mentioned as showing why ice collects and floats on the surface. Water in the act of freezing expands, hence the liability of water pipes to be fractured in times of frost; the fact that such fracture has been caused is, of course, not made manifest until the thaw occurs. This expansion of water on freezing exercises important influence in connection with the weathering of rocks and the disintegration of soil. Water is a very bad conductor of, and has a high capacity for, heat; it is taken as the standard with which the specific heats of other substances are compared. The influence of pressure upon the boiling-point of water has been referred to, but it should be mentioned that the boiling-point is raised when certain substances are contained in solution in the water.

Rain-Water.—The source from which all water is originally derived is rain. The rainfall in a locality may be of importance in many ways as regards health conditions. Now that it is becoming more and more commonly the practice to bring water from considerable distances, for the supply of thickly populated districts, the rainfall over a given "catchment area" becomes a matter of the first consequence in connection with the determination of the sufficiency of such an area for the supply of a community. The amount of rain falling upon the area will have to be considered, and also the extent to which it may be expected to percolate through the ground, in order that an estimate may be made of the quantity of water likely to accumulate in natural underground reservoirs, formed by the holding up of the water contained in pervious formations by underlying impervious strata.

The instrument employed for estimating the amount of rainfall is the "rain-gauge." The pattern used is generally 5 inches in diameter, and the rain collected passes through a funnel into a bottle, this arrangement being designed to check evaporation. From the bottle the water is from time to time removed to a measuring glass, and the quantity of rain collected per unit of surface is stated in inches, or fractions of an inch. The rainfall varies greatly in different parts of the world. The average yearly rainfall over the whole of England is upwards of 30 inches, but in the eastern counties it is less than 25 inches, while in the hilly districts adjoining the western coast the amount is much greater, and in particular localities it may considerably exceed 100 inches per annum. In some sparsely populated districts the population is dependent for its water supply upon the collection and storage of rain-water. The area of roof space in such cases assumes importance. The slope of the roof must not, of course, be taken into account, what is material being the horizontal area covered by it. If the projection of the roof on a horizontal plane be taken at 60 square feet per person, and if the rainfall be 30 inches per annum, and one-fifth (the ordinary allowance made) be deducted for evaporation, it will be found that the rain-water available only amounts to some two gallons per person daily.

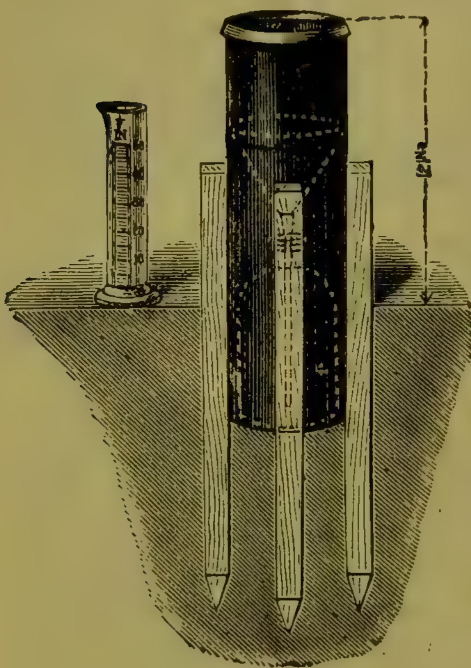

FIG. 25.
Rain-gauge.

In estimating how much water can be derived from a given area of ground a considerable deduction must be made for evaporation; and according to the steepness and slope of the ground, the porosity of the soil upon which the rain falls, the quantity of vegetation, and so on, varying amounts of water will either penetrate, or, on the other hand, run over the surface and find their way into water-courses. In hilly districts the conditions are necessarily much more favourable for surface flow than they are on flat lands, and while, in the case of sand or gravel, the large bulk of the rainfall sinks into the ground, upon clay hardly any infiltration occurs.

The extent of a gathering ground can be determined from a 6-inch ordnance map. Ordnance maps include "general maps" on a scale of 1 inch to 1 mile; "county plans" on a scale of 6 inches to 1 mile; "parish plans" on a $\frac{1}{2500}$ scale, *i.e.*, a scale of 25·344, or very nearly 25 inches to 1 mile (on this scale a square of 1·0018 inch corresponds to an acre, or approximately one square inch on the plan represents one acre); and "town plans" on a $\frac{1}{500}$ scale, *i.e.*, a scale of 10·56, or very nearly 10, feet to 1 mile. (The town plans of London, Dublin, Belfast, and some smaller towns are on a $\frac{1}{1056}$ scale, *i.e.*, a scale of 5 feet to a mile.) "Town plans," it may be incidentally noted, are invaluable in connection with study of insanitary areas. The 1-inch maps are all drawn parallel and perpendicular to a meridian line passing north and south through Delamere Forest. For the larger scales the maps are prepared by counties, and each county (or group of counties where it was found more convenient to group them) has its own meridian. All the large-scale plans are reduced to smaller scales by photography, and "for convenience in this reduction and also for convenience in numbering the plans, it was decided that all plans on the two larger scales should, when reduced to the 6-inch scale, fit into the 6-inch sheets. The proportion of the 25-inch or $\frac{1}{2500}$ scale to the 6-inch or $\frac{1}{10560}$ scale being nearly as 4 to 1, each 6-inch sheet, containing an area 6 miles by 4, was divided into 16 25-inch plans, each containing an area $1\frac{1}{2}$ miles by 1; and similarly the proportion of the town or $\frac{1}{500}$ scale to the 25-inch or $\frac{1}{2500}$ scale being as 5 to 1, each 25-inch plan, containing an area 120 chains by 80 (or $1\frac{1}{2}$ miles by 1), was divided into 25 town plans, each containing an area 24 chains by 16, whenever a town happened to come within the area of the 25-inch plan."*

The 6-inch sheets of each county are numbered from north to south, generally (but not always) by Roman numerals, *e.g.*, LX, and

* "Ordnance Survey Maps of the United Kingdom. A description of their scales, characteristics, etc." This pamphlet, printed for H.M. Stationery Office (price sixpence), should be carefully studied in connection with the use of ordnance maps.

are divided into quarter-sheets, lettered N.W., N.E., S.W., and S.E. The $\frac{1}{2500}$ plans, of which there are 16 on a full 6-inch sheet, are numbered 1 to 16 in Arabic figures, and referred to, for example, as LX. 9. There are 25 plans of the $\frac{1}{500}$ scale in one $\frac{1}{2500}$ scale plan, and these are numbered from left to right, as in the system adopted for numbering the $\frac{1}{2500}$ plans, and are referred to, for example, as LX. 1. 9. Each enclosure on a $\frac{1}{2500}$ plan has a reference number, except in Ireland, and the area is given under this number on the plan. Altitudes above mean sea level at Liverpool are shown on the plans. It has been found that the mean level of the sea around the coast is ·650 foot above the mean level of the Mersey at Liverpool; the altitudes given may therefore be taken as starting from a zero-point about ·650 foot below the mean sea level. For islands distant from the mainland altitudes are referred to a local mean sea level. For Ireland altitudes are given above low water level of Spring tides at Poolbeg Lighthouse, Dublin Bay. Trinity high-water mark is the level of the lower edge of a stone fixed in the face of the river wall on the east side of the Hermitage entrance of the London Docks, and is 12·48 feet above Ordnance datum.

Surface levels are shown along roads on the 6-inch and 25-inch plans, and in the case of the 10-feet plans one decimal is given. Figures, to which an arrow and the letters B.M. are prefixed, refer to "bench marks" cut on buildings, walls, milestones, etc. Contours begin, as a rule, 50 feet above Ordnance datum, but in some flat districts the 25-feet contour is shown. They only appear on the 6-inch and 1-inch maps, and are shown instrumentally (after 50 and 100 feet) at intervals of 100 feet, up to 1000 feet, above O.S. datum, and in some instances at closer intervals. Contours sketched by water level are shown at 100 and 250 feet intervals, on the 1-inch maps of England, for ground at greater elevation. Full account of the abbreviations, characteristics and symbols employed on ordnance plans is given in the pamphlet already referred to. Ridge or watershed lines are lines separating drainage areas, and forming therefore the boundary of catchment basins. The boundaries of a given catchment basin, or gathering ground, being determined, its area can be ascertained by use of the 6-inch map.

In estimating the amount of water which can be relied upon from a given "catchment area," it has to be borne in mind that the quantity of rain which falls varies from year to year. Hawksley's rule is to the effect that the average of 20 years less one-third gives the amount of rain in the driest year, while this average plus one-third gives the amount of rain in the wettest year. On the same authority the amount of storage which should be provided is often taken as being given by the formula $D = \frac{1000}{\sqrt{F}}$, D being the number of days' supply to be stored, and F the mean, in inches, of the rainfall of three consecutive dry years, or, say, five-sixths of the average annual rainfall.

As regards the amount of water required for a given population, about 30 to 35 gallons per head is that usually found necessary in most large communities in this country. The actual quantity consumed, in the form of food and drink, per person is only about half a gallon, another half a gallon would be required for cooking; considerably larger amounts are, of course, needed for washing and laundry purposes. The estimate given by Parkes is 12 gallons per head for ordinary domestic use, with 4 additional gallons for general baths, and 9 gallons for water-closet purposes and unavoidable waste. This makes a total of 25 gallons per head for ordinary household supplies, and leaves, on a basis of 30 gallons per head, only 5 gallons for trade and municipal purposes. This quantity is likely to be found insufficient in many manufacturing towns, and gives but scant allowance of water for washing streets, fire extinguishing purposes, etc. The average amounts supplied in London have varied in recent years from 30 to 35 gallons per head daily, but some of this undoubtedly represents waste. In Glasgow and in a few other cities considerably larger quantities are supplied. A formula of some use in connection with the discharge from water supply pipes may be here referred to. The discharge W in cubic feet per minute is $4{\cdot}72 \frac{\sqrt{H \times D^5}}{\sqrt{L}}$, H being the head of water, L the length of pipe the water flows through in feet, and D its diameter in inches. It will be found that $D = {\cdot}538 \sqrt[5]{\frac{L \times W^2}{H}}$.

Rain-water possesses the great advantage of being a soft water, and if due care be taken as regards collection, it contains but little added impurity. From what has been said already, it will be clear that recourse must be had to other means, than the mere collection of rain, for the water supply of communities.

Upland surface water nearly approaches rain-water in respect of the advantages already named; it is likely, on the other hand, to contain more dissolved solid matters, and sometimes yields evidence of the presence of considerable quantities of organic matter, which may be expected, however, to be rather of vegetable than of animal origin. Several large English towns have in recent years provided themselves with water collected upon "catchment areas" in hilly districts, utilising lakes, and where necessary raising their water level, and causing the natural area of the reservoir to be thus considerably extended, by the construction of dams of masonry. Such waters are eminently soft and possess great purity; peaty matter is sometimes present in considerable quantities, and the attempt has been made to improve the character of such peaty waters by filtration.

In some towns in the north of England water derived from moorland sources has given rise to lead poisoning in persons who have consumed it. In places in which symptoms of plumbism have been observed it has been found possible, by treatment of the water before delivering it to the consumer, to materially diminish the risk of such occurrence (*See* p. 115).

River Water.—Many large towns derive their supplies from streams, liable, in a greater or less degree, to pollution by trade effluents and raw sewage, or by sewage effluents which have undergone more or less satisfactory forms of treatment before being discharged into the water course. Moreover, river waters are, as a rule, hard waters, and they are thus ill adapted for manufacturing purposes, and are subject to other disadvantages incidental to the use of hard waters, which will be presently referred to. Much stress has been laid upon the self-purifying properties of river water. The dilution of any added impurity is, in some instances, so great as to make demonstration of the fact that it has been added very difficult, and it has been supposed that water plants, and forms of animal life present in the river, would materially assist in freeing the water from traces of impurity, and that processes of oxygenation would notably operate in a similar direction; it has been further contended that the influence exerted by light upon any pathogenic micro-organisms which may have obtained access to the water, must be an important factor in controlling risk of spread of specific disease. The Rivers Pollution Commissioners, however, as the result of their inquiries, were led to the conclusion "that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidisation." The spread of cholera and enteric fever in several well-attested instances has abundantly shown that, under ordinary circumstances, but little reliance can be placed upon the self-purifying powers of river water.

A good deal has been done of late years in the way of improving the character of the water derived from streams by processes of sedimentation and filtration through sand. It is an undoubted fact that an average sample of river water can be deprived of the majority of the micro-organisms it contains by carefully conducted sand filtration. The efficiency of such filtration can be materially increased by controlling the rate at which the water percolates, and by paying attention to the mode of construction of the sand filters.

The operation of the filter has been shown by Koch to depend, in the main, upon the formation of a slimy membranous deposit upon the surface layers of the sand. This deposit consists largely of intercepted bacteria, and the number of germs which penetrate into the deeper layers of sand is, under ordinary circumstances, exceedingly small. The slimy film is only formed after the water has stood on the sand for a number of hours, and, with the lapse of time, its interference with the rate of filtration becomes so considerable that it has to be removed. This is effected by scraping the surface of the sand and supplying fresh sand, or in some instances the plan adopted is to wash the sand removed, with water from a hose, and to then re-apply the sand to the surface of the filter. After scraping, the water yielded by the filter is, for a time, rich in micro-organisms, and Koch has, therefore, recommended that the water first coming through should be discarded, and that the filtrate should not have access to the filter-well, which supplies the reservoir, until the slimy deposit on the surface of the sand has had time to again form. Koch further recommended that the rate of filtration should not exceed 100 millimetres (200,000 gallons per acre) per hour, that the thickness of the sand should never be less than 30 centimetres, that each filter should be bacteriologically tested every day, and that the water supplied by any filter which was found to yield more than 100 micro-organisms per cubic centimetre should be rejected. Where such precautions are adopted, the risk of spread of disease by use of water which has been previously exposed to sewage contamination can be materially lessened, but there is always the chance, that some interference with the process of filtration—such as has been observed in Germany in times of frost, and in connection with the scraping of the surface of filters and their immediate use without special precautions after such scraping—may permit of the passage through the filter of enteric fever or cholera organisms. In some instances it has been thought to make assurance doubly sure by further filtration, and the plan of collecting subsoil water from land adjoining streams has been recommended, such subsoil water being, after collection, conveyed to filter beds, and thus made to undergo a second filtration.

Under ordinary circumstances, by the adoption of the means just described, river water yielding very small numbers of organisms of any kind—and, of course, the vast majority of the contained organisms, under ordinary circumstances, have no pathogenic property—can be supplied to town populations. Special difficulty is, however, experienced in dealing with flood waters. If a water company possesses large subsidence reservoirs, and has sufficient storage, the worst of the flood can be allowed to pass down the river, and such water as is taken can be allowed to stand in the subsidence reservoirs, until it is in a condition in which a fair result can be obtained on further subjecting it to adequate filtration. These conditions are not, as yet, generally realised in actual practice. In the forty-ninth, fiftieth, and fifty-first weeks of the year 1894 there was notable increase in the number of notified cases of enteric fever in London, and this increase followed shortly after the occurrence of exceptional floods in the Thames and Lea valleys in the forty-sixth and forty-seventh weeks of the same year. The water consumed immediately after the occurrence of these floods contained an excessive amount of organic matter (Memorandum appended to the Third Annual Report of the Medical Officer of the County of London).

Springs and Wells.—Springs and surface wells are the main sources of supply relied upon in sparsely populated areas, and in days when large schemes for water supply were not undertaken, the need of being able to readily obtain water, from local sources, led to the extension of towns, mainly, in directions in which the lie of the land was such as to render it possible to obtain water from shallow wells. London itself is a striking instance of this, as until early in the last century the only parts of the area now constituting London which were populated, were those in which superficial beds of gravel overlie the London clay, and in which it was possible therefore to obtain a supply of water by means of shallow wells, or to utilise the springs existing in places where the gravel terminated, and water, upheld by the underlying clay, flowed out at the surface.

In 1835 the famous well of Grenelle was bored in Artois, in France, through the superficial strata into the underlying pervious strata, and the reservoir of water in the latter was thus tapped. Since that time many of these deep "artesian wells," as they are called, have been constructed, and if the point at which such a well is sunk be situated in a valley, having beneath it underlying pervious strata so disposed as to form a kind of basin, the level of the underground water in these strata may be considerably higher than the level of the mouth of the well. Thus the water in the well at Artois rose some 60 feet above the surface of the ground when the boring had reached a depth of about 1,800 feet.

The way in which this comes about is illustrated in Fig. 26, in which B is an ordinary deep well, penetrating through the impermeable layers EE, and tapping the water bearing strata FF. C is an overflowing artesian well, the mouth of which is considerably below the level *a - - - a* of the underground water in FF. A well such as that shown in the Figure at D, which is merely sunk into a superficially lying porous bed of sand or gravel, containing water held up by an underlying impermeable layer, is termed a shallow well; such shallow wells are usually less than 50 feet deep.

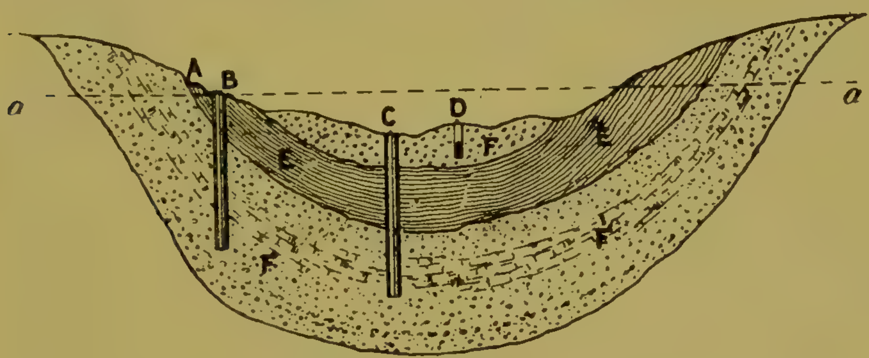

FIG. 26.

a - - - a, Line of saturation or level of underground water in deeper pervious strata, F F. A, spring cropping out above impervious strata, E E. B, deep well, and C, over-flowing artesian well, bored through impervious into pervious strata, F F. D, shallow or surface well, sunk into over-lying pervious strata, F.

Deep wells are sometimes carried as far as 1,000 feet or more below the surface. The shallow wells, which formerly served for the supply of a large part of the population, and which are still common in rural districts, were not constructed with a view to preventing the entry of water, which had not been adequately filtered by the material surrounding the well. They for the most part either possessed no special lining of brickwork at all, or were merely "dry-steined," the lining of brickwork being arranged in such a way as to secure a maximum yield of water. They were thus subject to pollution by surface drainage, and they were in many instances situated in close proximity to cesspools. They were, moreover, liable to be contaminated by receiving impurity through the mouth of the well. Such wells have been shown in many instances to have acted as agents for the dissemination of disease.

If a shallow well is used at all, it should be placed at a distance from sources of pollution, be protected against surface washings, and be closed over so as to avoid the chance admission of impurity from above. The sides of the well, for at least 20 feet from the surface, should be constructed of brickwork, set with hydraulic cement, so as to be impervious to water; iron cylinders are sometimes employed in the upper part of the well. Koch recommends that such iron tubes should be used, and that the space surrounding them should be completely filled in with clean gravel or sand, the water being raised to the surface by means of a pump.

Deep wells are usually constructed by digging to some depth, and then boring until the pervious strata it is intended to reach are tapped; precautions must, of course, be taken with a view to rendering the upper part of the well impervious, so that water from the deep strata only can have access to the well. In many instances horizontal adits are driven from the bottom of an excavation, with a view to penetrating water-bearing strata, and the amount of water obtainable is likely to be considerably increased when an adit strikes a fissure in such strata. In the chalk, more particularly, fissures yielding considerable quantities of water may be struck; there is always, of course, a possibility that material, which has been subjected to little if any purification by filtration through the ground, may, by obtaining access to a fissure, find its way into the well. Deep wells are utilised largely for trade purposes and for supplying isolated institutions, asylums, prisons, schools, etc. The quantity of water yielded by them is likely to prove insufficient for large populations, though they are in many instances employed to supplement supplies derived from other sources.

The water from a deep well yields, as a rule, very little organic matter, but it may contain iron and mineral salts in considerable quantity, and it is apt to be a hard water. Chalk water and waters from the oolite are hard, but their hardness is mainly temporary, and they are usually bright, sparkling, and charged with carbonic acid. In limestone and sandstone waters the total hardness is generally high, and there may be a considerable amount of permanent hardness. Deep-well waters may contain sufficient quantities of magnesium or calcium sulphates, or other salts, derived from the strata through which the water passes, to render them unfit for potable purposes. Excess of nitrates may be found in well water, apart from previous contamination with organic matter, in cases in which nitrates are present in the soil and can thus be dissolved out of it by the water.

The water from shallow wells is generally impure, though often bright and sparkling in appearance, and, it may be, pleasant to the taste. The organic matter may be excessive, and the amount of oxidised nitrogen high. Calcium and sodium nitrites and nitrates are often present in polluted surface-well water. Wells sunk near cemeteries are apt to contain excess of ammonia and organic matter; if the cemetery has been long disused these impurities may exist in only small amounts, but the quantity of chlorine and of nitrates or nitrites is likely under these circumstances to be considerable.

Impurities of Distribution.—In addition to the impurities derived at its source or on its way to the reservoirs, water is liable to be contaminated in various ways in the course of distribution. In particular, the practice of laying water mains and sewers in proximity to one another is apt to render the water of a leaky main subject to contamination by sewage. Where the intermittent system of supply has been in force, foreign material has at times been sucked into water mains in which some defect existed, and has then been delivered with the water from taps. Under such circumstances sewage, coal gas, and other impurities have been found to issue from taps within houses. It was thought that with the introduction of the constant system of supply such evils would be altogether remedied, but experiments have shown that a water main, "running full," will suck up impurity from the surrounding ground, if a defect in the pipe gives opportunity for such an accident to occur; disease is therefore still liable to be transmitted by such insuction to the consumers of water, even when they enjoy the advantages of a "constant supply," though, under such circumstances, this source of danger is very materially lessened.

The intermittent service entails of necessity storage of water in houses, and cisterns, unless they be constructed of suitable material such as slate or galvanised iron, be placed in a position in which they are not liable to receive added impurity, and be designed so that means of access of sewer air to them are precluded, are likely to themselves cause pollution of the contained water. Leaden cisterns may yield lead to the water, iron cisterns discolour it, and zinc is sometimes taken up by water. A cistern which contains water used for drinking purposes, should never communicate directly with a water closet. Impurity has been transmitted to the mains where this condition of things has existed, as will presently be seen. Again, sewer gas sometimes obtains access to cisterns, owing to the overflow pipe being carried directly into a drain The overflow pipe should, of course, be taken out into the open air, and made to serve as a "warning pipe." In any case a cistern should be placed in such a position that it is easily accessible for cleansing purposes, and it should be cleaned out at least once every three months.

The constant service has been largely substituted for the intermittent service in many large towns within recent years. With the former the house pipes are subjected to higher pressure, and more expensive fittings must be used; moreover, there is greater tendency with this service to waste of water, owing to negligence on the part of consumers who leave taps running; again, with the higher pressure there is greater likelihood of loss occurring from escape of water through leaky mains. By the use of Deacon's, or other forms of waste-water meters,* such defects in mains may be discovered and remedied; and if proper fittings are provided in houses, and a reasonable amount of care is exercised by the inhabitants, this waste can be to a very large extent controlled. No doubt in the past the waste from one or other cause has been excessive, and this has led in times of drought to failure of the constant service. When this has happened, in places where the use of cisterns has been discontinued upon the establishment of the constant service, serious inconvenience has resulted. In any case cisterns are required for the purpose of flushing water-closets and for supplying kitchen boilers, and there is advantage in possessing some means of storing water, in order that the household supply shall not wholly fail, at times when the water has to be cut off for the repair of mains, etc., or in consequence of the freezing of pipes, or other such exceptional occurrence. It has been suggested that to meet difficulties of this nature it is desirable to have a form of cistern consisting of an expansion of the service pipe, constructed in such a way as to exclude the possibility of the entrance of dirt and of accumulation of deposit from the water itself. Cisterns have been designed, moreover, provided with an arrangement which will admit of the removal from time to time of any deposit which may collect. In any case it is desirable that the ordinary domestic supply should be taken direct from the main, and that the cistern should only be brought into use if it is needed.

Another important question which has to be considered in connection with the distribution of water is the possibility of symptoms of plumbism being developed in association with the use of lead pipes. Waters which contain a considerable amount of earthy salts do not,

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* Water meters either register the number of times a cylinder of known capacity is filled, or alternatively the amount consumed is inferred from the velocity of flow registered by the meter. The auscultation of water pipes is of considerable use as a means of localising points at which leakage occurs, and the microphone has been employed with a like object.

as a rule, act upon lead; in the case of such waters a protecting coat of carbonate, or of other salts of lead or of calcium or magnesium, is formed, which shields the lead from the solvent action of the water. Free carbonic acid is also said to exert, as a rule, a protective influence, and importance has been attached to the presence of silica in water, as rendering it unlikely to actively dissolve the metal, an insoluble lead silicate being formed. Pure, soft, and highly-oxygenated waters are, on the other hand, likely to dissolve lead; rain water, and more especially certain upland surface waters, have been found to possess this property in marked degree. It has been said that the presence of organic matter, nitrites, nitrates, and chlorides, favours the solvent action of water. The condition, however, which appears especially likely to exert this influence is that the water should contain free acid, and the upland surface waters derived from moorlands in Yorkshire and Lancashire, and supplying peaty waters to some of the towns in those counties, have been found in certain instances particularly active, especially during, or shortly after, periods of drought.

It has been shown by Power and Houston that the solvent property of waters varies with the amount of their acidity, and has definite relation to the season of the year. These observers ascribe the acidity of the water to the activity of certain bacteria, which appear to find favourable conditions for their development under suitable circumstances in peaty soil. In Sheffield, in which town the question of lead poisoning by water has been particularly studied by Sinclair White and others, the plan adopted to prevent action of water on lead pipes is to add lime, with a view to neutralising any acid present in the water. The system appears to have been found effectual. Another method of dealing with the matter, which has been suggested, is to use block-tin pipes, or to line the leaden pipes with tin, or to employ iron pipes; the two first-named kinds of pipes do not appear to afford security against solvent action, and block-tin pipes are very expensive. Iron pipes are satisfactory, so far as obviating risk of lead-poisoning is concerned, but they are apt to become blocked by rust.

The Purification of Water.—The most satisfactory way of purifying water is to distil it, and this plan is often adopted on board ship, or in cases where necessity compels the use of a doubtful water for drinking purposes. The next best thing to do is to boil the water. So far as is known, all pathogenic bacteria which have been found in water are destroyed by exposure for some minutes to boiling temperature. If it is desired to render water absolutely sterile it may have to be subjected to more than one boiling process, as certain spores are able to resist the action of boiling water for a considerable time; reliance must therefore be placed upon first affording such spores the opportunity of sprouting, and then destroying the less resistant bacteria which develop from them.

For the treatment of hard waters numerous processes of purification have been devised. *Clark's process* is sometimes applied on a large scale to public water supplies; it consists in adding lime to the water, in such quantity as to cause the calcium bi-carbonate to be completely decomposed, forming calcium carbonate; the carbonates, being practically insoluble, are thus precipitated. Care must be taken not to add excess of lime, above the amount required to combine with the carbonic acid and thus convert the calcium bi-carbonate into carbonate. The precipitate of carbonate of lime is either allowed to settle or, as in the *Porter-Clark process*, is removed by filtration through filter-presses. These processes deal only with the temporary hardness; if it be desired to reduce the permanent hardness also, caustic soda is employed in conjunction with lime.

Domestic filters were at one time largely recommended and used with the object of purifying water. The fact, that wool, flannel, a piece of sponge, charcoal in powder or compressed into blocks, and certain compounds of iron, possess the property of removing impurities from water, was noted, and here, it was thought, was a means ready to hand of enabling consumers of water of doubtful character to protect themselves against any possibility of incurring risk. Many forms of domestic filter were designed. In some of them the materials used were those above mentioned, in others various patented preparations were employed; the principle relied upon was, however, for the most part, the same in all these filters. The immediate result produced was in many cases satisfactory, but it was found that after a time the filter failed to improve the character of the water.

Recent investigations have shown that these forms of filter, as ordinarily used, are a source of danger rather than of security. The filter becomes in many instances an actual breeding-ground for organisms, and under these circumstances the water, after filtration, may be more highly charged with impurity than was originally the case. Animal charcoal is a particularly unsatisfactory filtering agent, as it speedily loses its property of oxidising dissolved organic matter, and, moreover, adds to the water passing through it phosphate of lime, and thus renders it a medium favourable for the growth of bacteria. Filters which contain spongy iron, polarite, asbestos, etc., are less open to objection; again, silicated carbon and magnetic carbide are materials which have been recommended for use in filters. In Bischoff's spongy iron filter, spongy iron and oxide of manganese are employed, an asbestos cloth being also used to prevent impurity passing through the filter. No reliance can be placed upon the continuous action for a length of time of such filtering media, and they can only be recommended for the purpose of tiding over emergencies; they should in any case be freed from impurity before freshly bringing them into use.

The most satisfactory kinds of domestic filter are those introduced in recent years, in which an earthenware cylinder is employed; they give for a time a filtrate practically free from micro-organisms, and they readily admit of being effectually sterilised by brushing with a brush in hot water, or by subjecting them to the action of steam or to that of direct heat. The Pasteur-Chamberland filter consists of a case of metal or glass, enclosing a cylinder of unglazed porous porcelain made of kaolin. The space between the outer case and the cylinder is capable of being placed in communication with an ordinary tap, supplying water under pressure, and if this pressure be one of about two atmospheres—as is usually the case in an ordinary water service—it will force the water through the pores of the cylinder, in a stream delivering at the rate of about three quarts per hour. The filtrate is at first quite sterile, but the rate of delivery becomes reduced after a time, and unless the filter is removed and cleansed, germs are apt to pass through the porcelain and to gain access to the filtered water.

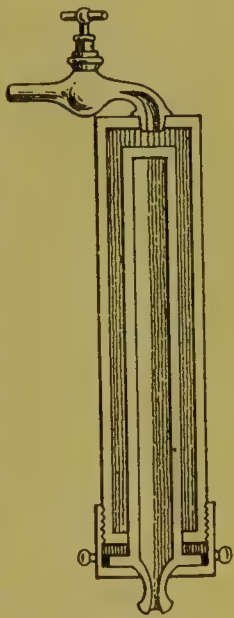

FIG. 27.
Pasteur-Chamberland Filter.

The Berkefeld filter is constructed on the same principle, but the filtering cylinder is made of infusorial earth. It effects at first complete removal of all bacteria, but after a time germs appear in the filtrate. The filtering cylinder or bougie is more fragile than the Pasteur-Chamberland cylinder, but the rate of filtration is said to be somewhat more rapid. In a paper by Horrocks, which appeared in the *British Medical Journal* of June 15, 1901, the degree of protection from water-borne disease afforded by the Pasteur-Chamberland and Berkefeld filters is discussed. The experiments made pointed to the conclusion that "typhoid bacilli are not able to grow through the walls of a Pasteur-Chamberland candle, and if proper care be taken to prevent the direct passage of the bacilli through flaws in the material or imperfections in the fittings, the Pasteur-Chamberland filter ought to give complete protection from water-borne enteric fever." It was found, on the other hand, that "typhoid bacilli can grow through the walls of Berkefeld candles after from four to eleven days," and hence, "in order to obtain complete protection," it is necessary "to sterilise the candles in boiling water every third day."

II.—The Examination of Water.

The sample of water for purposes of analysis is usually taken in an ordinary "Winchester quart," which holds about half a gallon; the bottle must be thoroughly cleansed, rinsed out with a little hydrochloric acid, and then repeatedly washed until all traces of acid are removed. At the time of collecting the sample the bottle is usually again rinsed out with some of the water, a sample of which is to be taken, and is then filled. In conducting this process it is well to make sure that the sample is taken in such a way as to fulfil the conditions, which are likely to be observed by persons having recourse to the source in question for their supply of water.

There are certain physical characters presented by water to which attention must be directed. Thus, the extent to which *turbidity* is present should be noted, and some of the water may be allowed to settle, with a view to collecting sediment; the character of such deposited material may afterwards be made the subject of study in the way to be presently described. Again, the *colour* of the sample is generally determined by examination of a portion of it in a two- or three-foot tube, the estimation being made by looking through the column of water at a white surface. If the water be perfectly pure it is quite clear, or has a slight bluish or greyish tint; any variation from this, in the direction of yellowish or brownish appearance, raises suspicion as to the character of the water, though such variation may be due, of course, to the presence of peaty matter, or of salts of iron. The *lustre* of the sample of water is said to indicate the amount of aeration; it may vary from what is described by the terms *nil* or *dull* up to *vitreous*, or to the maximum brightness, which is termed *adamantine*. The *taste* of the water may afford information, though it is advisable to know something of the sample before making use of this test. Its main value lies in the fact that it facilitates detection of iron, which gives appreciable taste to water when present to the extent of only about a quarter of a grain in

100,000 parts. Salt, on the other hand, may occur in very considerable amounts without causing its presence to be appreciated. What is ordinarily spoken of as the taste of water is mainly due to the gases dissolved in it. The sense of *smell* may be best applied after warming a little of the water, when it may be found that an odour indicative of putrefying organic matter can be distinguished.

Determination of the Chlorine.—One of the chemical tests most commonly applied to water is the estimation of the amount of combined chlorine. In rain water this does not exceed, as a rule, ·5 part per 100,000, and the purest waters do not contain more than about three times this amount. In sea water there are some 1,800 or 1,900 parts of chlorine per 100,000, and water obtained from tidal rivers, from deep wells near the sea coast, or from wells penetrating strata which contain deposits of salt, may contain considerable quantities of chlorine. Another possible source of chlorine is sewage contamination, and it is for this reason that the estimation of the amount present in water is important. The difficulty is, however, supposing a considerable quantity is found, to determine whether the chlorine represents organic pollution, or is merely due to some of the other causes already mentioned. If the average character of the waters of a district, from which a particular sample is obtained, is known, the amount of chlorine present in the sample then affords a valuable indication of the likelihood or unlikelihood of the water being dangerously contaminated.

The ordinary test for the presence of chlorides consists in the development of cloudiness, due to precipitation of argentic chloride, on addition of a solution of nitrate of silver. This cloudiness is not removed by a drop or two of nitric acid, and its existence can be recognised when only $1\frac{1}{2}$ parts of chlorine per 100,000 are present. The test can be made a quantitative one by using a standard solution of argentic nitrate and employing a few drops of a solution of chlorine-free chromate of potassium as an indicator.

The standard solution is run into a measured quantity of the sample of water, which is continually stirred, until the point is attained at which a permanent orange-red tint appears in the liquid. The chlorine has then all combined with the nitrate of silver, and on further addition of one or two drops of the solution, the red chromate of silver is formed. The presence of the few drops of chromate of potassium thus serves to indicate, with considerable precision, the stage, in the process of addition of argentic nitrate, at which this change commences. If the standard solution be so made that each c.c. corresponds to one milligramme of chlorine, the amount of chlorine per 100,000 parts in the water is given on determination of the number of c.c. of silver solution used.

If the water be initially acid in reaction it should be neutralised, as otherwise the red chromate of silver would be dissolved, and the value of the indication observed be thus interfered with. Again, if very small quantities of chlorine have to be estimated, it is well to concentrate the water before commencing operations.

Determination of the Hardness.—The *hardness* of water is of great importance as determining its suitability for use in certain trade processes, and also in connection with waste of soap in washing. When soap is mixed with pure water a lather is readily obtained, but if the water contains lime, magnesia, etc., a certain amount of soap is disposed of, in forming oleates of these bases, before any lather is formed. Free carbonic acid also unites with, and so uses up, some of the soap. "Hard waters," *i.e.*, those which contain considerable quantities of earthy bases, thus cause great waste of soap. Furthermore, "soft waters" are much more suitable for making tea, coffee, and meat extracts, and for various cooking processes, than "hard waters" are.

If a hard water be boiled, a deposit is formed, and the hardness of the supernatant fluid is found to be diminished. The deposit usually consists, in the main, of carbonates and sulphates of lime and magnesia, which were held in solution in the water by its contained carbonic acid; the carbonic acid being driven off by heat on boiling, these salts are precipitated. Certain salts, principally sulphates, chlorides, and nitrates of calcium and magnesium, remain dissolved in the water, and to these its *permanent* hardness is due. The total hardness of the water is made up of the *temporary* or removable hardness, that removed by boiling, plus the *permanent* hardness. The deposition of salts from hard waters, on boiling, causes incrustation, or formation of "fur," on the surface of boilers, and this leads, of course, to loss of heat and may cause explosions, and thus militates seriously against the use of such waters. The salts, determining the permanent hardness of water, consisting as they do mainly of alkaline sulphates, are apt, when present in appreciable amount, to render the water ill adapted for potable purposes. They cause, in some instances, digestive disturbance, and may impart definite aperient properties to the water.

The estimation of the hardness of water is usually made by means of *Clark's test*. A standard solution of soft soap is titrated with a measured quantity of water in a bottle provided with a stopper, which is inserted in order that the contents of the bottle may be well shaken after each addition of soap solution. When the point is reached at which all the calcium, magnesium, etc., salts have combined with the soap, forming insoluble oleates, the sound yielded on shaking the bottle becomes faint and soft, and a lather then commences to form. The addition of the soap solution is discontinued when about a quarter of an inch of lather is developed, and when this persists for five minutes on placing the bottle on its side. The soap solution used is generally of such strength that 1 c.c. will precipitate 1 milligramme of calcium carbonate. If 100 c.c. of the water to be examined have been taken, and the number of c.c. of soap solution required to produce the lather estimated, 1 c.c. must then be deducted (this being the quantity of soap solution required to form such a lather with 100 c.c. of distilled water), and the number of c.c. remaining represents the total hardness in 100 c.c. of the water. This number, therefore, gives the hardness in parts per 100,000. It is a frequent practice to express the hardness in "degrees on Clark's scale," one degree corresponding to one grain of carbonate of calcium in one gallon, *i.e.*, to one part in 70,000.

Sometimes 70 c.c. of water instead of 100 c.c. are employed for shaking with the standard solution, and the number of c.c. of the latter used, less 1 c.c.,* then gives the degree of hardness on Clark's scale. If the hardness of the water examined be high (exceeding 16° on Clark's scale), the precipitate produced interferes with the formation of the lather, and the hardness is apt to be overestimated. It is better under these circumstances, therefore, to dilute the 70 c.c. of water, by addition of an equal bulk of distilled water, and to then estimate the hardness of the mixture, deducting two, instead of one, from the number of c.c. of soap solution used. The soap solution employed should be comparatively freshly made, as it is found to vary in strength after a few days.

When the quantity of magnesia in the water is large, there is liability to error. Magnesia has a tendency to form double salts, and its amount cannot be so precisely determined, therefore, as is the case with lime or baryta. Wanklyn estimates that as much soap solution is required for one equivalent of magnesia as for one and a half equivalents of lime; the magnesia, moreover, requires a longer time to act. When there is much magnesia the lather formed tends to break up readily, and it has a dirty appearance, which distinguishes it

* This amount being taken as that required to give a lather with distilled water. When 100 c.c. of water are employed, an allowance of 1·5 c.c. "for lathering" is sometimes made.

from the white lather ordinarily observed. If this phenomenon is noted, it is well to considerably dilute the water to be examined and to shake the bottle vigorously, in order to facilitate the thorough combination of the magnesia with the soap.

The total hardness having been determined, 100 c.c. of the water must be mixed with 100 c.c. of distilled water, and boiled for about half an hour; the mixture is then allowed to cool and the deposit to settle, the supernatant water is poured off, the sediment being disturbed as little as possible, and its bulk is made up to exactly 100 c.c. with distilled water. The hardness of 50 c.c. of the mixture is determined, and this represents the permanent hardness of 100 c.c. of the original water. The temporary hardness is then, of course, the difference between the estimated total hardness and the estimated permanent hardness.

Determination of the Organic Matter.—The methods relied upon for ascertaining the amount of organic matter contained in water are based upon the determination of the carbonic acid, ammonia, or nitrogen yielded in the decomposition of such matter, or upon determination of the amount of oxygen absorbed by the contained oxidisable organic matter.

In the *combustion* process, devised by Frankland, the amounts of carbonic acid and nitrogen evolved when the dry residue from a given quantity of water is heated in vacuo, in a combustion tube, with oxide of copper, are carefully estimated. The residue operated upon is obtained by evaporating a measured quantity—usually a litre—of water, to which a small amount of saturated sulphurous acid, 15 to 20 c.c., has been added; the carbonates are thus decomposed, carbonic acid being expelled, and the nitrogen, contained in the nitrates and nitrites present, is eliminated as nitric oxide. The nitrogen and carbon existing in the form of organic matter thus alone remain to be burnt with the oxide of copper, and the quantities of the nitrogen and carbonic acid evolved are carefully measured volumetrically, and the results are expressed in terms of "organic nitrogen" and "organic carbon."

"A good drinking water," according to the Rivers Pollution Commissioners, should not yield more than ·2 part of organic carbon or ·02 of organic nitrogen in 100,000 parts. The character of the contained organic matter can, to some extent, be determined by the proportion the organic nitrogen bears to the organic carbon; if the carbon is high, with little nitrogen, this is said to be indicative of vegetable pollution, while the nearer the nitrogen approaches to the carbon the greater is the probability of the organic matter being of animal origin. This combustion process is a complicated and difficult one, and is, therefore, rarely used.

A much simpler process, and one which gives results which are, for practical purposes, little, if at all, inferior to those obtained by Frankland's method, is what is known as *Wanklyn's ammonia process.* The free ammonia contained in a measured quantity—usually half a litre—of water is, in the first place, driven off by distillation, the distillate being collected and the ammonia contained in it estimated. When some 200 c.c. of the water have been distilled over, all the "free ammonia" is exhausted. The next step is to add, to the remaining 300 c.c., about 50 c.c. of alkaline solution of permanganate of potash, and the distillation is again proceeded with. Ammonia, derived from nitrogenous organic matter, is now evolved, and the amount of this "albuminoid ammonia," as it is called, is determined.

The estimation of the ammonia distilled over is effected by the process known as "Nesslerising." Nessler's reagent is a saturated solution of mercuric iodide in potassic iodide, made with ammonia-free water and rendered alkaline with caustic potash. This solution, on being added to water containing ammonia, gives it a yellowish or brownish colour, owing to the formation of ammonio-mercuric iodide. The depth of coloration produced is greater the larger the quantity of ammonia present, and by comparing the tint yielded by, say, 50 c.c. of the water, with that yielded by a corresponding amount of a standard solution of chloride of ammonium (containing ·01 milligramme of ammonia in 1 c.c.) the quantity of ammonia contained in the water can be estimated. In making this comparison two cylindrical flat-bottomed "Nessler glasses," marked at 50 c.c., are placed side by side upon a dry, white slab. In one of them 50 c.c. of the sample water, and in the other the same amount of ammonia-free distilled water are placed; two c.c. of Nessler's reagent are added to the water in each of the glasses, and the tint developing, in the glass containing sample water, is precisely matched by adding to the distilled water measured quantities of the standard ammonium chloride solution.

In distilling the half-litre of water to be examined, the first 50 c.c. of distillate are collected in a Nessler glass, a second glass, then a third and fourth and fifth, if necessary, being substituted to catch the second, third, etc., amounts of 50 c.c. which distil over. In practice it is found that the first 50 c.c. of distillate contains three-quarters of the free ammonia, and if to the amount of ammonia estimated to be present in this first 50 c.c., one-third of that amount is added, the total gives the quantity of free ammonia contained in the half-litre of water. If the water contain much ammonia, this statement is not strictly true, and for this reason, and to obviate any possibility of error arising from other causes, it is usual to estimate the amount of ammonia in each of the first three sets of 50 c.c. which come over (matching the tint developed in each against that obtained in a control Nessler glass containing distilled water, to which ammonium chloride solution is added) and to then add together the amounts determined. If an appreciable result is obtained with the third sample of 50 c.c., a fourth quantity of distillate must be collected in a Nessler glass, and the amount of ammonia estimated; it may even be necessary to collect a fifth sample of 50 c.c. As a rule, however, in drinking waters, the first 150 c.c. distilled over contain the whole of the free ammonia of the half-litre of water.

All the free ammonia must be exhausted before the second stage of the analysis is proceeded with. When no more free ammonia is yielded, 50 c.c. of the alkaline permanganate solution (made by dissolving 8 grammes of permanganate of potash and 200 grammes of caustic potash in a litre of distilled water, and boiled, shortly before being used, for five minutes, in order to remove any trace of ammonia) are added to the water remaining in the retort, and the distillation is resumed. The nitrogenous organic matter in the water is now in part decomposed, its nitrogen being converted into ammonia, and this, as it distils over, can be collected and Nesslerised as before. The albuminoid ammonia comes over more slowly than the free ammonia; the second 50 c.c. of distillate sometimes contain as much ammonia as did the first 50 c.c., and the amount in each 50 c.c. must be carefully estimated as long as the quantity remains appreciable.

In good drinking waters the amounts of free and albuminoid ammonia are generally under ·002 and ·005 part per 100,000 respectively. In "usable" waters they may reach ·005 and ·01 part per 100,000 respectively. If the free ammonia be practically *nil*, the albuminoid ammonia may somewhat exceed the quantity specified; while if the albuminoid ammonia be practically *nil*, the limit given for free ammonia may be exceeded. About ·615 part of albuminoid ammonia per 100,000 parts may be taken as equivalent to one part of Frankland's organic nitrogen per 100,000. When the albuminoid ammonia comes over very slowly, this is said to indicate a vegetable, rather than an animal, origin of the organic matter.

Kjeldahl's process consists in distilling down half a litre of water to about 300 c.c.; this is allowed to cool, and then about 10 c.c. of nitrogen-free sulphuric acid are added, and thoroughly mixed with the water. The distillation is next continued until the residue is nearly colourless, and at this stage the flask is removed from the flame, and a little powdered potassium permanganate is introduced. When the flask has cooled, 200 c.c. of distilled water free from ammonia, and 100 c.c. of the alkaline permanganate solution employed in Wanklyn's process, are added. Distillation is commenced, and the distillate is carefully Nesslerised. The amount of ammonia yielded is multiplied by $\frac{N}{NH_3} = \cdot 824$, and the product gives the "organic nitrogen" (excluding oxidised nitrogen) contained in the water. The "organic nitrogen" of the Kjeldahl process is usually found to be about twice the amount of nitrogen determined in the form of albuminoid ammonia.

The oxygen, or Forchammer's, process has as its object the determination of the quantity of oxygen taken up from permanganate of potassium by the organic matter of the water.* A standard solution of potassium permanganate, of such strength that 10 c.c. yield 1 milligramme of oxygen, is employed, and an estimation is made of the amount of oxygen abstracted from the permanganate after the lapse of one and three hours respectively; sometimes half an hour is substituted for one hour in the case of the shorter period, and four hours' exposure instead of three are often given for the longer period.

Four flasks, two of which contain one-quarter of a litre of the water to be examined, and the other two one-quarter of a litre of distilled water, are taken, and are placed in a water bath and maintained at a temperature of 80° Fahr.; to each of them 10 c.c. of the standard permanganate solution and 10 c.c. of a standard solution of dilute sulphuric acid are added. If the water is very foul the permanganate may be entirely decolourised, and in that case a second and, if necessary, a third 10 c.c. of the solution must be added, so that the liquid in the flask retains a pink tinge throughout. After the lapse of an hour one of the flasks containing the sample water and one of those containing distilled water are examined, to ascertain how much permanganate solution remains unacted upon. This is effected by adding 2 c.c. of a standard solution of potassium iodide to each flask, free iodine being thus liberated in proportion to the amount of permanganate which remains undecomposed.† The amount of this free iodine is determined by titrating with a standard solution of hyposulphite of sodium, containing one gramme to the litre. The hypo-

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* The decomposition of the permanganate in the presence of the organic matter is that expressed by the equation $4KMnO_4 + 6H_2SO_4 = 2K_2SO_4 + 4MnSO_4 + 6H_2O + 5O_2$.

† $K_2Mn_2O_8 + 10KI + 8H_2SO_4 = 2MnSO_4 + 6K_2SO_4 + 8H_2O + 5I_2$.

sulphite combines with the free iodine,* and the yellow colour due to the iodine gradually disappears; when it is nearly gone the exact point at which the last trace of iodine vanishes is determined by adding 2 c.c. of starch solution to the contents of each flask. The blue iodide of starch is formed, and more hyposulphite solution is then dropped in until the blue colour disappears.

The object of employing a control flask containing distilled water is to determine the strength of the hyposulphite solution at the time when the water analysed is tested, the hyposulphite being an unstable salt and very liable to change. In the case of the distilled water, the number of c.c. of hyposulphite solution employed, gives the quantity of that solution equivalent to 10 c.c. of the standard solution of permanganate, *i.e.*, to 1 milligramme of oxygen. This being known, the amount of oxygen absorbed by the sample water, which corresponds to the observed difference between the quantities of hyposulphite solution required for the distilled water and the sample water, can be determined. Precisely the same process is applied in the case of the two flasks exposed for the longer period of three or four hours.

Putrefying animal matter is readily oxidised by potassium permanganate, and the flask exposed for the shorter period serves to indicate to what extent such material is present in the water; the flask exposed for the longer period testifies to the total amount of organic matter present. Nitrites, ferrous salts, and sulphuretted hydrogen reduce potassium permanganate, and if they are present in the water allowance must be made for the fact in estimating the organic matter by this process.

A water is regarded with suspicion if the oxygen consumed exceeds ·1 per 100,000 after an hour's exposure, or ·3 per 100,000 after four hours' exposure. Peaty waters, however, consume considerable quantities of oxygen.

Determination of the Oxidised Nitrogen.—When the organic matter in water decomposes, the nitrogen is first converted into ammonia, and this becomes subsequently oxidised, with formation of nitrites and nitrates. The amount of these salts is therefore, as a rule, indicative of the extent to which organic matter has been originally present in the water. Frankland deducted from the total amount of inorganic nitrogen, present in the form of ammonia, of nitrites or of nitrates, ·032 part per 100,000 as being the average quantity of nitrogen contained in rain-water, and

* $I_2 + 2Na_2S_2O_3 = 2NaI + Na_2S_4O_6$.

regarded the nitrogen remaining as representing "previous sewage contamination." The nitrogen in rain-water is, however, subject to some variation; moreover, when the matter is regarded from Frankland's standpoint, all soluble nitrates taken up by water are ascribed to sewage contamination, yet in the case of water from chalk and other formations appreciable amounts of nitrates may be found in association with extremely little organic matter. In deep well waters of the kind in question the pollution is presumably not of recent origin, and to speak of the nitrates present as indicative of "previous sewage contamination" is likely to give rise to misconception.

The formation of nitrites constitutes the first stage in the oxidation of nitrogen, and nitrites speedily tend to become further oxidised into nitrates; it follows, therefore, that if nitrites are present nitrates are also likely to be found. Nitrates may, however, exist in water unaccompanied by nitrites. The presence of nitrites is indicative, as a rule, of recent pollution, and hence any water containing nitrites must be regarded with suspicion.

There are certain tests which are responded to by both nitrates and nitrites; the qualitative test commonly used is the ***Brucine test***, which is applied by adding a drop of pure sulphuric acid and a minute crystal of Brucine to the dry residue of 2 c.c. or more of the water. A pink colour is developed if very minute traces of oxidised nitrogen be present. When the quantity existing in the water is more considerable, the test may be applied in an ordinary test-tube, in which a few drops of saturated solution of Brucine have been well mixed with half a test-tubeful of the sample water. If pure sulphuric acid be poured slowly down the side of the test-tube, a pink tint is developed at the line of junction, between the sulphuric acid and the mixture of Brucine solution and water overlying it. In performing this test the test-tube should be held against a white background, as the pink tinge soon changes to brownish-yellow.

The quantitative estimation of the amount of oxidised nitrogen in water may be made—

(*a*) By the *aluminium process*, in which the water is made strongly alkaline, and a piece of aluminium foil is then placed in it and left for some hours; hydrogen is evolved, the oxidised nitrogen is reduced, and on boiling the ammonia formed can be distilled over and estimated by Nesslerisation.

(*b*) By the *zinc-copper process*, in which the oxidised nitrogen is reduced to the form of ammonia, by employing a zinc-copper couple, and the ammonia thus yielded is estimated as before.

(*c*) By the *phenol-sulphuric acid method*, in which phenol-sulphuric acid is added to the residue obtained from 10 c.c. of the water, picric acid being thus formed. If nitrates be present this is converted into ammonium picrate on the addition of ammonia, and the intensity of the yellow colour produced is matched against that obtained by treating, in a similar manner, a standard solution of potassium nitrate.

(*d*) By the *indigo method*, in which pure sulphuric acid is added to the water, liberating nitric and nitrous acids. The amount of these acids is then estimated by testing their power of discharging the blue colour from a weak solution of indigo, against that of a weak standard solution of potassium nitrate.

The quantitative estimation of nitrites is usually effected by Griess's test, or by the modification of it known as Ilosvay's test. In performing *Griess's test*, 1 c.c. of dilute sulphuric acid and 1 c.c. of a solution of meta-phenylenediamine are added to 100 c.c. of the sample water in a Nessler glass; an orange-red colour is produced, and this is matched against that yielded by measured amounts of a standard solution of potassium nitrite.

Ilosvay's test is based upon estimation of the amount of coloration produced when solutions of sulphanilic acid and naphthylamine are added to the water. The pink colour is matched as before against that yielded by measured amounts of a standard solution of potassium nitrite.

Determination of the "Total Solids" in solution.— In making this determination 200 c.c. of the water to be analysed are evaporated to dryness in a platinum dish of known weight, the final stages of the evaporation being usually conducted in a hot air bath, so that the water of crystallisation is not driven off. As soon as the platinum dish cools it is weighed, and the difference between its weight, and that of the empty dish, gives the "total solids" in the measured quantity of water. The dish is then slowly heated to dull redness, again allowed to cool, and the loss of weight consequent on ignition is determined. The loss represents the "volatile solids," and is due, for the most part to the destruction of organic matter, nitrates and nitrites, volatilisation of salts of ammonium and certain chlorides, together with loss of combined water and combined carbonic acid. In order to prevent any loss from decomposition of carbonates, it is usual, after incineration, to add a little ammonium carbonate, dry, and again gently incinerate in such a way as to drive off the ammonia but to maintain full carbonation of the residue. The excess of weight of the platinum dish, after ignition, over the weight of the empty dish, is due to the "fixed solids." If ruddy fumes are evolved during incineration, nitrates or nitrites are present. If considerable quantities of organic matter were originally contained in the water, blackening of the residue and development of an appreciable odour, like that of burnt feathers, may be observed. Should these phenomena be noted, the sample must be regarded with grave suspicion, though, in the case of peaty waters, some slight blackening on ignition may occur. The total solids in ordinary samples of water vary from 3 or 4 to 50 or 60 parts per 100,000; the loss on ignition in a pure water will not exceed, as a rule, about 1·5 or 2 parts per 100,000.

Examination for certain Metals and for Sulphates, Phosphates, etc.—In testing for *lead*, *copper*, and *iron* a litre of the water is made slightly acid with hydrochloric acid, concentrated to about 200 c.c., and allowed to cool. A glass rod is then dipped into ammonium sulphide solution, and passed through some of the concentrated water, which has been placed in a white dish. If there is any development of a dark colour in the track of the glass rod, one of these metallic substances is present. If this darkening disappears or diminishes in intensity on addition of a drop or two of hydrochloric acid, iron is indicated, and the fact may be confirmed by applying the ferrocyanide of potassium and sulphocyanide of potassium tests. If the dark colour persists in the presence of hydrochloric acid, it is due to lead or copper; if to the latter, a few drops of a solution of potassium cyanide will bring about its disappearance. A confirmatory test for lead consists in the addition of potassium chromate, which causes formation of the chromate of lead. In the case of copper, the addition of ferrocyanide of potassium to the slightly acidulated water results in precipitation of cupric ferrocyanide. Again, on addition of a few drops of ammonia to the water, faint blue coloration is developed. Quantitative estimation of the amounts of these metals present may be made by matching the darkening caused by ammonium sulphide against that produced by standard solutions of plumbic acetate, ferrous sulphate, or cupric sulphate.

In the case of *zinc*, addition of ammonium sulphide yields a curdy, white precipitate; ferrocyanide of potassium gives a white precipitate insoluble in dilute acids, and ferrocyanide of potassium a yellow precipitate in neutral solutions. The presence of *arsenic* may be tested for, if this be deemed necessary, by applying Marsh's or Reinsch's test to some of the concentrated water.

Calcium is determined by addition of oxalate of ammonia in the presence of ammonia and ammonium chloride. The ammonium chloride keeps magnesium (if there be any) in solution, and the white precipitate of oxalate of lime yielded by a measured quantity of concentrated water, may be collected on a Swedish filter paper (of which the weight, after incineration, is known) and then ignited. The oxalate of lime is thus converted into carbonate of lime, the weight of which can be determined.

To estimate the *magnesium*, the lime must first be removed by precipitation as oxalate of lime, and to the filtrate ammonia and phosphate of sodium are then added. A crystalline precipitate of triple phosphate (ammonio-magnesium phosphate) is formed, the weight of which, after ignition, may be determined as pyro-phosphate.

Silicon may be determined by weighing such material as may be left, after treatment of the residue from a measured quantity of water with strong hydrochloric acid, washing it with boiling distilled water, filtering, igniting the material collected on the filter, and again treating it with acid and washing.

Sulphates may be estimated by adding hot solution of barium chloride to a measured quantity of concentrated water, rendered strongly acid with hydrochloric acid and heated to boiling-point. The precipitate formed is collected on a Swedish filter paper, thoroughly washed to remove all the barium chloride, ignited, and weighed as barium sulphate.

Phosphates are tested for by adding ammonic nitro-molybdate to concentrated water, and noting whether a yellow precipitate of ammonic phospho-molybdate appears. They may be quantitatively estimated by dissolving them out from the residue, after ignition at the lowest temperature possible, with warm distilled water, rendered acid with dilute nitric acid. After filtering and washing the filter with dilute nitric acid, nitro-molybdate of ammonium is added, and precipitation of the yellow phospho-molybdate is facilitated by keeping the solution at about 80° F. for a short time. This precipitate may be washed, dissolved in ammonia, precipitated by addition of magnesium and ammonium chlorides, and then washed with ammonia, ignited, and weighed as magnesium pyrophosphate.

Sulphides.—Hydrogen sulphide yields a black precipitate with plumbic acetate, and if in considerable amount, sulphides may be detected by the smell of sulphuretted hydrogen evolved on heating the water with a little acid. Sulphides give a bluish to a purple tinge with sodic nitro-prusside. If free sulphuretted hydrogen be alone in question, caustic alkali must be added, before employment of the sodic nitro-prusside, in order to obtain the purple coloration, as this is only developed in the presence of alkaline sulphides.

Determination of Dissolved Oxygen.—This is effected by Thresh's process, which depends upon the fact that if nitric oxide be present in the water it acts as a carrier of the dissolved oxygen. If sulphuric acid, sodium nitrite, and iodide of potassium be added to the water, not only is iodine set free by the nitrous acid ($2HI + 2HNO_2 = I_2 + 2H_2O + 2NO$), but the oxygen dissolved in the water, in the presence of nitric oxide, decomposes more hydrogen iodide ($2HI + O = H_2O + I_2$). Air must, of course, be excluded in conducting the estimation.

Thresh's apparatus consists of a wide-mouthed bottle, capable of holding about 500 c.c., closed with a stopper having four perforations, as indicated in Fig. 28. The tube B, which is passed through one of these perforations, communicates with a graduated burette C, containing sodium hyposulphite, for estimating the amount of iodine liberated. Through another opening passes the tube which forms the lower part of the receiver D, called the "separator"; this receiver is of known capacity, and is provided with a stopcock and a stopper. The tube E, which passes through the third perforation, is connected with the ordinary gas supply. Finally, the tube passing through the fourth perforation has connected with it a cork, G, which can be inserted in the place of the stopper of the "separator" D; moreover, this cork is perforated by a glass tube, and thus gas escaping through it can be ignited.

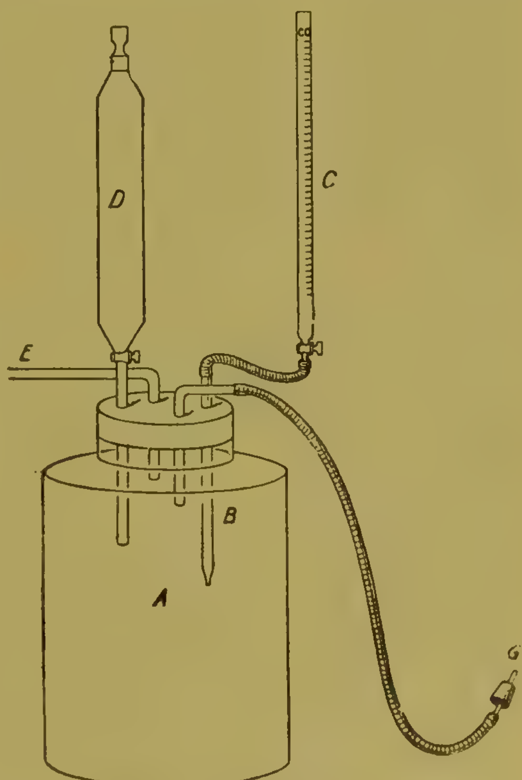

FIG. 28.
Apparatus used in Thresh's Process.

The "separator" D is first filled with the sample water; 1 c.c. of a standard solution of sodium nitrite and potassium iodide, and 1 c.c. of dilute sulphuric acid are then introduced by means of a pipette, and are allowed to descend through the water to the lower part of the separator. The stopper is then immediately replaced, displacing a little of the water and including no air. This proceeding is effected in such a way that neither standard solution nor acid is permitted to escape with the water displaced. The stopper being in position, the separator is inverted so as to facilitate mixture of its contents, the tube, at the lower part of the separator, is pushed through the perforation in the stopper of the bottle, and about fifteen minutes are then allowed to elapse for the reaction to take effect. A current of coal gas is now passed through the bottle, so as to displace its contained air. This process is deemed to be completed when it is ascertained that the gas escaping at G burns with a bright flame. The flame is then extinguished, the cork G quickly substituted for the stopper of the separator D, the stopcock at the lower part of D is turned, and the water flows into the bottle. The stopcock is now closed, the cork G removed, and the gas re-lighted.

Hyposulphite solution is next run into the bottle from the burette C, until the yellow colour has almost entirely gone (*see* p. 126). The exact point of disappearance of the iodine is determined by introducing 1 c.c. of starch solution into the bottle through D, and adding hyposulphite until the blue colour, which is developed on addition of the starch, is discharged. The coloration reappears usually after a few seconds, there being some oxygen dissolved in the hyposulphite solution; the further addition of a small quantity of hyposulphite causes it to finally disappear. The amount of hyposulphite used is now read off, and this corresponds to (i) the iodine liberated by the oxygen dissolved in the sample of water; plus (ii) that liberated by the nitrite-iodide solution and the oxygen contained in the acid and starch solution; plus (iii) that liberated by the oxygen dissolved in the hyposulphite solution added. The iodine due to the nitrite-iodide and the dissolved oxygen of the acid and starch solution is determined by introducing into the bottle, after finishing the estimation as above described, 5 c.c. of nitrite-iodide solution, and the same amounts of acid solution and starch solution, titrating as before, and taking one-fifth of the result as representing the quantity of hyposulphite corresponding to the 1 c.c. of each of the specified ingredients originally employed.

The correction for the amount of dissolved oxygen in the hyposulphite solution may be made by assuming that this solution contains as much dissolved oxygen as distilled water saturated at the same temperature. A titration with a small measured quantity of saturated distilled water is, therefore, made, to determine exactly what the amount of oxygen dissolved in it is.

If the hyposulphite solution be of such strength that 1 c.c. corresponds to ·25 milligramme of oxygen, the number of milligrammes of oxygen dissolved in a litre of the sample water is now known to be $= \frac{1000}{4f}(e - b - ed)$:

where f is the capacity of the "separator," less 2 c.c. for added reagents;

e is the number of c.c. of standard hyposulphite solution used;

b is the number of c.c. of this solution accounted for by the nitrite-iodide and the oxygen dissolved in the acid and starch solutions;

and d is the amount of hyposulphite solution corresponding to the oxygen contained in each c.c. of the saturated distilled water.

If nitrites be present in the water correction must be made for the influence they exert as oxygen carriers. The presence of nitrates does not interfere with the accuracy of the estimation.

As regards the actual amount of dissolved oxygen determined in particular cases, it may be stated that distilled water, thoroughly shaken with air at 60° F., is found to yield rather more than 10 milligrammes of oxygen per litre; in rain water an average amount is about 8·5 milligrammes. The quantity of dissolved oxygen in surface waters is considerably affected by the temperature of the air, and thus varies at different times of the year; the water of deep wells is not markedly affected by seasonal influences. In very deep wells the merest traces of dissolved oxygen are found. Dupré has suggested that the amount of dissolved oxygen in a water may be regarded as a test of the number of oxygen-consuming micro-organisms present in it.

Determination of Carbonic Acid.—Carbonic acid may exist in water as free acid, or in combination in the form of carbonates or bicarbonates. The "free CO_2" and that in the form of bicarbonate (the "half-bound CO_2") together make up the "volatile CO_2"—that expelled from the water by boiling. The remainder is the "fixed CO_2"—that existing in the form of carbonate. For estimating the "volatile CO_2" in water the method of Pettenkofer is usually adopted. To a measured quantity of the water (say 200 c.c.), 10 c.c. of neutral and nearly saturated solution of calcium chloride, 5 c.c. of saturated solution of ammonium chloride, and 35 c.c. of baryta water (standardised, immediately before testing, with oxalic acid, of which one c.c. corresponds to one milligramme of CO_2) are added. After standing for twelve hours, 100 c.c. are removed, without disturbing any of the precipitate formed, and divided into two portions of 50 c.c. each; the amount of uncombined baryta in both portions (one result being used as a check against the other) is estimated by titration with standard oxalic acid, phenol-phthalein being used as an indicator. The quantity of baryta which has been precipitated by the carbonic acid (free or in the form of bicarbonate) in the water can then be determined. The number of c.c. of oxalic acid solution employed, for 50 c.c. of fluid, must be multiplied by 5 (as there were originally 250 c.c. of fluid in the flask) and the result must be deducted from the number of c.c. originally required to neutralise 35 c.c. of baryta water. The calcium chloride decomposes any alkaline carbonate or other alkaline salt present, and prevents its acting upon the baryta water, while the ammonium chloride precludes precipitation of magnesia by the baryta.

The Microscopic Examination of the Sediment deposited from a sample sometimes yields evidence which serves to indicate whether or no the water has been exposed to risk of dangerous pollution. The sediment may be collected in a conical glass or in the pipette specially designed for the purpose, known as Wynter Blyth's tube. This instrument is shaped like a large pipette, and is provided at its lower extremity with a small cell, in which the sediment collects. The cell can be detached from the pipette, with its contained sediment, by means of a rod-shaped stopper, which is pushed down until it reaches the cell.

A great variety of objects may be detected on microscopic examination of the material thus obtained. The nature of any mineral particles present may be recognised, partly by their appearance and partly by the effect upon them of various reagents. Vegetable matter, starch cells, linen and cotton fibres, spiral vessels, dotted ducts, and other kinds of vegetable tissue may be detected. Dead animal matter, remains of insects, fragments of wool, hair, scales, epithelium, etc., may also be found. Living forms are usually present in abundance; they consist, however, in the main of bacteria and microscopic fungi, and little can, as a rule, be learnt concerning them by mere examination under the microscope. The means adopted for studying these minute organisms will be presently referred to. Among larger living forms, diatoms, desmids, and algæ may be seen in water from streams and in well waters; amœbæ, infusoria (*paramœcium*, etc.), and hydrozoa, especially the fresh-water polyps, may also be met with. These are for the most part of importance, in so far as they imply the presence, in appreciable quantity, of nutrient material in the shape of organic matter, upon which such organisms are dependent for their existence. The same remark applies to still larger forms which may be exceptionally observed, such as small leeches, wheel animalcules, water fleas, water bears (*Tardigrada*), the larvæ of beetles, and the pupæ of insects. Under very exceptional circumstances evidence of the presence of certain parasites may be forthcoming. The eggs and segments of tapeworms may be detected; the eggs of round and thread worms, too, have been found in water in this country, and other parasites (*Filariæ*, *Dracunculus medinensis*, the eggs of *Dochmius duodenalis*, the embryos of *Bilharzia*, etc.), may be found in drinking waters obtained in foreign lands. The most significant of the microscopical objects likely to be met with in samples of water designed for drinking purposes, and obtained in this country, are those which suggest the probability of sewage contamination; such are muscle fibres, fat cells, starch grains, epithelium, etc. If such objects as these be discovered the water must be regarded with the gravest suspicion.

Bacteriological Examination of Water.—An estimate of the number of micro-organisms present (and capable of development upon the particular nutrient materials used) in measured quantities of the water may be made, and under special circumstances it becomes necessary to ascertain whether or no the existence of particular kinds of micro-organism can be demonstrated. In exceedingly pure water, such as that derived from deep wells, very few bacteria are found, and by efficient filtration the number present in river and upland surface waters can be materially reduced. Koch has suggested a limit of 100 bacteria per c.c. as one which should not be exceeded if the filtration of such waters is to be regarded as being satisfactorily effected. Impure waters may contain from 10,000 to 100,000 bacteria per c.c. and upwards. The determination of the number of bacteria present in a c.c. of water is at best a very rough test; the question which is really important is, not how many micro-organisms are present, but whether forms capable of producing disease are contained in the water. The method of counting the organisms is of value, however, as a means of gauging the efficiency of filtration.

If it be desired to test for the presence of *Bacillus coli communis*, or *Bacillus typhosus*, a litre or more of the sample water should be passed through a sterilised Chamberland or Berkefeld filter; the micro-organisms are thus intercepted and may be brushed off the filter with a sterilised brush into a small quantity of the sterile filtrate. One c.c. of the mixture is then cultivated in carbolised gelatine or broth; carbolic acid, when present to the extent of ·05 per cent. or thereabouts being, as was shown by Parietti, capable of inhibiting the growth of most organisms likely to be present in water, while it does not hinder to a like extent the development of the typhoid bacillus. In such a medium, however, the *Bacillus coli communis* flourishes, and some other organisms occasionally manifest growth in spite of the presence of the phenol. Plate cultures are prepared with material derived from the carbolised media, and the appearance of colonies resembling *Bacillus coli communis*, or *Bacillus typhosus*, is carefully watched for. To distinguish between the two organisms it is necessary to obtain pure cultures of the colonies which develop on the plates, and to test the growth manifested in these cultures in various ways. The main points of difference to which importance is attached will be referred to later (*See* p. 378).

In examining water for the presence of the cholera spirillum, alkaline broth, containing 1 per cent. of peptone and 1 per cent. of sodium chloride, is inoculated with the suspected material, and incubated at 37° C. In such a medium, as was pointed out by Dunham, the cholera spirillum readily multiplies. After twelve to twenty-four hours' incubation, agar plate cultures may be made, and any suspicious colonies developing in these may be grown in sub-culture, and tested by ascertaining whether they give the "cholera-red reaction," or by animal inoculation. The cholera-red reaction is obtained on adding pure sulphuric acid (free from nitrous acid) to a pure culture of the cholera bacillus in peptone salt broth. If the culture be not pure the appearance of the coloration is not decisive, as some organisms are able, under the conditions of the experiment, to form indol from peptone, and others to reduce nitrates to nitrites, and hence the reaction may be produced; the cholera organism is able to effect both these changes, and, so far as is known, it is the only organism likely to be found in water which does this.

Many experiments have been made of late years with the object of determining the viability of the cholera and typhoid organisms in water. P. Frankland and Marshall Ward found that typhoid bacilli did not, as a rule, multiply in sterilised potable water, but that they remained alive and capable of development for periods varying from about 20 to 50 days. In unsterilised potable water the bacilli did not generally live so long as when the same water was sterilised, though deep well water was found to be exceptional in this respect.

Klein, experimenting with some of the waters supplied in London, filtered the samples examined through a sterile Berkefeld filter, in order to remove, as far as possible, the contained bacteria. He then inoculated the filtrate obtained with typhoid bacilli, and was able to demonstrate that the living organisms were recoverable from two out of three samples even after the lapse of eight weeks. In the same waters, filtered and then completely sterilised by heat, the bacillus proved viable for 85 days after inoculation. From ordinary tap water, not subjected to treatment as above described, the typhoid bacillus was recovered after 36 days. Comparative observations made with the cholera vibrio, showed that this organism is considerably more hardy than the typhoid bacillus; it survived six weeks in all the samples of London water not subjected to special treatment, and for 85 days in filtered and sterilised water.

III.—Water Supply and Disease.

Intense thirst, muscular prostration, and loss of mental vigour, are produced in the entire absence of water for drinking purposes. These phenomena are of very rare occurrence in civilised communities, though they have been observed in this country within recent years, in cases, for example, in which men have been imprisoned in the earth as the result of mining accidents. The "water famines" of dry seasons, in English towns insufficiently supplied with water, sometimes cause, however, great inconvenience, and, apart from this, they may prejudicially influence health conditions by favouring accumulation of filth and interfering with the adequate cleansing of sewers. Lack of water implies, too, economy in its use for purposes of ablution, and in instances in which such economy has been strictly exercised, as, for example, where many persons have used the same bath, the spread of skin disease and ophthalmia appears to have been favoured. The diminution of typhus in recent years has been attributed in part to the larger share of attention devoted by civilised communities to personal cleanliness and the washing of clothes.

Attention has been directed for a long period of time to the occasional ill effects of drinking grossly polluted water. Such phenomena were naturally attributed, when they were first recognised, to the most obvious forms of contaminating material. The phrase "putrid water, every drop a worm," illustrates this point of view, and in days gone by the standard applied to drinking water was undoubtedly a far lower one than it is at the present day. It is only, however, within quite recent years that precise study has been made of the relation between disease and water supply, and attention has been specially directed to this matter in connection with two maladies which have been found to be commonly water-borne among civilised communities. . . . .

In 1849 Dr. John Snow formed the opinion, as the result of inquiry which he made concerning outbreaks of cholera in London, that the disease was capable of being transmitted by water to which evacuations from cholera patients had obtained access. In 1854 an outbreak of cholera occurred in St. James, Westminster, which was traced to the use of water obtained from the famous Broad Street pump. This outbreak served to confirm the conclusions arrived at by Snow, and from that time onwards numerous other instances of the spread of cholera by water have been forthcoming. The facts demonstrated, in connection with cholera, no doubt stimulated inquiry with regard to the possibility of other forms of disease being transmitted by drinking water, and the belief that enteric fever may be so conveyed was entertained, by Dr. William Budd and others, very soon after the distinction between that malady and typhus was finally established by Jenner in 1849–51. Suspicion was raised, moreover, by the extent to which enteric fever had prevailed in Millbank Prison, an institution which, up to the year 1854, derived its water supply from the grossly polluted Thames. On a purer supply being procured, a remarkable diminution in the prevalence of the malady among the prisoners was observed. From 1867 onwards numerous outbreaks of water-borne enteric fever have been reported on by inspectors of the Privy Council and Local Government Board and by medical officers of health in this country, and similar outbreaks have been observed abroad. Cholera and enteric fever stand out pre-eminently as water-borne diseases, and it will be well to refer to them in some detail.

Cholera.—There have been four great cholera epidemics in England, and in each of them London has suffered severely. The first epidemic was that of 1831–32. Comparatively little is known concerning this outbreak, and the statistical records relating to it are far less complete than in the case of later epidemics, inasmuch as, prior to 1837, there was no registration system in operation. From particulars collected by the Board of Health, it appears that 52,547 persons died of the disease in the United Kingdom during this, its first visitation. In "London and its vicinity" 5,275 deaths were returned between February 14th and December 18th, 1832. If this figure be accepted as representing the mortality during this outbreak, in London, the following statement showing deaths occurring in the metropolis in the four epidemics may be given :—

	Deaths.	Annual Mortality per million living.
1832	5,275	3,702
1849	14,125	6,196
1854	10,738	4,289
1866	5,596	1,840

In the first three epidemics the brunt of attack was borne by certain South London populations.* In the fourth epidemic East London mainly suffered. Writing in 1856 (*i.e.*, before the time of the 1866 outbreak), Simon said: "As often as Asiatic cholera had been epidemic in London it had been observed to prevail with especial severity in certain registration districts on the south side of the river."

It was, moreover, noted † in connection with the second epidemic (that of 1849), "that the mortality from cholera increases generally in descending the river on the south side." Again, on making inquiry concerning the water supplied to different populations, it was ascertained that whereas only 15 deaths, per 10,000 persons living, occurred in six districts supplied with water taken from the Thames above Battersea, 123 deaths, per 10,000 living, occurred in the twelve districts supplied with water taken from the Thames between Battersea and Waterloo bridges.

The intakes of the five water companies drawing their supplies from the Thames were, in 1850, all situated within the tidal portion of the river: that of the Grand Junction Waterworks at Kew, six miles below Teddington Lock, was located farthest up stream; that of the West Middlesex was at Barnes, eight and a half miles below Teddington Lock; those of the Chelsea, and Southwark and Vauxhall, Companies were at Battersea; and that of the Lambeth Company was at Lambeth, near Hungerford Bridge. Moreover, at this time, prior to the introduction of the system of "interception," the greater part of the sewage of 2,360,000 persons was being discharged directly into the river within the metropolis. The extent of precaution which it was deemed necessary to take at this period may be judged by the fact that, in 1850, the culvert through which the Southwark and Vauxhall Company obtained its supply "was extended further into the bed of the stream, in order that the water should only be taken in during such portion of the ebb tide as permitted the reflux of the London drainage past the site of the Company's works."

In 1847 it became evident to the Lambeth Company "that water for domestic purposes could not longer continue to be taken from that part (*i.e.*, the tidal part) of the river." A scheme was, therefore, pre-

* In the epidemic of 1831–32 this was less markedly the case than in the two later epidemics. Thus while in the first epidemic, judging by the returns available, St. Saviour and St. Olave, Southwark, were the registration districts most severely attacked, Whitechapel was the district which came next in order. The mortality rate in St. James, Westminster, in the 1854 epidemic was high, this fact being due to dissemination of disease by means of the water of the Broad Street pump.

† Registrar-General's Report on Cholera in England, 1848–49, p. lix.

pared for transferring the intake works to Thames Ditton, above Teddington Lock, and the new supply was introduced in January, 1851. The Metropolis Water Act of 1852 imposed the obligation of abandoning the tidal portion of the river upon all the companies, but in 1854 the rearrangements necessary had not been completed, and when the third outbreak of cholera occurred in London, it found the districts in which its ravages during the second outbreak (that of 1849) had been most severely felt exceptionally circumstanced. While in 1849 water drawn from the Thames at or below Battersea was being generally consumed, in 1854 the Lambeth Company was providing the far purer supply obtained from Ditton, while the Southwark and Vauxhall Company was still purveying what had been described as "perhaps the filthiest stuff ever drunk by a civilised community." Under these circumstances materials for comparison on a large scale were to hand, for throughout the southern districts of London, as Simon pointed out, "masses of similar population were dwelling side by side, and the exterior influences which affected them were, with a single exception, apparently identical." Rival mains were "branching within the same area, often running parallel in the same streets"; there were, in fact, two "interfused populations," one drinking from the Thames at Ditton, the other from the Thames at Battersea. The inquiry which was instituted showed that "The population drinking dirty water suffered 3½ times as much mortality as the population drinking other water." Moreover, Simon estimated that while the population drinking dirty water suffered probably 10 per cent. higher mortality in the later epidemic than in the earlier one, the population which obtained its water in the later epidemic from Ditton suffered "not a third as much as at the time of its unreformed water supply." He therefore concluded: "By this experiment it is rendered in the highest degree probable that of the 3,476 tenants of the Southwark and Vauxhall Company who died of cholera in 1853–54, two-thirds would have escaped if their water supply had been like their neighbours'; and that of the much larger number—tenants of both companies—who died in 1848–49, also two-thirds would have escaped if the Metropolis Water Act of 1852 had but been enacted a few years earlier."

A great improvement was effected in the London water supply between 1850 and 1856. In compliance with the Act of 1852, the tidal portion of the Thames was abandoned as a source of supply; moreover, attention was now particularly directed to the question of filtration. At the time of the fourth outbreak of epidemic cholera (1866) the London water companies were understood to be providing water which was "efficiently" filtered, in accordance with the requirements of the Act of 1852. It was found that (excluding the districts supplied by the East London Company), there was a marked falling off in cholera mortality in this fourth outbreak. East London, on the other hand, suffered severely; and inquiry showed that in the case of the company supplying this district there had been distinct infringement of the provisions of the Act, inasmuch as the unfiltered water of certain uncovered reservoirs had been supplied to water consumers. Farr says (Supplement to the Twenty-ninth Annual Report of the Registrar-General): "It is enough to have in evidence, that immediately before the outbreak in July the foul water of the reservoirs was pumped over the parts of East London where cholera was epidemic." Netten Radcliffe writes in his report, which appeared in the Ninth Annual Report of the Medical Officer to the Privy Council: "The sudden and virtually contemporaneous development of the outbreak over the entire area of prevalence indicated a medium of propagation common to, and capable of, rapid diffusion over the whole area; its sudden declension indicated the temporary efficiency to this end of such medium. The area of prevalence approximated with remarkable closeness to a particular field of water supply, and there are facts which seem to prove that this approximation was not accidental. It is known that, immediately prior to the outbreak in the East district of the metropolis and neighbouring districts across the Lea, impure water was distributed over this field of supply, and it is highly probable that this water was charged with choleraic poison."

Since 1866 there has been no extensive epidemic prevalence of Asiatic cholera in London, and there is no evidence indicating that the disease has been communicated since that year by the water supplied by any London water company. The part played by water in disseminating cholera has, however, been studied in connection with manifestations of the disease occurring elsewhere.

Reference may be made to two outbreaks in particular—those which affected Hamburg in 1892 and Altona in 1893—inasmuch as much interest attaches to them in regard to the question as to the extent to which filtration can be relied upon as a safeguard against the danger inherent to the use of water from a polluted river. In 1892 Hamburg, supplied with unfiltered water from the Elbe, at a point where that river was relatively but little contaminated, suffered severely; while Altona, with water originally much more polluted than that of Hamburg, but subsequently purified by filtration, escaped. Later, in January and February of 1893, a number of cases of cholera developed in Altona, and the water supplied to the town fell under suspicion, inasmuch as inquiry showed that some kind of disturbance had occurred in the process of filtration. The number of germs found in the filtered water manifested increase from the 30th December, 1892, attained a maximum (1,516 per c.c.) on January 12th, then decreased again for a short time, but rose again in the last week of January. Examinations made in February showed that a particular filter was then mainly at fault, and some experiments which were instituted led to the conclusion that the defect in the process of filtration was due to freezing of the surface layers of sand during the process of cleansing the filter.

A comparatively small outbreak of cholera occurred in Hamburg in September, 1893, and in that year, as indeed had also been the case in 1892, a prevalence of enteric fever was manifested, which reached its height about three weeks later than that of cholera. There was thus reason for supposing (having regard to the length of the incubation period in the two diseases) that the infection of both was communicated at about the same time. At the precise date when the mischief must have been done, bacteriological examination of the water supplied in Hamburg was yielding such unsatisfactory results as to lead to the conclusion that local pollution of the main conveying filtered water must exist. Inquiry showed that a settlement, which had taken place in some masonry, permitted raw Elbe water to obtain access to the filtered water conduit. Steps were promptly taken to remedy this defect, and a marked reduction in the number of organisms in the water was immediately manifested. The source of pollution having been cut off, the outbreak soon came to an end.

Another water outbreak which is deserving of mention is that which occurred at Stettin. The town was supplied with filtered water obtained from the river Oder. Filtration was, however, performed with undue rapidity, inasmuch as the filtering area was inadequate to meet the demands made upon it. Bacteriological examination had from time to time given unsatisfactory results, but, shortly after the commencement of the outbreak, the presence of the cholera vibrio was actually demonstrated in water from the reservoirs of the filters supplying the town.

Enteric Fever.—Knowledge concerning the spread of this disease by means of polluted water is based upon the experience of an even more limited number of years than in the case of cholera.

In 1867 Buchanan reported on an outbreak at Guildford, in which some 500 persons were attacked. He showed that this outbreak was due to contamination of the high-level section of the water-supply of the town, by a leaky sewer running within 10 ft. of a deep well sunk in the chalk, from which that supply was derived. In the same year Thorne investigated an outbreak at Terling, in Essex, which he attributed to contamination of the shallow wells from which the villagers obtained their water. The same observer investigated an extensive outbreak at Lewes in 1875; the enteric fever was found to be practically confined to drinkers of the town supply, which was intermittent, and it appeared that, in connection with intermission of the supply, opportunity had been afforded for the insuction of sewage into the mains of the company.

Two other outbreaks which illustrate the risk attendant, under certain conditions, on the intermittent method of supply may be mentioned. In 1874 Blaxall reported on enteric fever at Sherborne, confined to a small group of houses obtaining water from a particular source. The water supply to these houses had on several occasions been shut off. In some instances the water was directly laid on to the closet-pans by pipes with taps, and a few of these taps were broken. As Blaxall said: "If a pan happened to be full of excrement, that excrement would be sucked into the water-pipe." Again an outbreak of enteric fever occurred at about the same time among residents in a particular court at Caius College, Cambridge. Buchanan found that the water-closets in this court were supplied directly from the main, without disconnecting cisterns; opportunity for pollution of the water in the supply pipe was, moreover, afforded by a "weeping pipe," which established communication between the supply pipe and a trap connected with the drain. The end of one of the "weeping pipes" was stained with matter of fæcal origin. About a fortnight before the enteric fever occurred the water supply to the court had been cut off, and probably, in connection with this intermission of supply, specifically tainted material had obtained access to the mains, and had been subsequently distributed to the residents in the court.

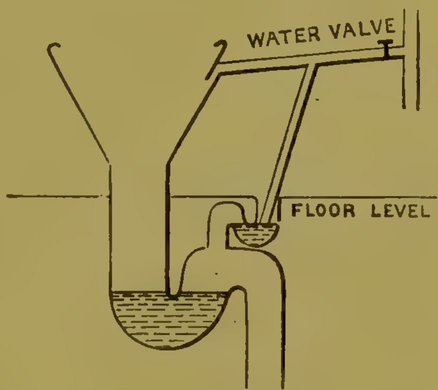

FIG. 29.
Defective arrangement for supply of water to water closet; absence of disconnecting cistern; a "weeping pipe" discharging over a "trapping bend" in the safe-waste.

In 1879 an outbreak of enteric fever at Redhill and Caterham, in which some 370 cases occurred, was investigated by Thorne, who discovered that a workman, who had been engaged in excavating an adit between two of the deep wells of the Caterham Company, had suffered from enteric fever, and had been attacked by diarrhœa on more than one occasion while working in the well.

The small amount of polluting material in this case, in comparison with the huge volume (nearly 2,000,000 gallons) of water infected, was the subject of much comment at the time. Buchanan, in 1881, estimated that not so much as one grain of excremental matter per gallon could have been present. Experiments made by Cory and Dupré showed, as indeed might have been anticipated, that it was possible to contaminate pure water with minute quantities of excreta, and yet not exceed amounts of organic impurity which would pass muster on a mere chemical analysis. Buchanan, in reviewing the matter, remarked: "The chemist can in brief tell us of impurity and hazard, but not of purity and safety."

In 1888 an outbreak at Mountain Ash was found to be caused by pollution of a particular water-main which was defective; the supply of water was intermittent, and the main became contaminated by reason of the fact that it was leaky.

In some outbreaks of enteric fever it has been found possible, by addition of mineral salts at the site of pollution, and their subsequent detection in the water, to demonstrate the possibility of communication, between a source of contamination and the water suspected of conveying disease. Thus at Lausen, in Switzerland, in 1872, a spring on one side of a hill, on the other side of which ran a contaminated brook, fell under suspicion; it was found that when the meadows in the valley, through which the brook ran, were watered, by damming up the water course, the yield of water from the spring increased. Salt was then placed in the brook, and it was ascertained that the water in the spring showed evidence of containing excess of sodium chloride. In a similar manner it was shown by Page, in 1889, that there was possibility of filth having travelled a distance of three-quarters of a mile, through a fissure in magnesian limestone, at Houghton-le-spring. An epidemic of enteric fever, which was traced to the public water supply in this place, probably originated as a result of pollution in the manner indicated.

In many of the earlier outbreaks wells had been found to be at fault, and it was thought the comparative freedom from movement of the water in the well, and the fact that it was kept in the dark, might have favoured the multiplication of disease germs. Within comparatively recent years, however, instances of communication of enteric fever by river water have attracted a considerable share of attention.

In an outbreak at Bangor, in 1882, Barry showed that the water supply derived from a small stream had caused the mischief; this water was nominally filtered, but the operation was only imperfectly carried out, and the water consumed was practically unfiltered water. An outbreak occurred at about the same date at Hitchin, and in this instance it was found, by Power, that a waste pipe occasionally admitted water from the river Hiz into the water-supply tank; the said river, which, however, is "hardly more than a ditch," was grossly polluted with sewage. Other outbreaks, in which river water was suspected to have spread the disease, were those at Gainsborough, Newark, and King's Lynn reported on by Bruce Low, and that at Farncombe, which was attributed by Jacob to water obtained from the Wey.

Two prevalences of enteric fever which occurred at the end of 1890 and the beginning of 1891 in certain areas near the mouth of the Tees, and which were investigated in great detail by Barry, constitute, however, the most striking and important of the instances in which dissemination of enteric fever on a large scale has been shown to be due to river water. Two outbursts of fever, as has been said, occurred; the first was especially marked during the six weeks ending October 18th, 1890; the second during the six weeks ending February 7th, 1891. In the two outbreaks 1,463 individuals were found to have been attacked. Within the area of the fever prevalence some 219,000 persons were obtaining water from the river Tees, while some 284,000 were deriving their supply from other sources. The attack rates per 10,000 persons during the first outburst were ascertained to be thirty-three, in the case of the persons drinking Tees water, and three in that of the persons drinking other water. During the second outburst, the attack rates were twenty-eight per 10,000 among persons drinking Tees water, and only one per 10,000 among persons drinking other water.

The Tees was found to be considerably polluted above the intakes of the companies obtaining their water from it, and in particular it was contaminated by receiving the drainage of the town of Barnard Castle. Shortly before each outburst and at a time which, taking into account the incubation period of the disease, would correspond with the time of infection, the river was in flood. Filtration was practised by the water companies distributing the infected water, but in the case of one of them the particulars given show that Koch's standard, so far as rate of filtration was concerned, was not complied with. Sir Richard Thorne in commenting upon Dr. Barry's report, observed: "Seldom, if ever, has the proof of the

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relation of the use of water so befouled to wholesale occurrence of enteric fever been more obvious or patent."

Among outbursts of enteric fever due to water supply in more recent years the following may be mentioned. In 1893 a large outbreak of enteric fever occurred in the neighbourhood of Worthing, in which upwards of 1,400 attacks were developed. The prevalence, in Worthing itself, was traced to sewage contamination of a heading made in a deep chalk well; an after prevalence, in adjoining districts, appeared to be due to pollution of water mains by entrance of filth through ball hydrants. A considerable outbreak (upwards of 500 cases) occurred at Newport in 1894, and this also was due to implication of a chalk well. At Maidstone in 1897 an outbreak, affecting upwards of 1,800 persons, occurred as result of contamination of the Farleigh springs of the Maidstone Water Company. Ernest Hart in 1897 prepared a summary of the facts relating to 206 outbreaks of "water-borne typhoid" which had been reported on in Great Britain and Ireland during the thirty-one years, 1863–1893.

Other Diseases.—In addition to the two diseases which have been already referred to, the relationship of which to the consumption of specifically contaminated water, has been repeatedly demonstrated, there are other maladies which may, with more or less certainty, be ascribed to a like cause. *Dyspepsia* and *diarrhœa* may undoubtedly be produced by drinking water in which there are impurities of certain kinds. Hard waters, particularly those containing calcium or magnesium (in the form of sulphates or chlorides) may give rise to digestive disturbance, and waters which contain iron occasionally cause dyspepsia, headache, and constipation. Again the fine particles of mineral matter sometimes suspended in water may mechanically exercise an irritant effect upon the alimentary mucous membrane, and so set up diarrhœa. If much organic matter, animal or vegetable, be present, a similar effect may be produced, and outbreaks of diarrhœa have been ascribed to water which has been exposed to contamination by sewer gas. There are many medicinal waters possessed of marked aperient action, particularly those which contain sulphur, and sulphate of magnesia or other mineral salts, and it is not surprising, therefore, that water which contains such materials in only small quantity, and which is not perhaps credited with the possession of any special aperient properties, should be occasionally associated with the production of diarrhœa. Waters rich in calcium and potassium nitrates have been found to produce similar effects, and the water from wells, sunk near graveyards, has been supposed to exert a like influence. In instances such as those last-named, excess of organic matter, or of nitrites and nitrates, may possibly be the cause of the symptoms produced.

The subject of *lead poisoning* has already been considered; water which contains other kinds of metallic impurity, as a result of the admission of trade refuse into streams, or owing to the action of the water on the pipes by which it is distributed, is likely of course to produce digestive disturbance or other forms of illness associated with the ingestion of the particular metallic poisons in question.

Dysentery has been traced, in numerous instances, to the consumption of polluted water; possibly the exciting cause of the malady, in some cases, has been the introduction of material derived from the evacuations of dysenteric patients. It has been supposed that *yellow fever* is occasionally produced in a similar way. *Malarial fever* is popularly supposed, in many localities, to be caused by the consumption of contaminated drinking water. The evidence is conflicting, and Manson concludes that it cannot be said that the possibility of infection being thus conveyed has been either proved or disproved.

Goitre is another disease which has been attributed to drinking water, and evidence has been adduced which shows that goitre often prevails among populations consuming water derived from certain limestone formations, and particularly from dolomitic rocks. On the other hand, in some localities provided with supplies derived from formations of the character specified, goitre does not occur. The question as to the precise relationship between goitre and drinking water still remains unsettled. *Rickets* has been supposed to prevail especially among populations drinking soft water, and the development of *urinary calculi* has been ascribed to the habitual use of hard waters. Neither of these theories has been found to bear the test of careful examination. *Diphtheria* is a disease which has been from time to time suspected to be water-borne, but here again the supposed relationship has never been conclusively demonstrated.

Some forms of parasitic disease are undoubtedly transmitted by drinking water. *Tænia solium* and *Tænia mediocanellata* are probably usually introduced with food. The embryos of *Bothriocephalus latus*, however, have been found in river water in certain countries bordering on the Baltic, and it appears likely that the parasite is not infrequently transmitted by the consumption of such water. *Tænia echinococcus*, the round worm (*Ascaris lumbricoides*), and the thread worm (*Oxyuris vermicularis*) are probably occasionally distributed by the same medium. Certain filariæ may in like manner obtain access to the body. The *Filaria sanguinis hominis* is deposited in water by the mosquito which has sucked it from the blood of infected persons, and it may be that it is transmitted to human beings who drink water so contaminated. The embryo of the *Filaria dracunculus* (the guinea worm) may be introduced by drinking polluted water, though it is also stated that the adult worm is the source of infection, and that it penetrates the skin of persons who bathe in streams which harbour it. *Dochmius duodenalis* is probably transmitted by means of water containing the ova or embryos; and *Bilharzia hæmatobia*, which causes the endemic hæmaturia of Egypt, and some other parts of Africa, is supposed to be introduced by drinking water containing the embryos of this parasite. The liver fluke of sheep (*Distoma hepaticum*), which in rare instances affects man, is transmitted apparently by water, inasmuch as its embryos have been found attached to water plants.

CHAPTER IV.

SOIL.

The surface soil and subsoil of a locality are formed, as a rule, by disintegration of the underlying rock. The surface soil, or mould, contains considerable quantities of organic matter, derived either from decaying vegetation, or from material of animal origin. The operations of earth worms in disintegrating the soil, and in bringing portions of it to the surface in their castings, exercise important influence on the constitution of mould. Burrowing animals, too, alter the character of the surface soil, and the superficial layers of earth abound with micro-organisms. Beneath the surface soil lies what is called the subsoil, in which there is comparatively little organic matter, and in which the disintegration of the underlying rock has not proceeded to so marked an extent as in the surface soil.

Origin of Soils.—The rocks of the earth's surface, the breaking up of which results in the production of soil, are classified as igneous, sedimentary, and metamorphic. The *igneous* rocks are derived from the cooling down of the molten matter of the once fluid globe; they consist for the most part of quartz, felspar, hornblende, and mica. Their chief chemical constituent is silica—those which possess more than 60 per cent. of silica are called "acidic rocks," and those with less than this amount, "basic rocks." The former are decomposed by "weathering" into clayey soils, while the latter, possessing as they generally do appreciable amounts of earthy bases, iron or manganese, yield marls* and coloured clays.

The *sedimentary* rocks are formed by the deposition of fine particles from water or air, or are the result of the growth of plants or animals. They present evidence, as a rule, of having been

* The term marl is usually applied to a clay containing 5—20 per cent. of calcium carbonate; if the amount of calcium carbonate exceed 20 per cent., the soil is described as calcareous. Soils containing 10—40 per cent. of clay may be described as "sandy loams"; if the amount of clay exceed this, as "loams"; if it exceed 70 per cent. as "clay loams"; and those with nearly 90 per cent. of clay are spoken of as "clay soils."

precipitated at the bottom of lakes and seas in the form of distinct layers, and they are hence sometimes called stratified rocks. According to the character of the materials which compose them they are termed sandstones, claystones or argillaceous rocks, limestones or calcareous rocks, and organic rocks. The formations last named include the chalk, which consists mainly of the remains of foraminifera; and coal, peat, etc., which are derived from plants.

Rocks which have become greatly altered *in situ* by pressure are termed *metamorphic* rocks. Such are gneiss, which is really altered granite, and schists, slates, marbles, and quartzites.

The weathering of rocks is effected by the action of air and by that of water with the dissolved gases contained in it, this action being greatly promoted by the splitting of the rock, which occurs when water freezes. Flowing water tends to wear away the surface of rocks, and iceborne boulders have a similar effect; the material carried away by water when deposited elsewhere, is termed alluvium, while what is called "glacial drift" consists of the *débris* carried away by the action of ice.

Order of Superposition of Rocks.—The order of superposition of the stratified rocks is determined by the character of the organic remains which they contain. As Geikie says: "Living species of plants and animals can be traced downward into the more recent geological formations; but grow fewer in number as they are followed into more ancient deposits. With their disappearance we encounter species and genera which are no longer living. These in turn may be traced backward into earlier formations till they too cease, and their places are taken by yet older forms." To some extent the depth of strata, he notes, affords indication of the length of time which has elapsed during the process of their formation, but while great thickness of rock undoubtedly corresponds to vast periods of time, "it cannot safely be affirmed that a much less thickness, elsewhere, represents a correspondingly diminished period."

The nomenclature of the stratified rocks is, as Geikie says, a patchwork. Some of the earliest names are lithological—chalk, oolite, greensand, and millstone grit; others are topographical—Jurassic (Jura), Permian (Perm in Russia), Neocomian (Neufchatel), etc.; others are taken from local English names—lias, gault, crag, etc.; others are based upon numerical considerations—Dyas and Trias. Those of the divisions, Palæozoic, Mesozoic, and Cainozoic (primary, secondary, and tertiary, as they are sometimes called), signify ancient life, middle life, and recent life. The

Table of Stratified Rocks.

Periods.		Systems.	Formations.	Life-Periods.	
Cainozoic.	Quaternary.	**Recent.**	Terrestrial, Alluvial, Estuarine, and Marine Beds of Historic, Iron, Bronze, and Neolithic Ages. Peat, Alluvium, Loess.		Dominant type, Man.
		Pleistocene (250 ft.).	Valley Gravels, Brick-earths. Cave Deposits. Raised Beaches. Palæolithic Age. Boulder-clay and Gravels.		
	Tertiary.	**Pliocene** (100 ft.).	Norfolk Forest-bed Series. Norwich and Red Crags. Coralline Crag (Diestian).		Dominant types, Birds and Mammals.
		Miocene (125 ft.).	Œningen Beds Fresh-water, etc.		
		Eocene (2,600 ft.).	Fluvio-marine Series (Oligocene). Bagshot Beds / London Tertiaries (Nummulitic Beds).		
Secondary or Mesozoic.		**Cretaceous** (7,000 ft.).	Maestricht Beds. Chalk. Upper Greensand. Gault.		Dominant type, Reptilia.
		Neocomian.	Lower Greensand. Wealden.		
		Jurassic (3,000 ft.).	Purbeck Beds. Portland Beds. Kimmeridge Clays (Solenhofen Beds). Corallian Beds. Oxford Clay. Great Oolite Series. Inferior Oolite Series. Lias.	Range of Birds in time	
		Triassic (3,000 ft.).	Rhaetic Beds. Keuper. Muschelkalk. Bunter.	Range of Mammalia in time	
Primary or Palæozoic.		**Permian or Dyas** (500 to 3,000 ft.).	Red Sandstone, Marl / Magnesian Limestone, etc. (Zechstein). Red Sandstone and Conglomerate. Rothliegende.		Dominant type, Fishes.
		Carboniferous (12,000 ft.).	Coal-measures and Millstone Grit. Carboniferous Limestone Series.		
		Devonian and Old Red Sandstone (5,000 to 10,000 ft.)	Upper Old Red Sandstone. Devonian. Lower Old Red Sandstone.	Range of Amphibia and Reptilia in time	
		Silurian (3,000 to 5,000 ft.).	Ludlow Series. Wenlock Series. Llandovery Series. May Hill Series.	Range of Fishes in time	
		Ordovician (5,000 to 8,000 ft.).	Bala and Caradoc Series. Llandeilo Series. Llanvirn Series. Arenig and Skiddaw Series.		Dominant type, Invertebrata.
		Cambrian (20,000 to 30,000 ft.).	Tremadoc Slates. Lingula Flags. Menevian Series. Harlech and Longmynd Series.	Range of Invertebrata and Plants in time	
		Eozoic. Archæan (30,000 ft.).	Pebidian, Arvonian, and Dimetian. Huronian and Laurentian.		

Greek word καινός (new, recent) also appears in the terms eocene, etc.—eocene being derived from ἠώς (dawn), and καινός (recent), and miocene, pliocene, and pleistocene from the same word in combination with μείων (less), πλείων (more), and πλεῖστος (most).

The table of stratified rocks, prepared in the geological department of the British Museum (*See* p. 151), shows the approximate depth in feet of the several systems, and indicates the range in geological time of the various forms of life.

The formations which lie superficially have been shown in distinctive colouring and lettering upon the inch sheets, and, in the case of some parts of the country, upon the six-inch sheets of the geological survey of Great Britain. In these maps faults are indicated by white lines, lodes by gold lines, the dip of strata is shown by arrows, and so on. Descriptive memoirs have been prepared to accompany many of the sheets, and certain general memoirs have also been published. A "Guide to the Geology of London and the Neighbourhood" originally planned in illustration of the Geological Model of London in the Museum at Jermyn Street, and a pamphlet on "Soils and Subsoils" appear in this series.

Soil Features in Relation to Health.—Districts in which the igneous rocks lie at the surface are usually hilly, the rainfall may be excessive, but the water for the most part runs away over the surface and does not percolate. In localities where the clay slates prevail, water is often scarce. The mill-stone grit, belonging to the carboniferous formation, is hard and impermeable, and water readily runs away over it. In limestone districts the country is as a rule undulating, and the water is hard; in the case of magnesian limestone question has been raised as to possible influence of the soil in favouring the prevalence of goitre. Sandstones and the chalk formation are permeable, and as a rule healthy.

The "London basin" is formed by deposits of chalk some 600 feet in thickness. These overlie the upper greensand, gault clay, and lower greensand, beneath which, to the south of London, outcrop the Weald clay and the Hastings beds. In the hollow of the basin, superimposed upon the chalk, are the lower London tertiaries, and these are overlaid by the London clay, while this again in places is covered by beds of the Bagshot series, and elsewhere by patches of glacial drift, river gravel, brick earth, or alluvium. The lower London tertiaries are of varying character, the lowest of the series, the Thanet beds, are for the most part sandy and dry, but the area of their exposure is of limited extent; the Woolwich and Reading beds contain sands, gravels, and clays, and localities where they outcrop tend to show signs of dampness; the Blackheath beds are of gravel, and places where they are exposed form excellent building sites. The London clay is, generally speaking, damp, and in very dry weather the soil cracks and fissures. If the surface be undulating, so that water can drain away readily, the disadvantages of London clay are minimised, and Symons held that "a house on a clay soil is not necessarily more open to objection than one on gravel." If the locality, however, be one in which London clay lies superficially in an area well nigh flat, or situated in a valley, so that water drains towards and not away from it, it is sure to be more or less damp.

High-lying river gravels and sands form as a rule excellent sites for habitations, and the Bagshot beds also possess this character. The valley gravels constitute for the most part the areas upon which Old London, and the villages surrounding it which are now absorbed in London, were built. In some instances, where these areas are low-lying, the level of the subsoil water is high, and the basements of houses are apt to show signs of dampness. The brick earth is practically impervious, and holds up water, but, other things being equal, to a less extent than clay. In many localities it has been excavated for brick-making, and the material removed has been replaced by house refuse or other rubbish. In many places, too, gravel has been excavated, and the pits formed have been filled in, sometimes with material containing decomposing organic matter Alluvium, being low-lying, is generally damp and liable to flooding, there is usually difficulty in providing systems of sewerage for alluvial tracts, inasmuch as their low level is apt to entail inadequacy of fall in the sewers. Some alluvial tracts have been artificially raised and houses have been built upon the made-ground, in other instances alluvial land has been utilised for the construction of docks.

In parts of Old London the "made-ground" is of some thickness, having accumulated to the extent of six inches or more in a hundred years. The Bank of England rests on about twenty-two feet of made-ground. If such ground be of ancient origin, or if good material has been employed for artificially raising its level, there can be no objection to its use for building purposes; but in instances in which refuse has been tipped with a view to filling up excavations, or raising levels, the inhabitants are eminently liable to exposure to emanations from the impure soil. In recent years practices of the kind referred to, have been to some extent controlled, by-laws being in force in some localities, which require the removal of refuse material before ground can be used for building purposes; again, when the soil upon which a house is built is not natural virgin soil, it is usual to insist upon the surface being covered with concrete to a specified thickness.

Ground Air.—All soils contain air, and only the very densest rocks are free from it; loose sands may yield 50 per cent. of air. Pettenkofer showed that there was a much larger amount of carbonic acid in ground air than exists in the atmosphere, the quantity becoming greater at increasing depths, and being subject to annual and seasonal variations. Rainfall has especially marked effect upon the amount of carbonic acid in ground air; an increase occurs after rain, the carbonic acid being locked up in the deeper parts of the soil, the amount subsequently diminishes, owing to absorption of the gas by the water in the soil. The oxygen in ground air diminishes at increasing depths. The quantity of nitrogen is fairly constant, being about the same as that in the atmosphere. The amount of air in a piece of rock may be estimated by weighing the rock in the ordinary way, then weighing it in water, and again weighing it after removal from the water, when it is saturated with moisture. The percentage of air

$$= \frac{\left\{\begin{array}{c}\text{the weight of the rock when}\\ \text{saturated with moisture}\end{array}\right\} - \left\{\begin{array}{c}\text{its original weight}\\ \text{in air}\end{array}\right\}}{\text{its weight in air} - \text{its weight in water}} \times 100$$

In the case of a loose soil, the dried and powdered material is placed in a burette, and water is allowed to rise through the soil until it just appears at the surface; then the percentage of air

$$= \frac{\text{the amount of water used}}{\text{the number of c.c. of dry soil}} \times 100$$

Ground Water.—If air and water exist together in a soil, the soil is said to be moist; when the point is reached, at which the interstices of the soil are entirely filled with water, the ground water level has been arrived at. This level of the ground, or subsoil, water may vary from only a few feet to many hundreds of feet from the surface. The ground water is in constant movement, ever flowing towards the nearest stream or towards the sea. Its level is liable to fluctuation, particularly in connection with rainfall. Pettenkofer first called attention to the importance of measuring the variations in level of the ground water; the necessary data may be ascertained by noting the levels of wells, and Pettenkofer and others were led to the conclusion that variations in the level of the subsoil water have important influence in favouring the spread of certain diseases, particularly cholera and enteric fever.

Soil Temperature.—Different soils possess very varying capacities for absorbing and giving off heat, but all soils are more readily warmed than water is. Sand is heated more rapidly than clay, and the damp clays which warm slowly are commonly designated cold soils. The ability of soils to radiate heat depends on their colour, and upon the extent to which they are covered by vegetation. As a rule soils cool more quickly than they become heated. The temperature of the deeper layers of the soil does not respond to fluctuations in atmospheric temperature so speedily as the temperature of the surface soil; thus, it may be some days after the summer maximum of temperature is attained, before the temperature at 1 ft. below the surface reaches its maximum, and at a depth of 3 ft. the maximum will be still longer delayed.

Födor, at Buda Pesth, found the average maximum temperature, at ½ to 1 metre, was reached in August; at a depth of 2 metres, not until September; and at a depth of 4 metres it was not observed until October. The influence of daily changes of temperature is not appreciable in this country at depths exceeding about 4 ft., while at 40 ft. annual variations of temperature cease to produce any effect. Below this depth the temperature of the soil increases about 1° F. for every additional 50 ft. below the surface.

In estimating soil temperatures Lewis and Cunningham caused an excavation to be made to a depth of about 6 ft. A lining of brickwork and means of drainage were provided; two openings in the side of the brickwork, at 3 and 6 ft. below ground level, were made to communicate with wide tubes of perforated zinc running horizontally through the soil; into these tubes thermometers were inserted, the opening in the brickwork being closed with a cover and coated over with moist clay. Importance has been attached to variations in the temperature of the soil, at a depth of from 1 to 3 ft. from the surface, in connection with summer diarrhœa; this question will be referred to later.

Micro-organisms in Soil.—Samples of the soil, the contained micro-organisms of which it is proposed to examine, may be readily obtained from a depth some distance from the surface by the use of what is known as Fränkel's borer. This instrument is provided at its lower end with a movable shell, which can be opened when the point is reached at which it is desired to obtain a sample of earth, and closed again as the instrument is withdrawn; the sample can then be removed for bacteriological examination. Small portions of the earth are mixed as thoroughly as possible with sterilised liquefied gelatine, and distributed, on the walls of a tube containing gelatine, with a platinum needle. From this tube sub-cultures can be made. As many of the bacteria in soil are anaerobic, it is necessary to cultivate in the absence of oxygen, in order to give such organisms opportunity to develop. The number of germs is said to increase, as a rule, up to a depth of a foot or more, but below a few feet from the surface there ensues marked diminution, and beyond 12 or 15 feet the organisms are very few in number, if indeed they be found at all. Much attention has been devoted of late years to the influence of forms of bacterial life upon the process of nitrification which occurs in soils. Schlösing and Muntz first suggested in 1877–78 that nitrification was the result of the growth of micro-organisms.

Soil and Disease.

Among pathogenic bacteria the tetanus bacillus, the bacillus of malignant œdema, and the anthrax bacillus have been often demonstrated in soil. In the case of some other diseases, although the specific germ which causes the malady is either unknown or cannot be shown to exist under natural conditions in the soil, the relation between particular soil states and prevalence of the disease has yet been clearly made out. There are again certain other diseases which are suspected on more or less conclusive grounds to be associated with particular conditions of soil.

Tetanus.—Among diseases belonging to the class first referred to tetanus is a striking example. The organism which produces this disease is an anaerobic bacillus, and it has been repeatedly isolated from soil. The fact that wounds of exposed parts of the body are specially liable to be followed by tetanus, is a reason for supposing that the bacillus may obtain entrance to the body with particles of dirt introduced into such wounds. It is said that the practice of walking bare-foot predisposes to infection. Inasmuch as grooms, and others who are brought in contact with horses, especially suffer from the malady, it has been suggested that the disease is in some way associated with horses, and that horse-dung may be the medium of its transmission.

Malignant Œdema is a malady caused by a bacillus, resembling in some respects the anthrax bacillus, but differing from it in being anaerobic. The organism is widely distributed, and can generally be demonstrated in manured garden earth. It produces a fatal disease in mice, guinea-pigs, and rabbits, and sometimes affects man, usually occurring in connection with compound fractures, and producing a rapidly spreading œdema, with emphysema of the subcutaneous tissues.

Anthrax bacilli have been found in soil, to which the discharges or blood of infected animals has had access, or in which the carcases of such animals have been buried; moreover, cattle pastured upon infected areas have acquired the disease. Pasteur suggested that the anthrax spores were brought to the surface by the agency of earth-worms, but this theory has been questioned on the ground that sporulation only occurs in the presence of oxygen. The risk of spread of the malady can be controlled to a large extent by burying deeply the carcases of animals dying of anthrax, and, particularly, by taking care to prevent blood and discharges from polluting the soil. It is important, therefore, that the infected carcase should not be opened before burial, and that no attempt should be made to utilise the hide or any other part of the animal.

Lead Poisoning.—The subject of lead-poisoning by action, more particularly of peaty waters, upon leaden pipes has been already referred to. Acidity of the water has been found to have important influence upon lead dissolving capacity, and Houston's experiments have shown that certain micro-organisms, which can be isolated from peaty soils, are concerned in communicating to the water the acidity in question.

Among diseases of the second group cholera, enteric fever, epidemic diarrhœa, and phthisis must be mentioned.

Cholera.—This disease shows such a remarkable tendency to originate time after time in particular localities that the possibility of some important relationship existing between it and states of soil has been a frequent subject of investigation. Pettenkofer, of Munich, was led to the conclusion that for cholera prevalence a pervious soil, and one in which the level of the subsoil water undergoes considerable fluctuations, is an absolute necessity. He held that the specific germ must be present in the soil, but thought it could only cause outbreaks of cholera under certain favouring conditions, and particularly when the ground water begins to fall, after having risen to a higher level than usual. A third factor, the importance of which he emphasised, is individual predisposition, and the co-existence of all three factors, x, y, and z, as he termed them, was, he held, necessary before cholera could occur.

These views have been freely criticised by Koch and others, and for some time there was much discussion between the "soil theorists" or "localists" on the one hand, and the "contagionists" on the other; the former attaching special importance to the influence of soil, the latter regarding the presence of the specific organism as of paramount importance, and the question of soil conditions (in relation to place, season, etc.) as a comparatively minor matter. According to Koch, the "localistic" view is to the effect that water has not an infective, but merely a predisposing influence; that in this way unfiltered water may be thought of as conveying filth into the dwelling, into the streets, into the soil, and thus bringing about a condition of soil favourable to the development of the cholera germ. Cholera prevalences in Europe in 1892 and 1893 established beyond all question the fact that the malady is frequently transmitted by water, and thus did much to strengthen Koch's contention that the cholera vibrio is the cause of the disease, and that water containing it must be regarded as possessing infective properties; the soil theory, on the other hand, fell into some disfavour.

The question as to the reason why cholera should from time to time be enabled to spread, from localities in which it is endemic, over the greater part of the world still, however, awaits explanation. In 1883 W. H. Power suggested that the germ "has phases in its life-history, during some of which it has not, and in others it has, the power of producing cholera." These he termed "the non-malignant and malignant phases." He further suggested that it is only within certain geographical limits—"its customary area"—that the organism has the faculty of passing from non-malignant into malignant phase. In both phases it has the power of multiplying, and in both it is liable to be conveyed and deposited here and there throughout the world. Where the local and climatic conditions are unfavourable, the tendency is towards the production of the non-malignant phase. Should, however, the said conditions become favourable, while the organism in its malignant phase is still present, cholera results. This hypothesis affords explanation of the fact that "local outbreaks of the disease are apt to be of small dimensions, when they appear for the first time, after the convection of cholera to a place." The conveyed organism then only produces cholera "in quantity proportioned to its own quantity, or to the quantity of its immediate descendants, produced during the maintenance of the requisite conditions." When, however, after an interval of freedom from the disease, the requisite conditions recur, the organisms which continue to live in malignant phase may have become more numerous than in earlier generations, and, if this be the case, the local outbreak produced may be of larger dimensions than the original outbreak.

This hypothesis opens up a further field of inquiry as to the influence of soil conditions upon the cholera organism. Experiments have been made, with a view to determining the vitality of the cholera organism in soil, by Cunningham, Dempster, and others. Houston has tested the organism "in rure" by sowing it in natural soil and exposing it "to conditions seasonal, meteorological, and other, such as would be likely to be encountered by Koch's vibrio, were it to become in the course of a cholera outbreak self-sown, as it were, in the soil, garden or other, of town or country." Houston tested in like manner the bacillus prodigiosus; this organism was recoverable from the soil after months, "whereas the exotic Koch's vibrio, though repeatedly sown in large numbers over several square feet of surface, could with difficulty be recovered from the soil after the lapse of a few days." There was in these, as in previous experiments by Klein, suggestion "of a tendency in Koch's vibrio under adverse cultural conditions to undergo morphological modification to an extent rendering it extremely difficult of identification." Experiments made in areas of endemic prevalence of cholera, in India, indicate that in certain soils the cholera vibrio can maintain its vitality and even multiply.

Enteric Fever.—The observations of Pettenkofer, with regard to the relation between height of ground-water and outbreaks of cholera, led to similar inquiries being made concerning enteric fever. Buhl, from examination of records relating to the Munich wells, concluded that prevalence of enteric fever occurs when the ground-water level is low, and particularly when, after rising to an unusual height, it has rapidly fallen. Pettenkofer confirmed these results, but in this country the relation in question has not been generally observed. Buchanan suggested that, even when enteric fever is found to spread, soon after a rapid fall following upon a sudden rise of the ground-water, it is possible that the prevalence is due to the falling water being the means of conveying impurity into wells and so causing contamination of drinking water.

The continued presence of enteric fever in large towns which have obtained pure supplies of water, and the fact that the disease shows a tendency to specially affect the same localities year after year, has, however, led to a number of observations being made with a view to determining what are the conditions, if there be any, which lead to soil states playing a part in connection with prevalence of enteric fever. Certain registration districts in Durham (including those in which the outbreak investigated by Barry in 1890 and 1891 occurred) have shown, for a number of years, excessive mortality from enteric fever; again, the death-rate in Dublin, from this disease, has for many years been high, and this fact has been attributed to saturation of the soil with the specific organisms which cause the disease. Sir Charles Cameron has pointed out that the number of cases of enteric fever among inhabitants of Dublin living on gravel soil is considerably higher than among those living on stiff clay, and he suggested, as a possible explanation, the greater likelihood of germs being carried into the air in the case of the porous soil than in that of the stiff clay soil.

The ability of the enteric fever organism to develop in soil has been made the subject of study by Sidney Martin for the Local Government Board. Dealing first with sterilised soils, he found that such soils, if they contained a large amount of organic matter, afforded a medium in which the bacillus retained vitality for periods of many months. In "virgin soils," similarly dealt with, no sign of vitality could be discovered after a few weeks. When, however, the vitality of the bacillus was tested in unsterilised soils, it was found that it at once died out; this fact being apparently due to its inability to compete with the bacteria natural to soil. On examination of the extent to which particular species of soil-bacteria were able to inhibit the growth of the typhoid organism, it was found that, while some of these species "quickly suppressed the typhoid bacillus and others of them flourished, so to speak, side by side with the microbe, others again not only could not compete with, but were inhibited by the micro-organism of enteric fever."

Houston mentions two reasons which, in his opinion, make it unlikely that *Bacillus typhosus* should thrive in the surface layers of soil. The first is that in soil from various sources *Bacillus coli* (a more hardy germ than *Bacillus typhosus*) "was not found to be by any means habitually present." Secondly, "the number of spores of aerobic bacteria in soils is enormous," and this seems to indicate "that the surface layers of soil must be frequently exposed to physical conditions inimical to microbial life." Houston refers, on the other hand, to the results obtained by Robertson at Sheffield. This investigator found that *Bacillus typhosus* could persist for long periods in certain soils, and that it could grow to the surface when planted at a depth of eighteen inches. Theodore Thomson, in 1899, in connection with study of enteric fever at Chichester, enumerated various considerations telling in favour of or against a hypothesis that soil had played a part "in fostering the vitality and morbific power of the infective material of enteric fever."

Diarrhœa.—The cause of the very fatal malady (of which diarrhœa is the most prominent symptom) which especially affects children under one year of age, and more particularly prevails in the late summer and autumn, has been held to be intimately associated with certain states of soil. This soil theory of diarrhœa was examined in great detail by Ballard. He showed that the mortality from the disease is greater, generally speaking, upon porous soils than upon hard, impervious soils. He particularly insisted upon the influence exerted by fouling of the soil with organic matter—for example, in cases in which dwellings are erected upon made ground; in localities in which the midden-privy system of disposing of excreta contributes to soil pollution; and again in places in which a somewhat similar condition of things is brought about by leaky cesspools or defective drains. As regards moisture, Ballard found that extreme dampness or dryness was not so favourable as the intermediate condition in which the soil, while damp, permitted air to circulate through its surface layers. The question of temperature he regarded as especially important; he found that the summer rise of diarrhœal mortality did not commence in any particular year until the mean temperature recorded by a "four-foot" earth thermometer had reached about 56° Fahr.

The late Dr. Tomkins, Medical Officer of Health of Leicester (one of the English towns having a specially high diarrhœal mortality), was of opinion that the temperature recorded by the "one-foot" earth thermometer was of more significance than that recorded by the "four-foot" thermometer. Some doubt has of late years been expressed as to whether any significance should be attached to the observed relation between diarrhœal mortality and earth temperatures at different depths. A certain number of days, it is urged, are required for incubation of the disease and for its gradual development to a fatal termination; again, time must necessarily elapse before the death can be registered. It may be argued, therefore, that the period of maximum mortality might be expected (on the assumption that high atmospheric temperatures favour diarrhœa) to lag behind that at which the highest atmospheric temperature is recorded. In fact, the date of maximum recorded mortality should, in view of the facts stated, stand in closer relation with the time at which maximum temperatures at some little depth below the surface are observed, than with that at which the maximum atmospheric temperature occurs. Even if the earth temperature hypothesis be regarded as altogether unconvincing, however, the other reasons for associating diarrhœa with soil-states still remain. Newsholme has recently pointed out that incidence of diarrhœa follows want of rainfall more closely than it does the mean temperature of the air. He concludes that the soil is an important factor in diarrhœa, but that by provision of impervious paving in streets and yards, and of impervious flooring in houses, and by flushing, cleansing operations, etc., the influence of this factor can be materially lessened.

The provisional hypothesis formulated by Ballard was to the effect that the essential cause of diarrhœa resides ordinarily in the superficial layers of the earth, and is intimately associated with a micro-organism as yet unisolated. The vital manifestations of this organism are dependent on season and on the presence of dead organic matter; on occasion it "is capable of getting abroad from its primary habitat, the earth, and becoming air borne," thus obtaining access to food, etc. From food and from the organic matter of particular soils the organism can manufacture a virulent chemical poison, and, according to Ballard, "this chemical substance is in the human body the material cause of diarrhœa."

Phthisis.—More than thirty years ago Buchanan in this country, and Bowditch in the United States, were independently led to the conclusion that phthisis mortality was greater upon retentive than upon permeable soils. The observations of Bowditch were made in Massachusetts; the subject was forced upon Buchanan's attention, in the first instance, as the result of an inquiry made by him in 1865–66, concerning the "results hitherto gained by works and regulations designed to promote the public health."

The work of improving the sanitary condition of the large English towns, which was undertaken as the result of the passing of the Public Health Act of 1848, was seen, as time went on, to be productive of marked benefit, and in 1865 it was held to be desirable to gauge the extent to which the mortality from different forms of disease had been affected. Dr. Buchanan, who was entrusted with this piece of work, selected as the field of his inquiry twenty-five towns with a total population of 600,000 persons, these towns being chosen, not because of any observed improvement in their mortality statistics, but as being places in which works of sanitary improvement had been most thoroughly done and had been longest in operation.

Some of these towns contained only 3,000 to 4,000 inhabitants; the largest of them, Bristol with Clifton, had a population of some 160,000 persons. The works carried out, the effect of which it was Buchanan's intention to study, were, in the main, works of improvement of drainage, water supply, and scavenging, and with these had to be considered efforts made to amend lodging accommodation, and to cope with overcrowding. The method proposed for testing the influence exerted by carrying out these works, was that of comparing the deaths recorded at a later, with those registered at an earlier period. Buchanan pointed out that "the quantity of non-medical certification of causes of death" was probably much less than it was twenty years previously, and that "the discrimination and naming of disease within the ranks of the medical profession itself," had within the same time much improved. Hence special deaths (*i.e.*, deaths from particular causes) "after the works," might not be in all instances fairly comparable with deaths given under a like heading "before the works," and, as he said, deaths which ought to have come within special columns were more likely to have gone astray in the years "before the works" than in the years "after the works." It was, however, found to be quite clear, after making due allowance for sources of error, that in these twenty-five towns the general death-rate from all causes had, with but few exceptions, notably diminished, and a similar result was apparent in the case of infant mortality. On coming to the "contagious diseases," cholera was found to have been "rendered practically harmless"; typhoid fever had diminished in twenty-two of the towns; with regard to diarrhœa the results were not so striking, but there appeared to have been reduction in mortality from this cause in localities in which purification of air and water had been effected; diseases of the lungs manifested "no regular reduction"; croup and diphtheria showed distinct increase.

The most noteworthy and altogether unexpected result was, however, that obtained in the case of "consumption." In certain of the towns the reduction of deaths from this cause was great, and, on study of the facts observed, Buchanan was led to conclude that the sanitary improvement which "coincided with decrease of phthisis in town after town with least frequent exception," was "drying of the ground on which the town stands." Buchanan set out the facts for each of twenty-four of the towns in tabular form. At the head of his list stood Salisbury and Ely, towns in which there had been "much drying" of the subsoil, with a diminution of 50 per cent. in their phthisis death-rates; at the foot stood Alnwick with no drying of its subsoil and with an actual increase of 20 per cent. in its phthisis death-rate.* The correspondence between the extent of drying of subsoil and the amount of reduction of phthisis mortality was exhibited with remarkable exactness in most of the twenty-four towns, though in Carlisle and Chelmsford it was noted that ground water had been removed to a greater

* In Salisbury special arrangements for drying the subsoil had been made. At Penrith and Alnwick the deep drainage consisted of impervious pipes laid down in compact channels, so that no extensive drainage of water could occur either through or alongside them.

extent than in other towns which stood better as regards reduction of phthisis mortality; while, on the other hand, in Worthing and Rugby, there had been greater reduction in phthisis mortality than in other towns where the removal of subsoil water had been more complete.

The results of this inquiry were seen to be of such importance that it was decided Dr. Buchanan should pursue the matter further, and make careful study of the relation of soil dampness to phthisis mortality. It was felt that it would not be sufficient, in distinguishing between permeable and retentive soils, to rely merely on the broad divisions of the geologist, but that surface peculiarities must be taken into account. The work of surveying these surface peculiarities had just been completed, so far as Kent, Surrey, and Sussex were concerned, and by a fortunate chance, there was no other part of the country in which "varieties of soil would be greater, and differences of other sorts less obtrusive."

The fifty-eight registration districts in these three counties were brought under examination, in the first instance, with respect to their phthisis mortality, and secondly, as regards "the numbers of population in each district living upon various kinds of soil, under various topographical conditions." In considering the statistics of phthisis mortality the ages 15—55 were selected for examination, as being those which might be expected to furnish the most trustworthy results, and the mean death-rate of the two sexes was primarily relied upon. Many disturbing influences had to be taken into account, such as varying rates of increase of population, confusion between consumption and other diseases of the lungs, the effect of hospitals and public institutions, the use of particular places as resorts for consumptive invalids, and "the special circumstances of large bodies of the male population, particularly in camps and dockyards." Again, with regard to varieties of soil, the distribution of population on the different formations, in the counties selected as the field of inquiry, had to be considered.

The kinds of soil dealt with were classified as follows:—

(*a*) Alluvium and shingle belonging to the *recent* group.

(*b*) The brick-earth and gravel and sand of the *post tertiary* were discarded as having no noteworthy population.

(*c*) The Bagshot beds, gravel on London clay, London clay with no gravel, and lower London tertiaries of the *tertiary* group.

(*d*) The chalk, upper greensand, and gault, of the *upper cretaceous* group.

(*e*) The lower greensand, gravel over Weald clay, Weald clay with no gravel, and Hastings beds of the *lower cretaceous* group.

A table was then prepared showing for each registration district the proportion of residents in each group, and in this table the districts were set out in the order of their phthisis death-rates as previously determined. On a summary view of this table Buchanan pointed out that while "the first impression from the table, perhaps, is that any of the great formations (with the exception of Weald clay) may have on them a large share of the population of a district, and yet that district may have any position in respect of its phthisis mortality;" yet on carefully "looking into the list of districts (after a separate study of each) with special reference to . . . . the wetness or dryness of soil, it soon appears that the districts arranged in the order of the prevalence of consumption in them, are also to a very great extent arranged in the order of the dryness or wetness of their soils."

As regards this last named order difficulty was experienced, not only because the main quality of degree of perviousness varied in different parts of the same bed, but because other qualities, such as elevation, slope of subjacent beds, etc., also required to have due weight attached to them. With a view to summarising the facts, a grouping of soils into "pervious" and "retentive" was made, and the registration districts were classified according to the greater or less extent of mortality from phthisis observed in them. The following table was thus obtained:—

	Groups of Districts.	On Pervious Soils.	On Retentive Soils.
A	With least phthisis . .	909	91
B	Next least phthisis . .	877	123
C	Middle as to phthisis . .	795	205
D	With still more phthisis	792	208
E	With most phthisis . .	642	358

The results were further analysed by selecting from the fifty-eight districts "such as were comparable with one another in regard to their position and geological structure," and then noting how their phthisis was affected "by the perviousness or imperviousness, elevation or lowness, slope or flatness" in the members of each more limited series (Tenth Report of the Medical Officer of the Privy Council).

Finally the following general conclusions were arrived at:—

"(1) Within the counties of Surrey, Kent, and Sussex there is, broadly speaking, less phthisis among populations living on pervious soils than among populations living on impervious soils.

(2) Within the same counties there is less phthisis among populations living on high-lying pervious soils than among populations living on low-lying pervious soils.

(3) Within the same counties there is less phthisis among populations living on sloping impervious soils than among populations living on flat impervious soils.

(4) The connection between soil and phthisis has been established in this inquiry

(*a*) By the existence of general agreement in phthisis mortality between districts that have common geographical and topographical features of a nature to affect the water-holding quality of the soil.

(*b*) By the existence of general disagreement between districts that are differently circumstanced in regard to such features; and

(*c*) By the discovery of pretty general concomitancy in the fluctuation of the two conditions, from much phthisis with much wetness of soil to little phthisis with little wetness of soil.

But the connection between wet soil and phthisis came out last year in another way which must be here recalled.

(*d*) By the observation that phthisis had been greatly reduced in towns when the water of the soil had been artificially removed, and that it had not been reduced in other towns where the soil had not been dried.

(5) The whole of the foregoing conclusions combine into one—which may now be affirmed generally, and not only of particular districts—that WETNESS OF SOIL IS A CAUSE OF PHTHISIS TO THE POPULATION LIVING UPON IT.

(6) No other circumstance can be detected, after careful consideration of the materials accumulated during this year, that coincides on any large scale with the greater or less prevalence of phthisis, except the one condition of soil.

(7) In this year's inquiry, and in last year's also, single apparent exceptions to the general law have been detected. They are probably not altogether errors of fact or observation, but are indications of some other law in the background that we are not yet able to announce."

Buchanan's conclusions were adversely criticised by Kelly in reports, for 1879 and 1887, on the combined sanitary district of West Sussex. His main contentions were, that the figures of later years, not available when the original inquiry was made, present certain contrasts with the earlier figures given by Buchanan; that, generally speaking, the impervious soils are to the north of the South downs, and that the question of exposed situation thus exercises disturbing influence; that the phthisis death-rate continued to show marked decrease subsequent to the date of Buchanan's inquiry, although improvements tending to cause drying of subsoil were not being carried out; and finally that social changes are largely responsible for the diminution of the rate of mortality from phthisis. As regards the first of these criticisms, Kelly's figures show that in recent years the phthisis mortality of West Sussex populations, living on what he termed "retentive soils," does not markedly exceed that of West Sussex populations living on "pervious soils"; this fact, however, is not incompatible with the different teaching of the earlier figures, but rather shows that subsoil drainage has had its effect, and that the retentive soils have now been brought into a condition in which they compare not unfavourably with the pervious soils. The question of bleakness of situation doubtless exercises influence comparable to the influence of elevation, slope, etc., considered by Buchanan; this disturbing element cannot, however, be regarded as invalidating conclusions based on examination of an extensive area, and dealing in minute detail with differences observed in the various localities of that area. As regards the cessation of improvement works in towns, it has been pointed out that the large amount of agricultural drainage effected throughout the kingdom might be expected to have produced results, in rural districts, similar to those brought about by sewerage works in towns. The final contention is, of course, a truism; the conclusion arrived at by Buchanan was not that dampness of soil was the only influence affecting phthisis mortality, but merely that it was one of the influences.

As examples of diseases belonging to the third group, referred to at the commencement of this brief review of the relation of soil to disease, the following may now be given. *Calculus* and *goitre* have already been alluded to, in connection with the subject of water, and need not therefore be further discussed. Again *cancer* has been said to especially prevail upon flooded, low-lying, clayey areas, but this conclusion is not established with any degree of certainty. *Diphtheria* has been held to be especially prevalent upon cold, damp soils. Adams of Maidstone has investigated the relation between diphtheria prevalence and fluctuations in the level of subsoil water. He concludes that as long as the soil is well washed in winter, when the subsoil level is high, and well aerated in summer, when the subsoil level is low, all goes well; but that disturbance of this natural sequence of events favours the spread of diphtheria.

In connection with these observations Newsholme's conclusions with regard to the relation between rainfall and diphtheria may be referred to. Briefly stated, his inquiries lead him to believe that diphtheria only becomes epidemic "in years in which the rainfall is deficient, and the epidemics are on the largest scale when three or four years of deficient rainfall immediately follow each other." Longstaff showed, some years ago, that increase in the death-rates from scarlet fever, erysipelas, puerperal fever, and rheumatism, occurred in years of deficient rainfall. Newsholme suggests that the organisms of diphtheria and of the other diseases mentioned, are capable of living in a saprophytic stage of existence in soil. Such an hypothesis, he observes, "may appear to give undue importance to climatic conditions, as contrasted with personal infection." He therefore points out that "there is no reasonable doubt that personal infection is the chief means" by which diphtheria is spread, but he argues that something more than personal infection is required to explain why diphtheria spreads more in some years than in others, and he concludes that among "the external cultural conditions leading to increased virulence of the diphtheria bacillus, and its greater readiness for assuming a parasitic life, exceptional deficiency of rainfall and consequent exceptional deficiency of moisture in, and exceptional warmth of, the subsoil form an essential part."

Dysentery is another disease which has been supposed to bear special relation to states of soil. The subject of the spread of dysentery has already been referred to in connection with water-borne disease. It may be that the dejecta from dysenteric patients contain a specific organism, which is not only capable of being transmitted by water, but is also able, under certain conditions, to maintain its vitality in soil. The endemic areas of dysentery are said to be characterised, as a rule, by possessing a damp, porous soil, in association with a heavy rainfall and a high level of the subsoil water. Further, it may be noted that outbreaks of dysentery in this country have been attributed to soil emanations. In the cases in question sewage has been spread upon the land adjoining asylums, and the outbreaks have been observed among the asylum inmates and have been attributed to the effluvia from the decomposing sewage.

Malaria has long been held to be associated in some way with a marshy condition of soil. Moreover, the effect of drainage operations in causing localities, at one time malarious, to become malaria free, has been repeatedly cited as evidence of the existence of such a relationship. Attention has been directed to the mineral constituents of these soils, and again to the influence of decaying vegetation. When the existence of a malaria organism was first suspected, question arose as to the possibility of its finding circumstances favourable to its development in particular conditions of soil. Later researches, concerning the rôle played by the mosquito in the dissemination of malaria, seem to point to the conclusion that local conditions are mainly operative by favouring the existence of the species of Anopheles which transmits the disease.

Certain *rheumatic affections* are associated with exposure to cold and damp, and are therefore likely to prevail in localities with damp soils. Chronic rheumatism is usually said to be especially prevalent in damp and exposed situations. The term rheumatism, however, is very loosely applied, and the relation of the forms of disease in question to soil states has not been precisely studied. Acute rheumatism, as Longstaff showed, appears to be intimately associated with conditions of subsoil, its prevalence notably increasing after a series of dry years. The association of acute rheumatism and some other diseases, with variations in amount of rainfall in successive years, has already been referred to in connection with diphtheria. Finally, *yellow fever* may be mentioned as an instance of a disease the prevalence of which appears to be favoured by soil conditions. The extent to which this malady tends to be endemic in some seaport towns in the tropics, particularly those having harbours with polluted foreshores, and unfavourably circumstanced as regards stagnation of water and absence of cleansing influence due to tidal movements, has led to the suggestion being made that the organism which produces the disease is able to find a suitable medium for growth in polluted harbour mud.

CHAPTER V.

FOOD.

THE materials used as food are generally classified as follows:—

1. *Organic.*—These include the nitrogenous (proteids and albuminoids), and the non-nitrogenous foods (carbo-hydrates, fats, and vegetable acids).

2. *Inorganic.*—These include mineral salts and water. A third group is sometimes made to comprise what are termed "food accessories," such as tea, coffee, alcohol, condiments, etc. The substances last named are not actually essential for the maintenance of life, but they are of importance, inasmuch as they act as stimulants, or impart flavour to food, in addition to promoting in some degree the nutritive value of a diet.

Proteids and Albuminoids.—Proteids contain in 100 parts about 16 parts of nitrogen, 54 of carbon, 22 of oxygen, 7 of hydrogen, and one part of sulphur. The albuminoids have practically the same percentage composition, though some of them do not contain any sulphur; gelatine, the chief member of the group, has a somewhat larger percentage of nitrogen than that just mentioned. The proteids and albuminoids constitute the one source from which the body is able to take up nitrogen. In plant life nitrogen is obtained from ammonia and nitrates, but the animal body cannot utilise the nitrogen obtained from such comparatively simple bodies, but is dependent for its supply upon the much more complex proteid molecule. Gelatine, and to a less degree other albuminoids, chondrin and keratin, can be employed to spare the proteids in a diet, but their nutritive value is less, and they cannot entirely take the place of the proteids.

The materials known as *extractives* are nitrogenous substances, which enter largely into the composition of meat extracts, beef-tea, etc. These substances serve a useful purpose in conditions of disease in which proteids cannot be assimilated, but the popular impression that they contain the nutritive properties of meat in a concentrated form is quite a mistaken one.

The chemical constitution of the proteid molecule is very complex. Proteid is converted by the gastric juice into syntonin, peptone, and albumose; when acted upon by the pancreatic juice it yields peptone and substances of allied nature, while some of the peptone is further decomposed, forming leucin and tyrosin. The products of proteid decomposition are absorbed mainly in the form of albumoses and peptones (which, unlike the other proteids, are dialysable), and are built up into, or serve for the repair of, nitrogenous tissue elements; they may also undergo further decomposition, yield fat, and possibly also carbo-hydrate, and become a source of supply of energy. The final products of the oxidation of the material originally represented in proteid are carbonic acid, water, urea, and other nitrogenous bodies.

Proteids are of animal or of vegetable origin. The animal proteids include *native albumens* (serum albumen and egg albumen), the globulins (myosin of muscle, serum globulin, and the vitellin of the yolk of egg); *derived albumens*, closely allied to which is the substance called casein; *insoluble proteids* (fibrin); *and albumoses and peptones*. Vegetable proteids include the globulins and albumoses of the cereals and leguminous plants, as well as legumin and gluten, which are allied to casein and the derived albumens. Animal proteid is said to be, as a rule, more readily and rapidly digested than vegetable proteid.

When proteids are consumed in excessive amount, nitrogenous waste products accumulate in the blood, and the excretory organs are apt to prove unequal to the task of removing these substances with sufficient rapidity from the body. Digestive disturbance results, and in some instances the development of gout and kidney disease appears to be favoured by such faulty dieting. Excess of proteid tends to cause oxidation of fat, while carbo-hydrate appears to lessen the oxidation of both proteid and fat. Thus, in Banting's treatment for obesity, the amount of meat is increased, while the quantity of starchy food is as far as possible reduced.

Fats are compounds of glycerine and fatty acids (palmitic, stearic, and oleic acids). The amount of oxygen contained in them is less than that required to enter into combination with their hydrogen so as to form water. Their main function is to serve as sources for the development of energy and heat, and they are usually found in considerable proportion in the diet of persons who live in very cold countries.

Carbo-hydrates, on the other hand, while consisting, like the fats or hydro-carbons, of carbon, hydrogen, and oxygen, contain the two latter elements in the exact proportions necessary to form water. They consist of three groups: the *glucose* group $(C_6 H_{12} O_6)_N$ (glucose, lævulose, and inosite); the *cane sugar* group $(C_{12} H_{22} O_{11})_N$ (milk sugar, cane sugar, and maltose); and the *starch* group $(C_6 H_{10} O_5)_N$ (glycogen, dextrine, starch, and cellulose). Cellulose is not capable of being digested, and is discharged from the body unchanged. The carbo-hydrates supply energy to the body, and they act as "proteid-sparing foods," and also serve to economise consumption of fats. The extent to which fats and carbo-hydrates are capable of replacing one another in a diet is not precisely known. Carbo-hydrates are converted in part, under certain circumstances, into fat. In the process of fattening pigs and other animals it is found that more adipose tissue accumulates than the fat contained in the food would account for. This excess of fat may be to some extent due to decomposition of proteid, but it is probably mainly derived from carbo-hydrates.

The **vegetable acids**, of which the most important are tartaric and citric acids, have an important function, inasmuch as their salts are converted into carbonates, which, being absorbed, maintain the alkalinity of the blood and other fluids of the body. They are derived mainly from fresh fruits and certain vegetables. To the absence of an adequate supply of fruit, etc., and consequent deficiency of vegetable acids, the disease known as scurvy has been attributed. It may be that vegetable acids are in part derived from some form of carbo-hydrate food.

Among **mineral salts** the most important are chlorides and phosphates of sodium, potassium, and lime, and compounds of iron. Sodium chloride—common salt—enters into the composition of almost all foods. It is present, on the whole, in less quantity in foods of vegetable than in those of animal origin, hence the reason for its being used, for example, in bread making. Phosphate of lime is of special importance in connection with the formation of bone, and is present in appreciable quantity in milk, the natural food of young animals. Iron is of importance, more particularly on account of its entering into the composition of hæmoglobin.

Nutritive Value of Food Stuffs.—Theoretically the amount of energy obtainable from various foodstuffs, their "nutritive value," can be determined by calculating their efficiency as heat producers, *i.e.*, by estimating the amount of heat yielded by the complete combustion of a given weight of the substance. This amount is expressed in heat units; the English heat unit is the amount of energy required to raise a pound of water one degree in temperature, *i.e.*, 772 foot pounds, if the degree in question is a degree Fahrenheit, or 1389 foot pounds if the degree be a degree Centigrade. The heat equivalents have been determined by calorimetry and it has been found, for instance, that one ounce (dried) of potatoes yields 475 English heat units, one ounce of egg albumen 628 units, one ounce of butter 815 units, and so on. In the case of non-nitrogenous foods the amount of heat yielded in the body is, roughly, equivalent to that registered in the calorimeter, but it is not so in the case of nitrogenous foods, for their combustion is not complete, and hence the heat equivalent of the urea, etc., formed, requires to be deducted from the estimated heat equivalent of the proteid. One ounce of dry proteid yields about $\frac{1}{3}$ oz. of urea, representing some 80 heat units. Thus the heat equivalent of the dry proteid of egg albumen, after making correction for the urea produced, does not greatly exceed that of the dry carbo-hydrate in potatoes. The heat equivalent of fat, it will be seen, is nearly twice that of proteid or carbo-hydrate.

If a man consume *per diem* food containing 24 ounces of dry proteid, fat, and carbo-hydrate, in the usual proportions to be presently more particularly referred to, there should be produced upwards of 12,000 heat units, or $12{,}000 \times \frac{772}{2240}$, say 4,000 foot tons of energy. Of this amount some 2,800 foot tons are expended in the performance of internal work and the maintenance of heat.

Thus about 250 foot tons are expended in maintaining the circulation.
" " 40 " " " " respiration.
" " 2,500 " " " " temperature.

There then remain 1,200 foot tons for the performance of external work. The body is, it is found, only capable of accounting for about one-fifth of the surplus. With 24 ounces of dry food yielding 4,000 foot tons of energy, therefore, the amount of external work may be estimated at about 250 foot tons; this represents only a moderate day's work. For a hard day's work, 500 foot tons, an additional allowance of food would need to be made, corresponding, however, to more than an additional 1,200 foot tons of energy, the amount of the former surplus, inasmuch as with increasing severity of work a diminishing proportion of the energy theoretically supplied is accounted for by the body. It will be seen that, when so many disturbing influences tend to vitiate the results obtained, and when in the final outcome only 20 to 25 per cent. of the surplus energy (over and above that required for internal work and heating purposes) is actually utilised for external work, these calculations are of little more than theoretical interest. This conclusion will be strengthened when it is considered how very materially the digestibility and assimilability of food affect the extent to which the energy theoretically contributed to the body is capable of being turned to account.

A subject of great practical importance is the amount of the various foodstuffs present in ordinary articles of food as influencing the proportions in which these articles should enter as constituent elements of a normal diet. The following table gives the approximate amounts of foodstuffs contained in some of the common articles of diet:—

IN 100 PARTS.

Article of Diet.	Water.	Proteids.	Fats.	Carbo-hydrates.	Salts.	Cellulose.
Lean meats... ...	75	20	3·5	—	1·5	—
Fat pork	40	10	47·5	—	2·5	—
Bacon	15	9	73	—	3	—
White fish	78	17	3	—	2	—
Egg (deducting 10 per cent. for shell)	75	13	11	—	1	—
Cow's milk	87·3	4	3·5	4·5	·7	—
Human milk ...	87	2·5	4	6	·5	—
Cream	66	3	26	3	2	—
Butter	9	3	87	—	1	—
Cheese	38	30	27	—	5	—
Bread	36	7	1·5	54	1·5	—
Flour	12	12	2	72	1	1
Oatmeal	15	12·5	5·5	64	3	—
Potatoes	75	2	·2	21	1	·8
Pea flour (dry) ...	11	25	2	57·5	3	1·5
Rice	13	8	1	76	1	1

The quantities of the various foodstuffs which are necessary for "subsistence" and for "light work," "moderate work," "severe work," etc., have been calculated by various observers. It may be approximately stated that a man weighing about 150 lbs. requires, to maintain his weight when taking little or no exercise, some sixteen ounces of water-free food. Such a subsistence diet should include rather more than 2 ozs. of dry proteid, about $\frac{3}{4}$ oz. of water-free fat, $\frac{1}{2}$ oz. of salts, and about 12 ozs. of dry carbo-hydrate food. For moderate work such a man would need 24 ozs. of water-free food, 5 ozs. of proteid, rather more than 3 ozs. of fat and 1 oz. of salts, and about 15 ozs. of carbo-hydrate. For very hard work as much as 30 ozs. may be required, including some 6 or 7 ozs. of proteid, 4 ozs. of fat, rather more than 1 oz. of salts, and 18 ozs. of carbo-hydrate.

By use of the table given above it is easy to determine the quantities of the various articles of diet required to supply water-free carbo-hydrate, proteid, fat, and salts in the necessary proportions in any particular case. It will be obvious that in a diet consisting largely of potatoes, the administration of the quantity of proteid indicated as necessary would entail the consumption of an amount of carbo-hydrate in excess of that required, and even under those circumstances the supply of fat would be inadequate. Again, if the diet of an adult consisted exclusively of milk it would be necessary, in order to obtain the requisite amount of carbo-hydrate, to consume excess of proteid, and an altogether excessive quantity of fat. By combining two or three articles of food which contain proteid, fat, and carbo-hydrate in differing proportions, it is possible to secure the supply of proper amounts of the three chief constituents of a dietary (the salts may be practically disregarded for the purposes of such a calculation) without the necessity of supplying an excessive quantity of any one of the articles of food.

Thus, suppose it be required to ascertain how much bread, butter, and cheese are needed to supply 5 ozs. of proteid, 4 ozs. of fat, and 18 ozs. of carbo-hydrate. Let the number of ounces of bread, butter, and cheese respectively be x, y, and z. Then from the table

$$\frac{7}{100}x + \frac{3}{100}y + \frac{30}{100}z = 5 \qquad (1)$$

$$\frac{1 \cdot 5}{100}x + \frac{87}{100}y + \frac{27}{100}z = 4 \qquad (2)$$

$$\frac{54}{100}x = 18 \qquad (3)$$

Multiplying (1) by 9 and (2) by 10 and subtracting, z disappears, and

$$\frac{48}{100}x - \frac{843}{100}y = 5 \qquad (4)$$

From (3) $x = \frac{100}{3}$

hence substituting this value in (4)

$$y = \frac{1,100}{843} = 1 \cdot 3 \text{ oz. approximately.}$$

And from (1) $\frac{7}{3} + \frac{33}{843} + \frac{3}{10}z = 5$

Hence $\frac{3}{10}z = \frac{2,215}{843}$ or $z = \frac{22,150}{2,529} = 8 \cdot 8$ ozs. approximately.

Thus $33\frac{1}{3}$ ozs. of bread, 1·3 oz. of butter, and 8·8 ozs. of cheese are required to furnish the specified amounts of proteid, fat, and carbo-hydrate.

On again referring to the table it will be seen that these quantities of bread, butter, and cheese will yield

$$\frac{33\frac{1}{3}}{100}\,1{\cdot}5 + \frac{1{\cdot}3}{100} + \frac{5 \times 8{\cdot}8}{100} \text{ ounce of salts,}$$

$$\textit{i.e.,}\quad {\cdot}5 + {\cdot}013 + {\cdot}44 \quad \text{or} \quad {\cdot}953 \text{ ounce of salts.}$$

This amount of salts is somewhat low and should be supplemented by an additional quantity of salt, or by employing salt butter in place of fresh butter.

The use of a diet such as this for any length of time would, however, inevitably lead to impairment of health; it is not sufficient to make sure that the amounts of the various foodstuffs stand in certain definite proportions to one another, the diet must also be sufficiently varied. Practically, therefore, calculation of the quantities of some two or three articles of food, needed to furnish the proportions of proteid, fat, carbo-hydrate, and salts theoretically determined to be necessary, is of little value. Life could, no doubt, be supported for a long period of time on a daily allowance of ¾ lb. of meat (containing fat) and 2 lbs. of bread, or on other combinations of articles of food, such, for example, as the bread, butter, and cheese above referred to, but for the maintenance of a vigorous, healthy condition of body a varied dietary is absolutely necessary.

Diet.—The several foodstuffs should be present in an ordinary diet-scale in more or less precise proportions. A common way of stating the case is that proteids being taken as 100, fats should be about 65, carbo-hydrates 315, and salts 23; or, to adopt a much more rough-and-ready rule, the nitrogen should bear to the carbon supplied the proportion of about 1 to 15. Again, it is sometimes said that a diet for an average man doing a moderate amount of work should contain 300 grains of nitrogen and 4,500 grains of carbon. Tests of this sort may be usefully applied to a composite diet in order to ascertain that the several kinds of foodstuffs are represented in proper proportions, but in using them the need for change and variety must on no account be lost sight of.

Variation in diet is generally secured by persons, who can exercise choice in the matter, on their own initiative. They become tired of one sort of food, and replace it by another sort. In the case of institutions, however, in which fixed dietary scales are adopted for reasons of economy and because the system renders it easy to check the quantities of food supplied, there is no doubt that too little regard has been paid, in the past, to the desirability of framing these scales in such a way as to avoid a too rigid adherence to a fixed routine. The occurrence of scurvy in ships' crews first led to the direction of attention to the question of impairment of health under conditions in which food, adequate in quality, but lacking in variety, was supplied. It was concluded that the symptoms observed resulted from insufficient supply of vegetable acids (such as, under ordinary circumstances are furnished in the form of fresh vegetables and fruit, articles which are not, as a rule, available on shipboard), and this conclusion was strengthened by the fact that in cases in which fresh vegetables and fruit, or in the absence of these the best substitutes available (dried vegetables and fruits, lemon or lime-juice, or even vinegar) were supplied, scurvy did not develop. Possibly there are other substances which are essential for a healthy condition of body, and which are consumed, albeit only in small quantity and from time to time, when the food is sufficiently varied, but which may by chance happen not to be comprised among the constituent ingredients of a fixed diet-scale.

Whether this be the fact or not there is no question that in the case of institution inmates the change from a monotonous diet to one of a more varied character has been attended in numerous instances with marked benefit. In certain poor-law schools, for example, the experiment has been tried of giving a double course at the midday meal; again, instead of repeating the same series of dinners week after week throughout the year, a system of extending the change of meals over a fortnight instead of a week has been in some instances adopted. Attention has been paid in some modern dietary scales to the question of season, somewhat larger amounts of fatty food being supplied in winter, and so on. The effect upon the health of the children receiving these more varied forms of dietary has been found to be marked, and the additional expense has been shown to be inappreciable or only very small, when once the initial cost of suitable appliances for cooking and serving meals has been met. A new Order regulating workhouse dietaries came into force on May 25, 1901. This Order embodies many of the recommendations of a committee appointed by the Local Government Board, to consider the question of diets.

As regards the question of age and sex in relation to diet, it has been seen that about 5, 3, and 15 ozs. of dry proteid, fat, and carbohydrate, respectively, are required by an average man weighing 150 lbs. who is doing a moderate day's work. The corresponding amounts for the average woman performing work of a somewhat lighter character may be taken, roughly speaking, at about four-fifths of those specified. A boy or girl from about twelve to fifteen years of age will eat, as a rule, as much as a woman; in young children smaller amounts of food are required, but the proteid, and still more the fat, supplied, should not be reduced to

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the extent permissible in the case of the carbo-hydrate. Thus a child eighteen months old, while only consuming about one-sixth of the carbo-hydrate taken by the adult man, will require about one-third the amount of proteid, and fully half the quantity of fat. In milk, the natural food of the infant, the amount of carbo-hydrate is about half as much again as, and the quantity of fat is about equal to, that of the proteid. In old age the amount of food taken should be somewhat less than in the prime of life; the quantity of proteid required is less, and the carbo-hydrate will also bear reduction. The fat may, however, with advantage even somewhat exceed the amount prescribed for the average adult.

As regards the arrangement of meal-times, it is usual to take food three or four times a day; the hours fixed for taking food should be so arranged as not to leave too long an interval between any two meals. When hard manual labour is being performed, the chief meal is generally taken in the middle of the day. If the nature of the ordinary daily work is intellectual rather than muscular, there is advantage in postponing the chief meal of the day until the early hours of the evening, that is, until after the labour of the day is done. It is, in any case, undesirable to consume considerable quantities of food immediately before bed-time, as the processes of digestion are carried on less actively during sleep. The time necessary for the digestion of different articles of food is very variable; it has been found that flesh remains, as a rule, from two to five hours in the stomach, while starchy foods are somewhat more speedily disposed of. Veal and pork are less readily digested than other forms of meat.

The digestibility of food is in most cases somewhat assisted by cooking, which, moreover, develops certain flavours, making the food more appetising, and has also important influence in favouring the destruction of parasitic forms of life (including pathogenic micro-organisms) which may be present in the food. Vegetable foods, as a rule, take up water and lose a certain amount of salts as a result of cooking processes. Animal foods, on the other hand, generally lose weight on cooking, this loss being chiefly due to diminution in the percentage of water contained in the food. The average loss of weight in roasting meat is about one-third: in the process of boiling the loss is only about one-fifth of the total bulk. The proteids of meat are partly coagulated by cooking, but complete coagulation would render the meat indigestible, and this should be avoided. In roasting, it is usual to expose the joint to considerable heat, until the external portions are coagulated and the retention of the juices of the meat is thus favoured. The subsequent roasting is then continued at a somewhat lower temperature, in order to avoid complete coagulation of the greater part of the proteids.

Diseases Connected with Food.

The diseases associated with the consumption of food are many, and may be best considered in relation to special articles of diet. Certain conclusions with regard to food generally may, however, be first stated. If food is taken in excess it is not, as a rule, readily absorbed, but undergoes decomposition in the alimentary canal, producing digestive disturbance; the products of decomposition may even give rise to a condition of blood poisoning. The consumption of excess of proteids is in some cases associated with the development of gout. If the amount of food is insufficient wasting occurs, and diarrhœa, ophthalmia, stomatitis, and skin affections may be developed; the power of resistance to many of the forms of specific disease, and particularly to tuberculosis, may, moreover, be notably impaired.

The connection between *scurvy* and an insufficient supply of vegetable acids has already been noted. *Rickets* is another malady which stands in marked relation to improper dieting. Young infants cannot digest starch, and it is particularly in the case of children brought up by hand, and supplied with starchy foods, that this malady occurs. A form of infantile scurvy has been observed of late years in infants fed upon preserved foods, and it has been suggested that sterilisation (carried out with a view to destroying pathogenic organisms) may result in depriving milk of some property essential to it, if it is to perfectly discharge its function of nutrition. In the malady just referred to, which is known as *Barlow's disease*, hæmorrhages sometimes occur under the periosteum of the long bones, and the ordinary symptoms of rickets may also be developed. The administration of grape juice, uncooked meat juice, and other remedies has been recommended in these cases; a liberal supply of fresh milk is also indicated. It has been contended that by heating to boiling point and then immediately cooling, milk may be deprived of the capacity of transmitting specific disease, without suffering any impairment of nutritive quality. Again, the system of exposing milk for 20 to 30 minutes to a temperature of 155°—165° F. ("pasteurisation") has come largely into use in the preparation of infant foods.

Meat.—In connection with the transmission of disease by consumption of meat, attention has been specially directed to some of the higher parasites occurring in animals, which manifest ability to undergo development in human beings consuming the contaminated flesh as food; further, the fitness for use as food of the flesh of animals affected at the time of being slaughtered by well-recognised forms of disease needs to be considered. Of late years outbreaks of illness have been repeatedly traced to the consumption of certain kinds of meat, of which neither of these hypotheses appears to afford adequate explanation. It has been conjectured in such cases that some form of bacterial life must have found a favourable medium for its growth in the meat, and that the germ in question has then caused the mischief. Again, in recent years the possibility of the spread of tuberculosis by consumption of the flesh of animals has attracted a large share of attention.

To deal first with the higher parasites which infest the bodies of animals commonly used as food. These forms, producing as they do, in most instances, appearances which may excite suspicion, even on naked eye examination, were the first to attract attention; but in this country, at any rate, the rôle which they play in the production of human disease is not a considerable one.

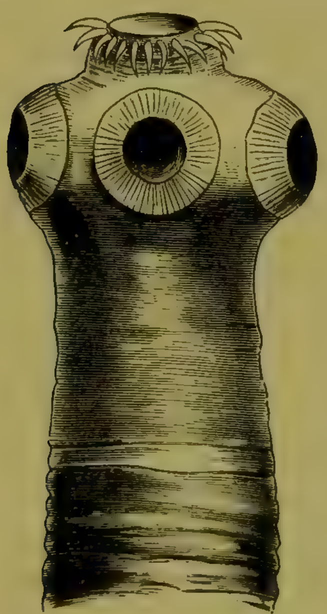

FIG. 30.
Head of *Tænia solium*.
(*After Leuckart.*)

There are species of tape-worm which affect man and food-animals. *Tænia solium** is probably introduced as a rule into the human digestive tract by the consumption of what is known as "measly pork." The affected muscles of the pig, and, it may be, the liver of the animal, present a mottled appearance due to the presence of numerous small oval cysts, from $\frac{1}{20}$ inch to as much as $\frac{1}{2}$ inch in their long diameter. Each cyst is a cysticercus (*Cysticercus cellulosæ*), or bladder-worm, and represents a stage in the development of *Tænia solium*.

The capsule of the cysts is sometimes partly calcified, and a gritty feeling is then produced on cutting through the muscle substance involved with a knife. The affected flesh becomes, moreover, flabby and soft. The worm contained in the cyst is found on microscopic examination to present a somewhat square-shaped head with a

* Dr. Krehl, whom Leuckart consulted with reference to the etymology of this strange appellation, declared it impossible to derive the word *solium* from the classic languages. He offered as an explanation "the certainly somewhat remote Syriac word for the tape-worm," namely, *schuschl-*[illegible] (properly "chains").

sucker at each angle, while within the circle of suckers are two successive rows of hooklets. The cysticercus stage is very rarely met with in man, and the adult tape-worm is not of common occurrence in this country. It is occasionally found, however, in consumers of imperfectly cooked pork. It sometimes attains a length of several feet, and may comprise 700 to 800 segments. The head of the adult worm is about the size of a pin, the segments adjoining it are correspondingly minute, but the largest segments attain a size of about 12 mm. by 5 mm. The eggs, which the lower segments contain in vast numbers, are round, and enclosed in a firm shell, the outside of which is thickly covered with little rods.

*Tænia mediocanellata** (*T. saginata*) is of more common occurrence in man in this country than the tape-worm already described. Its cysticercus stage (*Cysticercus bovis*) is passed in the ox, in which the parasite produces what is called "beef measles." The head of this cysticercus presents no hooklets, but has four prominent suckers, often surrounded by a pigmented border, while within the circle of suckers there is a pit-like depression. The adult tape-worm attains a length of some 20 feet and includes upwards of 1,000 segments. The eggs are slightly oval, and about ·03 mm. in diameter. They appear to have a covering of little rods.

Bothriocephalus latus probably passes its larval stage of development in the pike. The adult form is met with in man in some of the countries bordering on the Baltic, it attains a greater length than the tape-worms already mentioned, the head has no suckers, but has a deep furrow or groove on each side (hence the term Bothrio-cephalus, βόθρος, a hole, a pit, and κεφαλή, the head). There are no hooklets and the body, which is ribbon-like in shape, may contain upwards of 3,000 segments.

FIG. 31.
Head of *Bothriocephalus latus.*

Tænia echinococcus is found in its adult stage in animals of the dog tribe, the larval form is met with in man, more particularly in Iceland, and produces what is known as hydatid disease, which usually affects the liver or lungs.

The adult tape-worm in this species is only about two inches long, and it has three or four segments; its head has four suckers and a double row of hooklets. The eggs to the number of about 500 are contained in the last segment; they are spherical in shape, and in-

* So called by Küchenmeister, who was under the erroneous impression that the uterine stems of the joints were united together into a common longitudinal canal.

clude an embryo with six hooks. On reaching the alimentary canal of man or that of some other animal, the embryo finds its way usually to the liver, and there a large cyst with numerous secondary cysts, or "brood capsules," may be developed. Each brood capsule contains one or more "scolices" as they are called; each scolex possesses a ring of hooklets, and is capable, if it obtains access to the body of a dog, of developing into a mature tapeworm. It is supposed that man is usually infected by consuming uncooked vegetables upon which the eggs have been deposited, though the parasite may be conveyed by the dog in the act of licking its master.

FIG. 32. *Tænia echinococcus.* - (*After Leuckart.*)

The fact that hydatids are of not uncommon occurrence in the food-animals makes it desirable that dogs should be rigidly excluded from slaughterhouses; if this be not done, by feeding on the offal they may themselves become infected, and they may cause contamination, of the slaughterhouse surroundings and of the meat itself, with the eggs of the adult worm.

Trichina spiralis is a parasite which mainly occurs in the pig. In Germany symptoms of trichinosis have not infrequently been observed in man. The muscles affected present numerous cysts about $\frac{1}{70}$ inch in length, which lie between the muscular fibrillæ with their long diameters disposed in the direction of the muscle fibres. The cyst walls are sometimes more or less calcified, and each cyst contains an immature worm about $\frac{1}{40}$ inch in length. The diaphragm is usually a favourite site for the development of the parasite, and the intercostal muscles are also often affected. Thin sections of the suspected flesh should be made in the direction of the muscle fibres. These should be immersed for a few minutes in liquor potassæ, which renders the muscle fibres translucent,

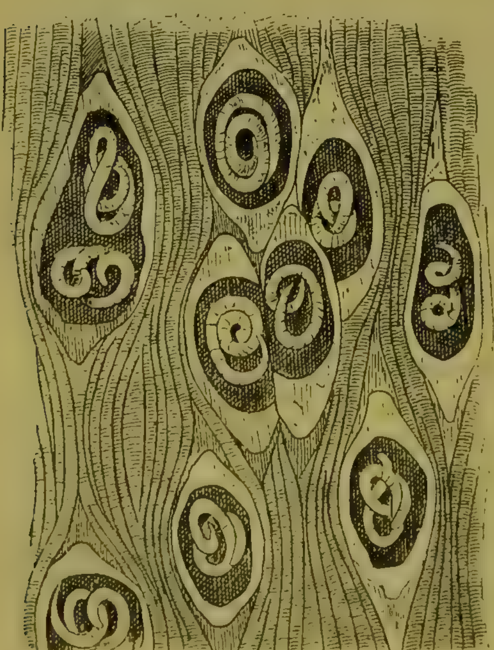

FIG. 33.
Muscle affected by *Trichina spiralis.*

and the cyst with its coiled up worm, if present, will then be evident on examination with a low power of the microscope.

Trichinosis in man is an acute febrile affection in which muscular pains are, as a rule, a prominent symptom. It has been confused at times with rheumatic fever and with typhoid fever. The disease is not infrequently fatal. Symptoms usually develop about a week after the ingestion of the diseased flesh, and last for a fortnight or more. The affected muscles become swollen and tender, and œdema sometimes occurs. The voice may be hoarse, prostration is marked in severe cases, and peritonitis or pneumonia may supervene.

There are often present in the flesh of oxen, sheep, and pigs small oval or kidney-shaped semi-transparent objects known as "Rainey's capsules," or "psorospermia"; these bodies are enclosed in an investing membrane with delicate linear markings, and internally they consist of granular particles, they lie within the sarcolemma of the muscle fibre, and with a little care are readily distinguishable from trichinæ; they must on no account be confused with the psorospermia often found in the liver of the rabbit and some other animals (*See* p. 316).

The flesh, in cases in which the animal is known to have been suffering from some form of specific malady at the time of slaughter, may be rendered abnormal in appearance, and, if such flesh shows signs of commencing decomposition, or exhibits any offensive odour (when tested by inserting a long knife and smelling it after withdrawal), or shows marked discoloration or iridescence, it should not, of course, be eaten. A sodden, flabby condition of the meat, the presence of hæmorrhagic points in the fat, the existence of evidence of emaciation in the carcase, or of signs of pleuritic adhesions, and especially any indication of the fact that the pleura has been stripped with a view to concealing the existence of such adhesions, all point to the conclusion that the meat is diseased and unfit for food. The flesh of animals which have died, or have only been slaughtered in a dying state, is generally dark and discoloured by reason of not having been bled, and such flesh sets badly and quickly decomposes. The flesh of animals that have been overdriven, or have been slaughtered during parturition, often presents abnormal appearances, but such flesh need not necessarily be regarded as unfit for food provided the departure from the normal condition is but little marked.

Pleuro-Pneumonia is a disease which occurs in the ox, and the evidence of its existence is found after slaughter in the condition of the lungs and pleural membranes. The disease is not transmissible to man, and if the flesh presents no marked deviation from the normal appearance, it is usually passed as fit for food.

Foot-and-Mouth Disease is also a localised malady, and provided the parts implicated are destroyed, and the flesh is not notably deteriorated, the carcases of affected animals may be used for food without danger to health.

Rinderpest or cattle plague is said to render flesh unfit for human food, though when the malady last appeared in this country, the flesh of animals which had presented evidence of the disease was consumed without ill effect in some instances.

Anthrax is probably not often communicated to man by means of food, but the carcases of animals affected with the disease should be unhesitatingly condemned; indeed, when the nature of the malady is recognised, the carcase should not even be incised, but should be buried with every precaution against the spread of infection.

The term *Braxy* as applied to disease in sheep appears to include more than one morbid condition. The flesh, in cases in which braxy has been diagnosed, is usually altogether abnormal in appearance, and quite unfit to be eaten. A similar remark may be made concerning—the flesh of sheep affected with what is called *Variola ovina;* that of cattle which have suffered from the disease of the joints, known as *Joint ill*, or *Joint felon;* and that of pigs which have presented symptoms of *Swine fever*.

Actinomycosis involves, as a rule, the tongue and lower jaw of the ox; it may also occur in the lungs, alimentary tract, and in other parts. It has not been shown that the disease has been communicated to man by the consumption of the flesh of animals suffering from actinomycosis, but the only safe course is to condemn such flesh.

The liver fluke, *Distoma hepaticum*, produces what is termed "rot" in sheep. The parasite is shaped like a very small sole, and it is about one inch in length. Provided the flesh is not abnormal in appearance, the risk from consuming it is practically infinitesimal; but animals suffering from the malady often become emaciated and dropsical, and when this is the case the carcase should, of course, be condemned.

The consumption of flesh in which decomposition has set in is often attended with the production of gastro-intestinal disturbance, though, curiously enough, venison and game are usually eaten in a state in which decomposition has made some progress.

The ill effects of such flesh have been attributed to the production of chemical poisons in the decomposing tissues; in "the eighties" careful study was made of the poisonous products of bacterial growth. It was found that substances resembling vegetable alkaloids in chemical composition, and like them possessed of marked poisonous property, result from the growth of certain putrefactive bacteria; these substances were called "ptomaines" (πτῶμα, a dead body). Later researches showed that poisonous proteid substances (albumoses, etc.) were also produced under such circumstances. A few years ago it was the fashion to speak of cases in which food was found to be at fault as examples of "ptomaine poisoning." Since it has been made clear that poisonous proteids may be also concerned in such instances, it has become more usual, when the chemical nature of the poison is not precisely known, to speak of "toxines" as the cause of the mischief. Several ptomaines and poisonous albumoses have been isolated from products of bacterial growth. In some cases of food-poisoning a distinct incubation period occurs: the significance of this fact will be further referred to later.

A number of cases of food-poisoning have from time to time been investigated for the Medical Department of the Local Government Board, and Ballard in 1891 summarised the results of the observations made, by himself and Klein, with regard to them. In the Welbeck outbreak the consumption of particular hams caused illness in a number of persons who attended a sale in June, 1880, on the estate of the Duke of Portland. Klein found in the suspected ham certain bacilli, and these bacilli were also found in the kidney of a man who died of the disease. The organisms were pathogenic to guinea-pigs and white mice. The same bacilli were found in some pork the consumption of which caused a number of cases of food-poisoning at Nottingham, in 1881. In a fatal case at Chester in the same year, American sausage was suspected to have been the cause of the illness. At Oldham in 1882, members of a family who had consumed American tinned pigs' tongues were attacked with symptoms of food-poisoning. At Bishop's Stortford in 1882, individuals belonging to three families who ate some ribs of beef were similarly affected, and at Whitchurch instances of food-poisoning from the consumption of roast pork and of brawn were observed in 1878 and 1882, respectively. At Wolverhampton in 1884, members of a family who had consumed a "blown" tin of salmon were attacked with symptoms of poisoning. At Carlisle in 1886, twenty persons who were present at a wedding breakfast were affected, and suspicion in this instance especially fell upon certain gelatinous articles which had been eaten. At Trowbridge in 1886, a group of cases occurred among persons who had partaken of veal pie. At Metford in 1887, a number of cases were attributed to eating pork pie or brawn. At Carlisle in 1889, pork pies and boiled salted pork fell under suspicion, and at Portsmouth in 1891 persons who had eaten a beef pie were attacked.

One of the most remarkable instances of food-poisoning referred to was the outbreak of pneumonia which occurred at Middlesbrough in the early part of 1888 and caused the death of 490 persons. Ballard, who investigated this outbreak, was led to the conclusion that American bacon was the medium by which infection was conveyed, and Klein, from samples of the bacon, isolated an organism which he had previously found in the lung juice or lung tissues of persons suffering from pneumonia. This organism, which he called *Bacillus pneumoniæ*, proved to be pathogenic in rodents, and these animals, when fed with cultures, developed lung and visceral lesions similar to those observed in the Middlesbrough cases in man. Moreover, during the progress of Klein's experiments an epidemic of pneumonia occurred among mice, guinea-pigs, and monkeys kept in the building in which the work was being carried on, and in the animals affected the pneumonia bacillus was also found.

In some of the above-mentioned cases of food-poisoning symptoms developed shortly after the suspected food was eaten, in others an incubation period of a number of hours extending to twenty-four, and in one instance to forty-three, hours intervened. Ballard attributed the malady to a chemical poison in cases of the kind first named, but pointed out that where some hours for incubation of the disease were necessary, a living organism was probably at work. He noted, moreover, the frequency with which pig meat was at fault, and he further expressed the opinion that the gelatine of the meat was the medium in which the organisms found special opportunity for their development. He concluded that meat was particularly liable to become contaminated as the result of exposure to putrid emanations, and he insisted upon the great importance of cleanliness in connection with cooking operations.

In 1885 Gaffky and Paak isolated a bacterium from horse-flesh, the consumption of which had given rise to illness affecting eighty persons. In 1888 Gärtner showed that an organism, which he called the *Bacillus enteritidis*, was the cause of a particular outbreak of illness affecting fifty-eight people who ate some of the flesh of an ox, which there was reason to suppose was diseased. This bacillus was probably identical with that isolated by Gaffky and Paak, and has been since isolated in other cases of meat-poisoning, and it, or a closely allied form, appears to be the cause of a malady termed "psittacosis" which has been observed in parrots. Gärtner's bacillus gives a serum reaction similar to that yielded by the typhoid organism, and examination of the serum of persons who have suffered from symptoms of food-poisoning has now come to be regarded as an important aid to diagnosis. (*See* an Address on "The Present Knowledge of Outbreaks due to Meat Poisoning" by H. E. Durham, *Brit. Med. Journal*, Dec. 17, 1898.) Yet another organism, the anaerobic *Bacillus botulinus* (*botulus* signifies a sausage, and the term *botulismus* has been applied abroad to certain cases of food-poisoning), has been isolated by van Ermenghem from poisonous ham.

Tuberculosis.—The important question as to the nature and means of combating the risk involved in consuming the flesh of food-animals affected with tuberculosis has been studied by two Royal Commissions, those of 1895 and 1898. The inquiries of the first Commission resulted in the conclusion that tuberculous disease in bovine and certain other animals is identical with that occurring in the human subject (Koch raised question as to this matter, however, in 1901, *see* p. 207). The facts before the Commission showed that, in cows particularly, tuberculosis is a common disease. In the case of milch cows a large proportion of the carcases examined are affected—in some instances 40 per cent., though the incidence varies considerably in animals belonging to different herds and breeds. Sheep are seldom attacked, but in pigs the disease is not uncommon.

Tuberculous deposit very rarely occurs in the muscular substance, but Sidney Martin has pointed out that there is considerable risk that in the process of dressing, the carcase, or joints of meat, may become contaminated by the use of a knife, which has been employed to incise collections of tuberculous material. Experiments were made for the Commission of 1895 as to the efficiency of various modes of cooking, which showed that in the inside of a joint the temperature seldom reached 140° F. Thus, while infective material on the exterior was comparatively readily dealt with, it was found, when pieces of meat artificially contaminated on the surface were rolled up, that cooking did not destroy their infective property. Boiling, on the whole, was more effectual than roasting.

It has been pointed out that the mortality from tuberculosis has notably declined, in recent years, at the age-periods at which meat is especially consumed, and this reduction has been accompanied by an actual increase in the amount of meat eaten. It is probable that tuberculosis is not transmitted to man by the consumption of meat, therefore, to any very great extent. There has been much discussion as to whether the existence of small foci of tubercular mischief in an animal should necessitate the destruction of the entire carcase. On the one hand it has been maintained that danger is only to be feared when actual tubercles are found in the muscle substance; on the other hand it has been alleged that the only safe course is to destroy the entire carcase, inasmuch as the disease, though apparently localised to the naked eye, is, as a matter of fact, generalised.

The Royal Commission of 1898 made the following recommendations with regard to condemnation of the carcases of tuberculous cattle:—

(*a*) When there is miliary tuberculosis of both lungs ... ... (*b*) When tuberculous lesions are present in the pleura and peritoneum ... ... (*c*) When tuberculous lesions are present in the muscular system, or in the lymphatic glands embedded in or between the muscles ... ... (*d*) When tuberculous lesions exist in any part of an emaciated carcase ...	The entire carcase and all the organs may be seized.
(*a*) When the lesions are confined to the lungs and the thoracic lymphatic glands ... ... (*b*) When the lesions are confined to the liver ... ... (*c*) When the lesions are confined to any combination of the foregoing, but are collectively small in extent	The carcase, if otherwise healthy, shall not be condemned, but every part of it containing tuberculous lesions shall be seized.

The Commissioners add:—"In view of the greater tendency to generalisation of tuberculosis in the pig, we consider that the presence of tubercular deposit, in any degree, should involve seizure of the whole carcase and of the organs. In respect of foreign dead meat seizure shall ensue in every case where the pleura have been 'stripped.'"

Recognition of the risk of the spread of tubercle by the consumption of meat has emphasised the necessity of adequate inspection, by trained inspectors, of animals at the place of slaughter, in order to give opportunity for thorough investigation, not only of the flesh, but also of the lungs and other viscera, and of the carcase generally. Such a system of inspection is only practicable when slaughtering is conducted in public abattoirs; in many towns on the Continent, and in a few in this country, the necessity for this has been recognised. Meat is stamped with a distinctive mark in many of the Continental towns before it is allowed to be removed from the abattoir for sale. In some instances meat which is regarded as suspicious is cooked with special precautions, or is sterilised by the application of steam, and then sold at a reduced rate. Much opposition has been encountered in this country to the institution of public abattoirs, as it has been alleged that the attractive appearance of home-killed meat can only be produced when the butcher has the opportunity, of preparing animals for slaughter and killing them, on his own premises, in which the carcase can be afterwards hung and allowed to set properly. The handling of freshly-killed meat, and its removal immediately after slaughter, doubtless interfere with this setting process, but this difficulty has been met by the provision of cold-storage, and the advantages of the private slaughter-house are now no longer apparent. On the other hand the disadvantages arising from multiplication of such establishments, to an extent which makes it practically impossible to exercise supervision as regards the fitness for food of the meat dealt with, render their abolition most desirable, apart altogether from the nuisance which is likely to result from the continued existence of such places in close proximity to houses.

Horseflesh can be sold for human food if it is sold as horseflesh; to supply it to a consumer as other meat, or in sausages, etc., is a contravention of the provisions of the Sale of Horseflesh, etc., Regulation Act, 1889. The flesh of the horse is darker and coarser as a rule than beef, and possesses a characteristic odour. The fat is yellower than beef suet, and has a peculiar taste. Horseflesh is rich in glycogen, and this fact may be utilised as a means of detecting fraud, when such flesh has been substituted for ordinary meat. A concentrated infusion of the meat is made, and to this, when cool, dilute nitric acid is added, and the mixture is filtered. A saturated, hot, freshly-prepared, solution of iodine is then slowly poured down the side of the vessel containing the meat extract and acid, in such a way that it comes in contact, but does not freely mix, with them; at the junction of the liquids a ring of colour, red to violet, is developed if the meat extract is derived from horseflesh.

Fish possesses high nutritive value and is, as a rule, readily digestible; improved means of communication and of preservation have led to increasing use of this form of food, especially by poor persons dwelling in large towns at a distance from the coast. Fish contains a notable amount of phosphorus, and has hence been held to possess special value as a means of making good waste of nervous tissue. Fish harbour numerous parasitic worms, but the only species known to be transmitted to man is the *Bothriocephalus latus*, met with in countries bordering on the Baltic. Poisoning has resulted in some instances from consumption of fish; mackerel, in particular, a fish which undergoes decomposition with special facility, has been said to occasionally produce gastro-intestinal disturbance. In two outbreaks of enteric fever which occurred simultaneously in districts in South London, in 1900, there was evidence pointing to the conclusion that fried fish was at fault.

Milk contains certain proteids (of which the most important is casein), carbo-hydrates (lactose), and mineral salts in solution, and it holds in suspension microscopic globules of fat. The globules rise to the surface when the milk is allowed to stand, forming cream. The amount of cream present may be determined by allowing the milk to stand for twelve to twenty-four hours in a cream-tube, a cylindrical tube provided with a graduated scale at its upper part, upon which the amount of cream which separates can be read off. On the average, the yield of cream should be about 8 to 10 per cent., though in the case of the milk of Alderney cows it sometimes exceeds 30 per cent. More complete separation, than is attainable by merely allowing the milk to stand, can be effected by centrifugalisation in a "separator." The specific gravity of milk varies from about 1027 to 1034; it is determined by means of the instrument called a lactometer, and regard should be paid to the temperature at which the estimation is made; each rise of 10° F. above 60° F. corresponds, roughly speaking, to a fall of one degree in the specific gravity of milk. At 60° F. a fall of about 3 degrees in specific gravity is produced by the addition of 10 per cent. of water to the milk. Skim milk is of higher specific gravity than whole milk, and thus, by addition of water to skim milk, the fluid may be again reduced to the specific gravity it originally possessed before the cream was removed.

Cow's milk contains more proteid and salts, and less carbo-hydrate, than human milk does. Hence, in employing cow's milk as a food for young infants, it is necessary to dilute it, so as to imitate, as nearly as may be, the proportions in which proteids and salts exist in human milk, and further to make up for the deficiency of carbo-hydrates by the addition of milk sugar. An important difference between cow's and human milk, moreover, lies in the fact that while the latter forms a loose, flocculent curd, when it is acted upon by the digestive juices, the tendency of the former is to clot in masses, which are less readily digestible. In the artificial rearing of infants, it is, therefore, usual to add barley water to the cow's milk used, with the object of securing, by the mechanical action of this medium, a flocculent curd, such as is yielded under ordinary conditions by human milk. Ass's milk approaches human milk more nearly in composition than cow's milk does, but it is deficient in fat. Goat's milk contains excess of both fat and proteid as compared with human milk. Both these last named kinds of milk yield a flocculent curd. Mare's milk affords considerably less fat and less proteid than human milk. "Koumiss" is prepared from mare's milk; part of the cream is removed, and a fermentation process is then set up, by which some of the milk sugar is converted into lactic acid.

Cow's milk varies in composition according to the breed, the age, the period since calving, and the number of pregnancies, of the cow from which it is obtained. The season of the year, the stage of milking, the nature of the food given to the cow, and the conditions under which the animal is kept, also exercise influence. The "fore milk," that first drawn, contains very little cream; the "strippings," the milk last drawn, contain excess of cream. Much discussion has, therefore, arisen as to what should be accepted as the minimum standard for the various ingredients of pure milk. It is usual to fix the limit at either 3 per cent. or 2·75 per cent. in the case of fat, at 8·5 per cent. for the "solids—non-fat," and at ·7 per cent. for the ash.

The "total solids" are determined by evaporating a measured quantity of milk (say 2 c.c.) to dryness in a shallow dish, care being taken to prevent charring, and then weighing the solid residue. Thus suppose 2 c.c. of a sample of milk of specific gravity 1030 be taken. The weight of the 2 c.c. is 2·060 grammes. If the residue after evaporation be found to weigh ·28 gramme, the percentage of total solids yielded $= \frac{\cdot 28 \times 100}{2\cdot 06} = 13\cdot 42$ per cent. The total solids in a sample of milk usually range from 12 to 13 per cent. The amount of fat present in the sample may then be determined, and on deducting this amount from the total solids, the amount of "solids—non-fat" is known.

The estimation of the fat is usually made as follows: The sample is well shaken, and 5 c.c. are placed in a small beaker and weighed. As much of the 5 c.c. as possible is then soaked up by a coil of bibulous paper freed from fat. The coil being removed, the beaker and its contents are again weighed, and the amount of milk taken up by the paper is thus determined. The coil of paper, after being thoroughly dried in a water oven, is subjected, in a Soxhlet's apparatus, to the action of anhydrous ether, which accumulates time after time around the coil, and every few minutes, as the level of the ether attains to the necessary limit, is syphoned off. After repeated syphonings, the ether which has extracted the fat from the coil of paper is evaporated at 212° F., and when at length a constant weight is obtained, the quantity of fat is determined. The amount of ash can be ascertained by incinerating the dried residue and weighing. It should be about ·73 per cent.

In estimating the extent to which milk has been adulterated with water, the "solids—non-fat" are usually taken as affording a more reliable indication than the fat itself, inasmuch as the quantity of the latter varies more in different samples of milk than that of the former. If the "solids—non-fat" are only 7·5 per cent. instead of 8·5 per cent. (the standard adopted), the sample contains only $\frac{7 \cdot 5}{8 \cdot 5}$ 100, *i.e.*, 88 per cent. of pure milk, and the estimated amount of added water is therefore 12 per cent. The added water may be also determined from the ash. Thus, if in a particular sample the percentage of ash is found to be ·6 instead of ·73, the sample contains only $\frac{\cdot 6}{\cdot 73}$ 100, *i.e.*, 82·2 per cent. of pure milk, and the estimated amount of added water is therefore 17·8 per cent. The addition of adulterants to milk tends, as a rule, to increase the amount of ash, and in instances in which formalin has been added the amount of total solids yielded is said to be somewhat increased, in part by polymerisation of the formic aldehyde and formation of a non-volatile substance, and in part by conversion of lactose into galactose. The standard ·73 per cent. for the ash is somewhat high, and ·7 is often adopted. If the milk is not perfectly fresh, a slight reduction in the amount of "solids—non-fat" will be observed. Lactic acid is soluble in ether, and, if lactic acid fermentation has taken place, the fat is likely to be over-estimated, and the amount of "solids—non-fat" to be correspondingly diminished. If the milk be only slightly sour, a little ammonia restores its fluidity, and such addition is sometimes made before attempting to take up the milk with the bibulous paper in determining the fat. If the souring process has progressed to any considerable extent, the examination cannot be satisfactorily undertaken.

A Departmental Committee was appointed by the Board of Agriculture to inquire and report upon the desirability of Regulations under Sec. 4 of the Sale of Food and Drugs Act, 1899, for milk and cream. A majority of this Committee recommended that if the total solids do not amount to 12 per cent. the presumption should be raised, until the contrary is proved, that the milk is deficient in the normal constituents of genuine milk. Further, that if this limit be not attained, and either the amount of milk fat be less than 3·25 per cent., or the non-fatty milk solids less than 8·5 per cent., the presumption should be raised, until the contrary is proved, that the milk is adulterated. The Committee made also other suggestions, among which was included the recommendation, that separated milk should be branded, or "ear-marked," by the addition of some suitable and innocuous substance. The Sale of Milk Regulations, 1901, issued by the Board of Agriculture, do not follow the Committee's finding, but merely stipulate that if there be less than 3 per cent. of milk fat, or less than 8·5 per cent. of milk solids other than fat, "it shall be presumed for the purposes of the Sale of Food and Drugs Act, 1875 to 1899, until the contrary is proved, that the milk is not genuine." The Regulations also fix 9 per cent. as the limit of milk solids in skimmed or separated milk.

Certain preservatives are very commonly added to milk. Formalin is employed in solution containing about one part of formaldehyde in eighty parts, half-a-pint, or thereabouts, being sufficient to "preserve" a churn of milk; the milk thus contains about one part of formaldehyde in 20,000 parts. The presence of formalin may be tested for by ascertaining whether a blue colour appears on addition of sulphuric acid; or by distilling the sample of milk into solution of diphenylamine in water, acidulated with sulphuric acid, and boiling, when, if formaldehyde be present, a white precipitate is formed. Boracic acid may be detected by evaporation and incineration of the milk, taking up the ash with a little water, and then adding enough hydrochloric acid to produce slight acidity, and testing with turmeric paper. On drying the paper, if boracic acid has been added to the milk, a brownish red colour is produced, which becomes bluish green on moistening with alkali. Or alternatively a few c.c. of milk may be evaporated, a few drops of strong hydrochloric acid added when the evaporation is almost complete, and the Bunsen flame then made to play across the top of the evaporating dish. If there be any borax, a green tinge will be detected in the flame. Salicylic acid, if present, may be extracted from the milk by shaking with a mixture of ether and petroleum naphtha, and filtering and evaporating the extract, then dissolving the residue in distilled water, and adding dilute ferric chloride, when a purple colour is developed.

It has been found, in particular instances, that the addition of preservatives to milk has been attended with harmful results; on the other hand, it has been contended that suitable preservatives, if used in sufficient dilution, are capable of preventing deterioration of milk without rendering it injurious. Fresh milk, however, needs no preservative, and for the feeding of infants it is especially necessary that milk which is above suspicion should be used. Annatto and turmeric are often added to milk to impart a yellow colour to it, and thus bring about an unnatural appearance of richness. Their use gives opportunity, therefore, for abstraction of cream. In 1901 a Departmental Committee of the Local Government Board reported upon the use of preservatives and colouring matters in the preservation and colouring of food. The conclusions arrived at by this Committee were that the use of formaldehyde or preparations thereof in articles of food or drink should be prohibited, and that salicylic acid should not be used in larger proportion than one grain in a pint or pound of food; that preservatives and colouring matter in milk should be altogether prohibited, but that in the case of cream, butter, and margarine, boric acid or borate of soda, in strictly limited quantity, not exceeding ·25 per cent. in cream and ·5 per cent. in butter or margarine, should be permitted; that in preparations intended for infants or invalids chemical preservatives should be altogether prohibited; that the use of copper sulphate as a colouring ingredient for tinned peas should not be allowed; finally, that a Court of Reference should be established, or that a new obligation should be imposed on the Local Government Board to exercise supervision over the use of preservatives, etc., and to issue schedules of such preservatives as may be considered dangerous.

Tyrotoxicon, the poisonous alkaloid isolated by Vaughan from cheese, is sometimes, though very rarely, found in milk. To detect it, sodium carbonate may be added, the milk being then shaken up with ether. The ethereal extract is next separated and evaporated, a little water is added to dissolve the residue, which is then filtered, and the filtrate is evaporated. On adding a mixture of equal parts of pure phenol and sulphuric acid, an orange red or purple colour is developed if tyrotoxicon be present.

Preserved milk has of late years come largely into use. In some instances the cream is abstracted before the milk is concentrated or "condensed"; but the importance of the fact that condensed separated milk necessarily contains less fat than condensed whole milk does, has only quite recently been fully appreciated. For the purpose of feeding infants condensed skim milk is quite unsuitable. The amount of fat in different brands of condensed milk ranges from less than 1 to as much as 10 or 18 per cent., it is therefore of great importance that the varying constitution of these preserved milks should be generally recognised.

The microscopic and bacteriological examination of milk is a matter to which a growing amount of attention is being devoted. So little care is given to the question of cleanliness in milking operations, in many instances, that it is not uncommon to find gross evidence of pollution on examination of the sediment which collects when milk is allowed to stand. The udders of the cow and the hands of the milker should, of course, be carefully cleansed prior to milking, but this is by no means the invariable practice; indeed, in connection with many cow-sheds, no facilities for washing are, at the present time, provided, and often but little regard is paid to the obvious precautions necessary for preventing excremental pollution. It is a frequent occurrence, moreover, for one or more cows in a shed to present chronic mastitis, or some other condition causing the milk yielded to be of abnormal character. The question whether such milk shall go into the churn or down the drain, often, unfortunately, depends merely upon the caprice of a milker, who, it may be, takes a somewhat broad view as to what is fit for human consumption.

The milk secreted by a healthy cow is free from micro-organisms, but some contamination is necessarily incidental to the process of milking, even when it is carefully conducted, and many of the organisms introduced rapidly multiply, milk being a very favourable medium for the growth of bacteria. The microscope may show the presence of epithelium, pus, casts of the lacteal tubes, blood corpuscles, various fungi and micro-organisms, and cow-dung (discoloured vegetable tissues). Some 400,000 organisms per cubic centimetre are not infrequently found in milk, and larger numbers have been counted; the lactic acid bacillus, *Bacillus butyricus*, *Bacillus coli communis*, various micrococci, sarcinæ and moulds, are commonly present. For the detection of tubercle bacilli, 10 to 15 c.c. of milk are injected into the peritoneal cavity of a guinea-pig, and after three or four weeks the animal is killed and examined for evidence of tubercular mischief. It may be necessary also to examine for the presence of typhoid or diphtheria bacilli in milk.

Milk in Relation to Disease.

Milk readily becomes contaminated by gases and effluvia to which it is exposed. Thus the not uncommon practice of selling milk in shops in which petroleum is retailed, leads from time to time to complaint being made with regard to the taste and smell of the milk. So far as the particular source of contamination mentioned is concerned, it is very doubtful whether any serious injury to health is produced. The possibilities of pollution by drainage effluvia, by emanations from decomposing organic matter, and by exposure to the atmosphere of dwelling-rooms (or, indeed, to the air of ill-ventilated rooms generally) all need to be carefully borne in mind, as they may involve risk of communication of harmful property to the milk. In some instances it has been found that metallic impurity (lead and copper) has been taken up from vessels in which milk has been stored, and unless milk measures, churns, etc., are kept scrupulously clean, there is liability to collection of material derived from the milk, and of foreign substances, in crevices and corners, and this source of contamination requires to be carefully looked to. Milk which has become sour is apt to produce digestive disturbance, particularly in young infants; the fact that the epidemic diarrhœa of warm weather is comparatively rare in breast-fed infants, but common among children brought up by hand, makes it specially necessary to take every possible precaution with a view to avoiding the addition of impurity. The milk should, of course, be boiled or "pasteurised" as an additional precaution, but heat does not necessarily affect the chemical poisons produced by the growth of bacteria, and it is not desirable to attempt to bring about the destruction of resistant spores (*See* p. 179.)

The milk of cows may be rendered abnormal in quality in consequence of peculiarities in the animals' food. Thus cows which have eaten *Rhus toxicodendron* have been found to yield milk which causes digestive disturbance, and ill effects are said to have been observed after the use of the milk of animals fed upon "brewers' grains." The milk of newly-calved cows, which presumably contains colostrum corpuscles, milk which is "ropy" or "stringy," milk contaminated with pus, *e.g.*, in cases of abscess of the udder, and the milk yielded in cases of chronic mastitis, should not be sold for human consumption. The milk of cows suffering from foot and mouth disease is said to produce stomatitis in man. The "thrush" of infants has been attributed to the presence of *Oïdium albicans* in milk, and other fungi have been described as being present, in instances in which gastric disturbance has been observed to follow the use of milk. In cases in which milch cows are affected with anthrax, the specific bacillus has been found in the milk. In many acute constitutional diseases of the cow the yield of milk is lessened or ceases altogether; in tubercular disease the amount of milk secreted is often considerable, even in the later stages of the malady. The poisonous alkaloid tyrotoxicon, isolated by Vaughan from cheese, has been found to be present in rare instances in milk.

The Reports of the Medical Officer of the Local Government Board for 1893-94 and for 1895-96 give account of occurrences of an "epidemic skin disease" in certain workhouse infirmaries. Dr. Copeman, who investigated these outbreaks, found reason for concluding that the disease had been distributed by milk, but it was not possible to make "exact inquiry as to the changes to which the milk . . . was subjected before being delivered to the inmates of the institutions in question."

The ability of milk to act as a means of conveying the infection of specific disease requires to be particularly considered in connection with enteric fever, scarlet fever, diphtheria, cholera, tuberculosis, and diarrhœa.

Enteric Fever.—Dr. Michael W. Taylor found that at Penrith, in October and November, 1857, cases of fever occurred in seven houses, the families living in which were supplied with milk from a particular dairy. He published, in the *Edinburgh Medical Journal* of May, 1858, a paper entitled, "The Infection of Fever by Ingesta," in which an account was given of this, the first recognised, instance of milk-borne infection. In 1870 an outbreak of enteric fever in Islington was traced by Ballard to milk, and from that time onwards many similar prevalences have been shown to have originated in like manner.

In 1881, Ernest Hart summarised, in a paper read before the International Medical Congress of that year, the facts relating to fifty outbreaks of milk-borne enteric fever, of which he had been able to collect the particulars, and in a later report, dated 1897, which appeared in the *British Medical Journal*, he was able to include forty-eight others, making a total in all of ninety-eight outbreaks. In one instance, reported upon by Geo. Turner, who investigated the circumstances, in South-East London in 1891, ice-cream was found to be at fault; it may be that, in this case, infective property was imparted to the ice-cream by milk, but it is also possible that the infection was directly communicated to the ice-cream, and was not derived from milk.

In some of the instances recorded by Ernest Hart the pollution of the milk was ascribed to the fact that the milk-cans were washed with polluted water. Thus, in an outbreak at Leicester in 1882, in one at Exeter in the following year, in one at Clapham in 1882, in one at Lancing in 1886, in one at Edinburgh in 1890, and in one at Torquay in 1892, well waters, which were shown to be liable to excremental contamination, were employed in the dairies implicated. In other cases—for example, in an outbreak in Warwickshire, in 1883, and in one at Plymouth, in 1892—infection was ascribed to the fact that persons suffering from enteric fever were employed in connection with the milk business. In an outbreak at Derby, in 1884, the mother of a patient suffering from enteric fever was engaged in milking the cows and in washing the milk-cans. In other instances milk, proved to possess infective property, was stored under conditions which made it possible that specific polluting material conveyed through the atmosphere might have obtained access to it. In some of the outbreaks included in the summary no possible source of contamination of the milk was detected.

In connection with an inquiry at Eagley and Bolton, in 1876, made by Power, question was first raised as to the possibility of the milk having obtained its infective properties owing to the existence of some cow malady. A similar suspicion has been entertained in one or two other outbreaks, and Dr. Allan, of Pietermaritzburg, was led, as the result of his experience, to the conclusion that milk may become contaminated in this manner. Klein has recently shown, by inoculation experiments, that *Bacillus typhosus* is able to multiply and develop in the lymph glands of the calf.

Scarlet Fever.—M. W. Taylor, of Penrith, in the year 1867, found reason for supposing that this disease was capable of being transmitted by milk. In the *British Medical Journal* (vol. ii. 1870) account is given of an outbreak, due to this cause, at St. Andrews, which was recorded by Professor Bell, and in the same volume appears M. W. Taylor's paper, "On the Transmission of the Infectious Fevers by means of Fluids," in which he alludes to the outbreak at Penrith, and describes how scarlet fever "followed the trail of the milk carrier" in that town. Ernest Hart's paper of 1881 contained reference to fifteen prevalences of milk-borne scarlet fever, and his later paper of 1897 to thirty-two further outbreaks. Among the earlier group was included an instance in which guests who partook of cream at a dinner party given in South Kensington in the year 1875 were affected.

In many of the earlier prevalences of milk-borne scarlet fever, the contamination of the milk was ascribed to infection imparted to it by some person suffering from the disease; or, again, the conditions under which the milk was stored were assumed to have facilitated the acquirement of infectious property. In 1882, however, in an outbreak in St. Giles and St. Pancras, investigated by Power, it was found that milk obtained from a Surrey farm was at fault, but that it was impossible to discover any means by which the milk "could have received infective quality from the human subject." It was noted that a newly-calved cow which had recently come into milk at the farm was suffering from some ailment of which the loss of hair in patches was a symptom.

THE HENDON OUTBREAK.—In December, 1885, an outbreak of scarlet fever was traced to milk supplied from a Hendon farm, and the inquiry made by Power into the circumstances is of such importance as to require special consideration. Investigation as to antecedent disease among the Hendon population failed to give any positive result, and the farm itself was "sanitarily perfect." The question therefore arose whether the cows themselves "had something or other to do with any scarlatina which had been distributed along with their milk." The milk from these cows was retailed in five districts by various vendors :

1. By Mr. X, in Marylebone, among whose customers disease appeared at the end of November, and they suffered heavily up to the end of the third week in December.

2. By Mr. Y, in Hampstead, whose customers were attacked in two groups, a small group at the end of November, and a larger group in the latter half of December.

3. By Mr. Y, in St. Pancras, whose customers suffered to a less extent, but the attacks were grouped in the manner already noted in Hampstead.

4. By Mr. Z, in St. John's Wood, whose customers escaped altogether until after the end of the year.

5. By Mr. P, in Hendon, to a few families, two of which were implicated in the early part of December.

In the absence of other explanation of the way in which infective property could have been imparted to the milk, inquiry was instituted as to any new condition pertaining to the cows coincidently with acquirement of ability of their milk to produce scarlatina—at the end of November, in four milk districts : throughout December, in Mr. X's district; after an intermission, in December, in Mr. Y's two milk districts; while the condition in question was absent from the cows that furnished milk for Mr. Z's business.

It was found that on the 15th of November three newly-calved cows from Derbyshire arrived at the Hendon farm, and on the 4th of December four additional cows were received from Oxfordshire. In the third or fourth week of November, the milk allotted to Mr. X was derived from two of the four sheds at the farm, described as the "large" and the "middle" sheds; that sent to Mr. Y came in part from the "middle" shed, and in part from a shed called the "small" shed; Mr. Z was supplied from the "small" shed.

The 15th of November cows had been placed on their arrival at the farm (with a view to making sure that they were not suffering from foot and mouth disease) in what was known as the "quarantine shed"; their milk was sent on some days to Mr. X, on other days it was employed to make up the supply of Mr. Y, and frequently it went to both these retailers on the same day, but it rarely, if ever, went to Mr. Z.

On the assumption that the milk of these 15th of November cows was infective, the incidence on X and Y, and the exemption of Z would therefore be explained; but, as Power pointed out, if the above concurrence was, in truth, indicative of cause and effect, it must be possible to set down, *à priori*, "certain other parallel events which, if they had occurred, would greatly strengthen the inference."

Thus, the limitation of the disease, shortly after its first appearance, to Mr. X's district, suggested that the 15th of November cows had been transferred in the last days of November, or the earliest days of December, to the large shed, and it was found that towards the end of November they were so transferred. Again, the fact that, after an intermission in the early part of December, Mr. Y's two districts were again involved, suggested that "about the second week of December some of the 15th of November cows, or some of the 4th of December cows (which up to December 11th had occupied the quarantine shed), or some other cows, that had been during early December in close relation with the 15th of November cows, were probably transferred to the middle shed and their milk delivered from thence." Here, again, it was found, as a matter of fact, that on or about the 11th of December, two of the 4th of December cows were placed in the large shed, and the other two in the middle shed. Finally, the escape of Mr. Z's customers suggested that "it was not probable that at any time up to the end of the second week in December, any of the 15th of November cows, nor any of the 4th of December cows, nor any cow that had been in close relation with such cows, had been transferred to the small shed." As a matter of fact, this had not happened. Thus, as Power said, "what had been seen to be a succession of probabilities, if the scarlatina in London districts were indeed the outcome of the milk distributed from the Hendon farm, was now established as a succession of facts."

On the 15th of December, Mr. X returned his milk to the Hendon farmer, and on the 16th of December and subsequent days it was consumed by persons living in Hendon, and some half-dozen families so supplied were attacked; conversely, new cases ceased to occur among Mr. X's customers in Marylebone. In the last days of December the two cows placed, on the 11th of December, in the middle shed (being now suspected) were removed to the large shed. On the 31st of December and following days, several cows at the farm were found to present sores on the teats and udders; this condition was very general in the large shed; the 15th of November cows presented scars; two of the 4th of December cows had sores, one of those transferred from the middle shed being especially affected; in the middle shed several recent cases were discovered, and two early cases were noted in cows in the small shed. It was ultimately ascertained that one of the Derbyshire cows had first presented evidence of this cow disease, that then other cows in the same shed, and a 4th of December cow in the middle shed, had suffered, and that latterly the malady had spread abroad in the large shed and middle shed, and had begun to invade the small shed.

This sequence of events, when considered in relation with the scarlet fever incidence in the different districts, was quite consistent with the hypothesis that the cow malady was the cause of the infective property being communicated to the milk. In Marylebone, as already noted, cases ceased to occur towards the end of December, subsequent to discontinuance of the employment of Hendon milk. There was diminution of the disease in Mr. Y's district about Christmas, and a recrudescence was observed in the early days of January; these phenomena corresponded with the removal of the two 4th of December cows to the large shed, and the reappearance, shortly after, of new cases of cow disease in the middle shed. Finally, in the early days of January, the daughter of one of the cowmen supplied from the small shed was attacked, and Mr. Z's customers began to suffer; "these events corresponded to a nicety with the appearance for the first time of the cow disease among the animals in the small shed."

The nature of this infective cow malady was investigated from the bacteriological side by Klein, who found that certain of the viscera of affected cows presented diseased conditions similar to those observed in fatal cases of scarlatina in man, and that a streptococcus, which he called the *Streptococcus scarlatinæ*, could be isolated from material derived from the affected cows, from the blood of persons suffering from scarlatina, and from the internal organs of persons dying of scarlatina. He further found that subcultures, derived from man or from the cow, produced, when inoculated into calves, "every manifestation of the Hendon disease, except sores on the teats and udders"; that subcultures inoculated into recently-calved cows produced the characteristic ulcers on the teats; that in rodents, subcultures, whether from man or from the cow, produced identical effects, and that calves fed on subcultures established from human scarlatina developed the Hendon disease.

Much controversy arose as to these results. An eruptive disease of the teats and udders of cows in Wiltshire, which did not give rise to scarlet fever, was investigated by Crookshank, who arrived at the conclusion that this disease was cow-pox. Klein pointed out that the Hendon disease differed from cow-pox in the more rapid course of the eruption, the more pronounced infiltration of the corium, the shorter duration of the crust stage, and the more speedy progress of healing. Again, the appearances on inoculation of calves differed in the two maladies, while in the Hendon disease sores did not develop on the milkers' hands, and there was distinct visceral disease in the affected cows. Klein further investigated eruptive maladies of the cow (associated with spread of scarlet fever, or infectious disease resembling scarlet fever, to man), which were observed in Camberwell, in Glasgow, and in Edinburgh.

In other outbreaks (*e.g.*, one at Macclesfield and Upton in 1889, one at Sutton Coldfield in 1891, and one in the south-east of London in 1892) question as to cow disease having been concerned in imparting to milk the property of communicating scarlet fever was raised. It is noteworthy that in the first of these outbreaks the symptoms were not altogether typical of scarlet fever—the rash was ill-defined, desquamation scanty, kidney complication was rare, and purging and vomiting were frequent at the commencement of the illness. In other outbreaks associated with milk, difficulty has been experienced in making a diagnosis, sore throat being, as a rule, a pronounced symptom, but the type of disease not altogether typical of either scarlatina or diphtheria. Thus, Warry gives account of a prevalence of throat illness "accompanied by much enlargement of the glands of the neck and considerable weakness," which occurred in Hackney in 1900. Information was received concerning 151 cases of throat illness in 88 households, of which 138 cases occurred in 75 households receiving milk from one vendor. A somewhat similar outbreak at Hornsey was reported on by Kenwood in 1895.* It has been stated that in milk-borne scarlatina there is comparatively little tendency of the disease to spread from person to person.

In the Twenty-seventh, Twenty-eighth, and Twenty-ninth Annual

* Prevalences of throat illness, presenting similarity to the Hackney and Hornsey outbreaks, were described by Wheaton in 1894 (*Epidemiological Society's Transactions*), and by Reid, in 1896, in a paper read before the Society of Medical Officers of Health. In these instances, however, milk was not, as at Hackney and Hornsey, held to be at fault.

Reports of the Medical Officer of the Local Government Board, the outcome of further inquiry concerning the bacteriology of scarlet fever is given. The Twenty-seventh Report contains a paper by Klein and Mervyn Gordon on results obtained on investigation of "Return Cases of Scarlet Fever." It was found that the *Streptococcus scarlatinæ* or *conglomeratus*, "though ever present in the throats of patients suffering from scarlet fever in its earlier stages," could not be demonstrated, during convalescence, in the skin, the urine, or in material derived from cases which had developed otitis. It was, however, isolated in some instances in which nasal discharge was observed, and was found to persist and even to recur in abundance in the throat secretions of particular individuals long after they had, to all appearance, completely recovered from an attack of scarlet fever.

Mervyn Gordon, in the above-cited Twenty-eighth Report, gives account of careful study of the streptococcus group of organisms, and records further investigations made concerning scarlet fever cases. The *Streptococcus scarlatinæ* was originally differentiated by Klein from other streptococci mainly by its cultural characters in broth (the fluid remaining clear, while the organisms formed a single coherent conglomerate mass, or several smaller ones, at the foot of the test tube), by its ability to clot milk and to show certain peculiarities in agar cultures, and by its pathogenicity as determined in mice and rabbits. Mervyn Gordon attempted, by comparing the organism with other streptococci, to facilitate its more rapid and complete distinction from them. His further study of scarlet fever cases confirmed previous results obtained with regard to throat secretions, inasmuch as he found that the *Streptococcus scarlatinæ* was present in such secretions up to a late stage of convalescence, and even after seeming complete recovery.

Mervyn Gordon later set himself to ascertain what, if any, was the predominant organism in the scarlatinal cadaver. In the Twenty-ninth Report the result of his detailed inquiry into this matter, based on examination of material from fifty-six sources, in ten fatal cases of the disease, is given. He made careful comparison of the characters (1) of the *Streptococcus scarlatinæ* or *conglomeratus* obtainable from mild forms of scarlatinal sore throat, (2) of the same organism after passage through the mouse, and (3) of the streptococcus which is found to be the predominant organism in the scarlatinal cadaver. He concluded that it is highly probable the last-named streptococcus is in all cases a modified form of *Streptococcus scarlatinæ* or *conglomeratus*. Incidentally, certain characteristics of the *Streptococcus scarlatinæ* were noted by Mervyn Gordon, who found that it does not always clot milk, and that it shows a tendency to develop bacillary elements which at times resemble forms of the diphtheria bacillus. After passage through the mouse, the growth, in agar condensation fluid, customarily manifested an arrangement which was compared to that of "lacework," and, in some instances, colonies derived from the organs of mice were found to consist exclusively of bacillary forms. This "*Bacillus conglomeratus*," as he terms it, Mervyn Gordon regards as merely a different phase, or, in botanical language, a "sport," of *Streptococcus conglomeratus*.

Diphtheria.—In 1878 an outbreak of diphtheria in Kilburn and St. John's Wood was shown by Power to be due to milk, and "it was possible to assert that none of the agencies by which milk, after being taken from the cow, may become infective could, with any shadow of probability, have been in operation." In fact, already at this date the question of "risk from specific fouling of milk by particular cows suffering, whether recognised or not, from specific disease," was seen to be arising. In Ernest Hart's paper of 1881, seven outbreaks of milk-borne diphtheria and allied throat ailments were referred to, and in his later Report of 1897 the facts concerning fifteen further outbreaks were given. The acquirement by milk of the ability to communicate diphtheria has been attributed, as in the case of the diseases already referred to, either to storage amid insanitary surroundings and particularly to contamination by drain effluvia, or to specific pollution from an antecedent case of diphtheria affecting one of the persons engaged in connection with the milk business.

In an inquiry in 1883 at Hendon, the fact that the implicated milk was found to be "ropy" was noted by Power; and in a milk-borne outbreak at York Town and Camberley, in 1886, the same observer found that two cows presented chaps on their teats, and subsequently one cow which had suffered in this way developed a "scab or crust, not unlike those which, at a later stage of their malady, had been observed to replace ulcers on the udders of certain Hendon cows." At Barking, in 1888, and at Croydon, in 1890, contagious eruptive disease of the teats and udders of cows was found associated with spread of diphtheria to persons consuming milk derived from these animals. Klein found, in 1890 and 1891, that inoculation of the diphtheria bacillus under the skin of the shoulder of newly-calved cows was followed, in one instance, by the appearance of a papular eruption on the udder and one teat; vesicles and, later, crusts were developed, and visceral changes, corresponding to those produced by inoculation of the diphtheria bacillus in the cat, were also observed; finally, the presence of the diphtheria bacillus was demonstrated in the milk of the affected cow.

In the York Town and Camberley outbreak, Power noted the fact that the disease particularly affected the better-class customers, and a similar phenomenon has since been observed in outbreaks of scarlet fever, and is no doubt attributable, to quote Power's conclusions, to "difference of amount (and related difference of use, and difference of conservation) of milk distributed" among better-class and poorer customers.

There are certain peculiarities of milk-epidemics of enteric fever, scarlet fever and diphtheria, which are deserving of note; in the first place, the outbreak is usually sudden in its appearance, the persons attacked developing symptoms almost simultaneously, thus precluding the possibility of attributing any considerable proportion of cases to direct infection from earlier cases. Again, multiple house invasions are of common occurrence. Further, it is usually found that the households in which large quantities of milk are consumed suffer to a disproportionate extent, and in cases in which milk is stored or kept overnight, there seems to be greater liability to attack; persons who only take milk in tea or coffee, or who are in the habit of boiling the milk before using it, have, moreover, been found to escape. Again, the incidence of the disease is greater upon young children and women than upon men. Finally, in some milk outbreaks, the disease produced has been found to present certain peculiarities as regards its symptoms (this matter has already been referred to), the infective power of the disease (from person to person) has been said to be comparatively slight, and the mortality observed has been usually low.

Cholera.—This disease, like enteric fever, scarlet fever, and diphtheria, is capable of being spread by milk. The fact was demonstrated by Simpson in the case of an outbreak of cholera on board the ship *Ardenclutha*, lying off the port of Calcutta. The implicated milk in this case was found to be diluted with water derived from a tank to which the cholera poison had obtained access.

Tuberculosis.—There are certain considerations which suggest that milk may be an important agent in the conveyance of the infection of tubercle. On the one hand, bovine tuberculosis is a common disease, and milch cows are specially subject to attack; and on the other, the mortality of children under five years of age from tabes mesenterica has not shown noteworthy diminution during recent years, despite the fact that the number of deaths ascribed to tubercle of the lungs has undergone marked abatement. "Tabes mesenterica," as used in death records, is, no doubt, a very indefinite term, but it probably, "more than any other, represents tuberculosis in infancy." Failure of noteworthy diminution in the number of deaths attributed to this disease has coincided, it has been further observed, in point of time, with a large increase in the consumption of milk. It may be noted that among children aged 0—1 the death-rate from tabes mesenterica has actually increased during recent years.

The conclusion arrived at by the Royal Commission of 1895 was that, no doubt, the largest part of the tuberculosis which man obtains through his food is derived from milk containing tuberculous matter. The Royal Commissioners of 1898 reported that it was not proved "that tubercle bacilli had ever been detected in milk, unless drawn from a cow with tuberculosis of the mammary glands." The Commissioners recommended that notification of every disease of the udder should be made compulsory, and that powers should be given to local authorities to slaughter animals affected with tuberculosis of the udder, and to take samples of milk sold in their districts and make analysis of the same. The Dairies, Cowsheds, and Milkshops Order of 1899 extended the definition of disease so as to include "such disease of the udder as shall be certified by a veterinary surgeon to be tubercular," the effect of this extension being that milk derived from a cow affected with tubercular disease of the udder is prohibited from being mixed with other milk, or being sold or used for human food.

Examination of the cows in London cowsheds, made on behalf of the London County Council, in 1899, showed that, out of a total number of 5,144 cows, seven were affected with what appeared clinically to be tubercular disease of the udder, while five other cases were regarded as suspicious. Similar examinations were instituted in 1900 and 1901. Six inquiries in all were made, upwards of 4,000 cows being dealt with in each instance. The cows found to be affected with tubercular disease of the udder numbered 6, 8, 6, 4, 6, and 4, moreover 4, 6, 10, 8, 4, and 3 other cows were classed in the six successive inquiries as suspected cases of tubercular disease of the udder. Hope showed, so far as Liverpool was concerned, that samples of country milk manifested ability to produce tubercle more than twice as frequently as did samples from the town (where proper inspections are carried out). Thus, of 312 town samples, nineteen, or 6 per cent., while of ninety-five country samples, fourteen, or 14·7 per cent., were found to be infected. Again, Warry reported that seventeen, or 22 per cent., of seventy-seven samples taken from milkshops in Hackney, contained virulent tubercle bacilli, while only one udder clinically affected with tubercle was discovered in all the cowshed premises in the same parish. Examination, made by Klein, in 1900, of ninety-eight samples of country milk coming into London, showed that in seven virulent tubercle bacilli were present.

Koch, in a paper read before the British Congress on Tuberculosis in 1901, expressed the view that the extent to which infection is transmissible to man, by the milk and flesh of tubercular cattle and the butter made from such milk, is so inconsiderable as to make it not advisable to adopt any measures of prevention. In conjunction with Professor Schütz, Koch had attempted to infect nineteen young cattle, which had stood the tuberculin test, with sputum and with pure cultures of tubercle bacilli of human origin. The animals were found absolutely insusceptible, though the result was entirely different when similar experiments were made with tubercle bacilli of bovine origin. Koch, therefore, felt justified in maintaining that human tuberculosis could not be transmitted to cattle.*

The converse proposition, relating to the susceptibility of man to bovine tuberculosis, does not, Koch says, admit of a direct answer. He, however, premises that it can only be assumed with certainty that tuberculosis has been caused by food when the intestine suffers first—*i.e.*, when a so-called primary tuberculosis of the intestine is found. Such cases are admittedly extremely rare, but there is difference of opinion with regard to the significance of this fact. Sidney Martin had already noted in 1895 the absence of any lesion in the alimentary tract in the tuberculosis resulting from feeding pigs with the meat and milk of tuberculous cows. (Report of Royal Commission, appendix 3, pp. 18, 19.) Lister has pointed out that the intestinal mucous membrane is by no means a favourable site for the development of tubercle bacilli, inasmuch as only about two-thirds of the bodies of those who have died of pulmonary tuberculosis present tubercular lesions in the intestines. As bronchial mucus must be perpetually swallowed in such cases for months or years, the extent to which the intestinal mucous membrane escapes being involved is remarkable. In the child, Lister says, "the intestinal mucous membrane seems to allow the bacilli to pass through it more readily than in the adult; but, even in a young child, pathologists seem agreed that pulmonary

* In the case of swine fed daily for three months with tubercular sputum, no traces of tuberculosis were found beyond a few nodules in the lymphatic glands of the neck, and in one instance a few grey nodules in the lungs. On the other hand, tubercle of bovine origin produced conspicuous results.

tubercle is much more common than tabes mesenterica. The fact that tubercle bacilli of bovine origin are virulent in very diverse species of animals, has been held to render it likely that they are also dangerous to man. Finally it remains to note that tuberculin produces a specific reaction in tuberculous cattle, whether human or bovine tubercle bacilli have been used in its preparation.

A Royal Commission was appointed at the close of 1901 to inquire further as to the transmissibility of tuberculosis from animals to man, and from man to cattle. Meanwhile, on September 6th, 1901, a circular letter was addressed by the Local Government Board to sanitary authorities, urging that there should be no relaxation in the efforts made to deal with milk from cows suffering from tubercular disease of the udder, and with meat derived from animals affected with tuberculosis. The Board further call attention as regards the latter to the principles laid down by the Royal Commission (*See* p. 188); they note, moreover, that special qualifications should be possessed by meat inspectors, and point out that in any case of doubt the inspector should obtain the advice of the medical officer of health.

Diarrhœa.—Outbreaks of diarrhœa have from time to time been attributed to the use of milk. In the following instances question was raised as to a particular organism being at fault.

On the night of Sunday, October 27th, 1895, a sudden outbreak of diarrhœa occurred, affecting fifty-nine in-patients, at St. Bartholomew's Hospital. It was found by Andrewes that every person attacked had recently partaken of milk, and no difference was observed corresponding with use of milk in the boiled or unboiled condition. In specimens of the evacuations of patients large numbers of oval glistening spores were seen, and Klein succeeded, by making anaerobic cultures, in isolating the organism, an anaerobic bacillus, from which these spores were developed. This bacillus somewhat closely resembled, in many respects, Koch's bacillus of malignant œdema, but was distinguishable from it by certain morphological and cultural features. In many of its characteristics it resembled Botkin's *Bacillus butyricus*, but, unlike that organism, it had marked pathogenic action on guinea-pigs. Klein called the organism "*Bacillus enteritidis sporogenes*." It was isolated from a sample of milk obtained from the source from which the supply of the persons suffering from diarrhœa had been derived. Later researches showed, however, that "milk as sold retail in this country is apt to contain spores of the bacillus." It was further found by Klein that the same spores were readily demonstrable in cases of cholera nostras, and also in acute diarrhœa.

On Sunday, March 6th, 1898, a second outbreak of severe diarrhœa, affecting 146 patients, occurred at St. Bartholomew's Hospital, and again there was reason for suspecting that milk was the infecting medium. Again, too, the rods and spores of *Bacillus enteritidis sporogenes* were found to be abundantly present in the stools of affected persons. Klein, as the result of further study of the organism, was able to show that it inhabits, albeit sparsely, the human intestine in health, as well as in disease.

A third outbreak of diarrhœa occurred at St. Bartholomew's Hospital on August 5th, 1898, affecting eighty-four patients and two nurses, and Andrewes showed that the vehicle of infection in this instance was rice pudding, made with milk. The temperature attained in baking the pudding he found did not exceed 98° C., and in many parts of the pudding a range of 90° to 92° C. was obtained. Large bacilli resembling *Bacillus enteritidis sporogenes* were present in a sample of the pudding, and on making cultures and inoculation experiments in guinea-pigs it was found to be "reasonably certain that the bacilli which were, microscopically, present in the rice pudding" belonged to this species.

In each of these outbreaks a definite incubation period was observed, suggesting a bacterial infection rather than a chemical poisoning. If this infection were indeed due to the widely distributed saprophyte in question, it seems clear that its power of causing mischief must have resulted from the existence of special conditions which led to its virulence being enhanced. What these conditions are has not been hitherto determined. The ability of milk, and, curiously enough, of milk after being cooked in the process of baking rice pudding, to act as an infecting agent, seems, however, to have been clearly established by these outbreaks.

Butter.—The Sale of Butter Regulations, 1902, of the Board of Agriculture, prescribe that if the proportion of water in a sample exceeds 16 per cent. it shall be presumed that the butter is not genuine. The admixture of foreign fat is detected—by testing the specific gravity (that of pure butter fat is rarely below 910, that of margarine rarely above 904); by determining the melting point of the fat, after separation from the casein (butter fat melts, as a rule, at 88°—91° F., but the melting point of margarine is rarely above 82° F.); by estimating the amount of the insoluble fatty acids (these should not exceed 89·5 per cent., while in animal fats they are generally about 95 per cent.); and by determining the amount of the soluble volatile fatty acids, butyric, caproic, and caprylic acids (this is rarely less than 5 per cent. of the total weight in butter fat, rarely more than ¾ per cent. in margarine). A further valuable test is that known as the iodine absorption test, the amount of iodine absorbed being less in the case of pure butter than in that of animal fats, and far less than in the vegetable oils sometimes used as adulterants. Butter was shown by Shirley Murphy to have been, in all probability, the infecting agent in an outbreak of diarrhœa which occurred in a large hospital. It appears, too, that butter at times contains tyrotoxicon. Bacilli closely resembling, if not identical with, tubercle bacilli, have, moreover, been detected in butter.

Cheese.—Tyrotoxicon has been shown to be present in cheese, and also in milk, cream, and butter. (For the test employed, *see* p. 194.) Vaughan isolated this substance, which he regarded as a diazo-benzene-butyrate, from cheese which gave rise to illness, affecting in all some 300 persons, in Michigan, in 1883 and 1884. Outbreaks of cheese poisoning occurred in various parts of London in 1901, which were traced to the use of Dutch cheese. In Finsbury, seventeen cases were heard of, and it was ascertained that tyrotoxicon was present in samples of the implicated cheese. (Newman, *Public Health*, January, 1902.) The effects produced by tyrotoxicon are in the main gastro-intestinal disturbance, together with, in some instances, symptoms somewhat resembling those of atropine poisoning.

Preserved Foods.—Meat is preserved by freezing, by salting, and by drying; milk by concentration and the addition of sugar; vegetables and fruits by drying. Meat is also preserved by heating it in tins, which are, after exclusion of air, hermetically sealed. The tins under such circumstances usually present, by reason of the vacuum produced, concave upper and lower surfaces. Sometimes putrefaction occurs in the contents of such tins, which become "blown" as result of growth of bacteria and accumulation of gas consequent upon their development. In some instances blown tins have been punctured in order to allow the gas to escape, and the aperture has been subsequently closed by application of solder. The consumption of the contents of tins which have been dealt with in this way is, of course, attended with serious risk.

It has been, occasionally, found that metallic impurity has been taken up by food preserved in tins. The presence of tin sulphide has been demonstrated in tinned foods, in some instances, and in others lead has been found; when vinegar is used, as in pickles, fish, etc., there is special risk of metallic impurity being taken up. Tinned vegetables, and particularly peas, are sometimes coloured green by exposing them to the action of sulphate of copper. It has been alleged that an insoluble compound of the copper and the legumen of the peas is thus produced, and that no harm is, therefore, likely to result in connection with this practice; on the other hand, it has been maintained that the albuminate of copper which is formed may be rendered soluble by the digestive juices.

Shellfish.—The notion has for some years been here and there entertained that certain forms of shellfish, and notably oysters, may act as a medium for transmitting the poison of enteric fever. In connection, moreover, with cholera prevalences in this country in 1893, shellfish from Cleethorpes and Grimsby fell under suspicion of having served to spread that disease. Sir Wm. Broadbent in 1895 expressed the opinion that the evidence of communication of enteric fever by means of oysters was "of such a character as to produce conviction" in his mind. In the preceding year an outbreak of enteric fever had occurred at Wesleyan University, Middletown, Connecticut, in which the circumstances were such as to make it quite clear that oysters were at fault, and the report of Professor Conn upon that outbreak was received in England at about the same date as that on which Sir Wm. Broadbent's announcement was made. Since that time other instances of conveyance of the infection of enteric fever by oysters have been recorded; a case reported by Chantemesse, in which the contents of a barrel of oysters were eaten by fourteen persons at Saint André in Hérault, may be particularly referred to—all fourteen persons became ill and manifested gastro-intestinal symptoms, and in two instances well-marked enteric fever, which ended fatally, was developed. The following particulars concerning the Connecticut outbreak, which was one of special interest, may be given.

Between October 20th and November 9th, 1894, twenty-five cases of sickness developed among the students at Wesleyan University. Of these twenty-three were diagnosed as enteric fever, thirteen proved to be severe cases of the disease, and four deaths occurred. Investigation of the water, milk, ice, and ice-cream, supplied to the students, failed to throw any light on the cause of the outbreak, and no defects of drainage or plumbing arrangements were discoverable which could be held accountable for it. The lady students entirely escaped. As regards the men, it was noted that those who belonged to three of the seven "college fraternities" (which included among their members most of the students) had especially suffered; indeed, of the twenty-three patients all but three belonged to those three fraternities. No drainage defects were discoverable in the club-houses belonging to the three fraternities, and careful inquiry into the ordinary food supplies provided at these club-houses elicited no clue to the origin of the disease. It was found, however, that on October 12th suppers were given by each fraternity, on the occasion of certain "society initiations," and one of the three patients who did not belong to any of the fraternities specially attacked, had attended the initiation banquet held by one of these three clubs.

Inquiry concerning the articles of food and drink supplied at the suppers showed that "only one article of food or drink was used by the three societies which was not used equally by the other four fraternities. This article of food was oysters, and they were eaten raw." Of the other four fraternities two did not eat oysters at all, one ate oysters obtained from a different source, and the fourth fraternity derived oysters from the same source as the affected fraternities, but only used them cooked. Further, another of the three exceptional cases referred to above* was accounted for on the hypothesis that the oysters were at fault; this patient had, in fact, partaken of the implicated oysters, for though he had not eaten them at an initiation banquet, it transpired that he had purchased some belonging to the same batch from a dealer in the town. Six cases of enteric fever were later traced among visitors who had partaken of oysters at the three initiation suppers, and yet another attack was heard of as having affected a person who had obtained oysters in town from the dealer who had supplied the fraternities involved in the outbreak.

On making investigation concerning the implicated oysters, it was found that they came from a creek "where they had been allowed to fatten, for a day or more, within 300 ft. of the outlet of a private sewer, and in such a position as to make contamination from the sewer a possibility. At the time when the oysters were thus deposited, there were two persons in the house supplying the sewer who were in the incubation period of typhoid fever, the period during which no attention would be paid to their excreta." It was, further, found that some of the oysters from this creek had been sent to Amherst College, and inquiry showed that of seven cases of enteric fever which had occurred among students at that institution, in five there was a history of having partaken of the oysters in question, on October 12th, the date of the initiation suppers at Wesleyan College. As Professor Conn, who reported on these facts, remarked, they show that "the public health is placed in jeopardy when oyster dealers, for the sake of producing plumpness,

* The cause of illness in the third case could not be traced. There was some doubt, however, as to whether the case was one of enteric fever.

place oysters in the mouths of freshwater creeks in close proximity to sewers."

An exhaustive inquiry was made by Bulstrode concerning the extent to which oyster layings in this country were subject to risk of sewage contamination; his report appeared as a supplement to the report of the Medical Officer of the Local Government Board for 1894-5. In the same volume were also published Klein's observations upon the viability, in sea-water, of the typhoid bacillus and of Koch's vibrio, and upon the phenomena observed when oysters are brought into relation with the organisms named. Briefly stated, Klein's conclusions were that both organisms remain viable in sea-water for upwards of a fortnight, "the typhoid bacillus retaining its characteristics unimpaired, whilst the cholera vibrio tends to lose them"; that typical typhoid bacilli were recoverable from oysters, which had been kept in sea-water infected with these organisms, as late as the seventeenth day, but that Koch's vibrio appeared to undergo definite modification, within the shell contents, even more rapidly than had already been found to be the case when this microbe was kept in sea-water in which oysters had been placed; furthermore, in one instance an oyster, obtained from a source exposed to risk of sewage contamination, was found to contain the typhoid bacillus.

Bulstrode's report contains information concerning other forms of shellfish. To the mussel attention was particularly directed: it, like the oyster, is sometimes eaten uncooked; mussels are, however, usually subjected to a cooking process; periwinkles and cockles appear to be almost always cooked. It is doubtful whether, in "cooking," the temperature attained is sufficient to ensure the destruction of the micro-organisms of enteric fever or cholera, should they chance to be present. M. K. Robinson, as long ago as 1883, in commenting upon two cases of enteric fever, laid stress on the fact that the persons attacked had consumed mussels procured from the neighbourhood of the Ramsgate sewer outfall. At Teignmouth suspicion was excited, in 1894, with regard to cockles or mussels obtained from the neighbourhood of the outfall drain of an infectious diseases hospital. Question arose, too, in 1895, with respect to mussel beds, in the river Blyth in Northumberland, situated in dangerous proximity to the sewer of an isolation hospital. Again, Newsholme, as the result of inquiry made in 1894-5-6 concerning enteric fever at Brighton, was led to suspect that raw mussels, procured from a sewage-contaminated river, were at fault. Other instances in which mussels have fallen under suspicion have since been observed. Klein has recently (Annual

Report of the Medical Officer of the Local Government Board, 1899-1900) made investigation, with regard to the extent to which cockles, obtained from areas on the seashore obviously polluted by sewage, retain in their interior living microbes of sewage, and, in particular, as to their ability to harbour living typhoid bacilli.

Under certain circumstances consumers of mussels develop a group of symptoms (diarrhœa, vomiting, and urticaria) known as mussel poisoning. The phenomenon has been attributed to copper taken up by the mussels from docks, ships' bottoms, etc., to the spawn of the starfish, to a poison contained in the gills of the mussel, and to a small crustacean (*Pinnotheres pisum*) which is sometimes found in the mussel's gills. In an outbreak which occurred at Wilhelmshaven, in 1885, it was found that a toxic principle could be extracted from the liver of the implicated mussels. Brieger thus isolated a ptomaine, $C_6H_{15}NO_2$, which he termed mytilotoxine, and which he supposed was produced by a special microbe. This ptomaine is, at the present time, generally supposed to be the immediate cause of the symptoms of mussel poisoning.

Vegetable foods are the main source from which carbo-hydrate is obtained; very little fat is, however, derived from them (oats and maize contain a considerable quantity of fat, as also do some nuts; olive oil, moreover, is an instance of a vegetable fat, but fat, as a rule, is obtained from animal foods). Vegetables contain proteid in the form of gluten, the substance produced when the globulin and albumose of wheat flour are acted upon by water; legumin and conglutin—substances derived from the proteids of the seeds of the leguminosæ—may also be present.

In the case of the seeds of the cereals, and of some leguminous plants, the outer coats are usually first removed, and the remaining inner portions are then converted into flour. This separation of the outer coats generally somewhat lowers the percentage of proteid, and more distinctly lowers that of salts; the percentage of carbo-hydrate, on the other hand, is increased. The bran of wheat contains much cellulose, which cannot be digested, and is, moreover, said to interfere with the absorption of digestible foods; cellulose acts, too, as an irritant, stimulating peristaltic movement, and for this reason many persons cannot eat brown bread which contains it. By special treatment it has been sought to minimise, as far as possible, the irritating property of the bran, and thus to utilise the whole grain in making flour. Such "whole-meal" flour yields a somewhat larger percentage of proteid and salts than ordinary flour does, but, on the other hand, it contains also excess of cellulose. The leguminous seeds (peas, beans, etc.) contain some 20 to 25 per cent. of proteid, *i.e.*, even more than meat, but the vegetable proteid is found to be less digestible than that of flesh. Certain "oily seeds," as they are termed—the walnut, hazel-nut, almond, peanut, etc.—contain almost as much proteid as the pea and bean, and they also yield a large percentage of fat. These oily seeds are not, however, easily digested.

The most important carbo-hydrate of vegetable foods is starch; sugars, however, occur, *e.g.*, cane sugar in the sugar-cane and grape sugar in ripe fruit; dextrin is present in gums, and indeed is generally found in small amount in association with starch. Starch grains vary in structure and size, according to their origin, and study of these variations enables distinction to be made between starch granules

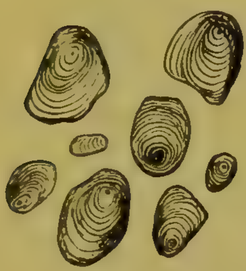

FIG. 34.
Potato Starch.

FIG. 35.
Bermuda Arrowroot Starch.

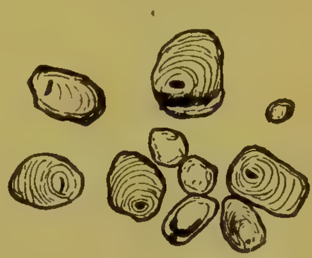

FIG. 36.
St. Vincent Arrowroot Starch.

derived from one or other source, and facilitates the detection of adulteration. The starch grain, when examined (after mixing the starch with a drop of a solution of glycerine and water) under a magnification of about 200 diameters, is seen to present a hilum, about which more or less distinctly marked lamination is observed.

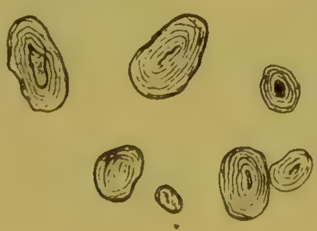

FIG. 37.
Pea Starch.

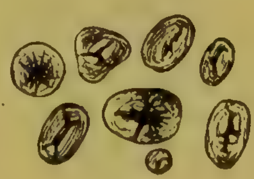

FIG. 38.
Bean Starch.

Again, some grains are of even contour, or unfacetted, having been originally free in the cell cavity; others are facetted from juxtaposition of other grains in the cell cavity. These characters, taken together with differences of size and shape, serve to distinguish between the several kinds of starch grain.

To the unfacetted group, those with even contour, belong potato starch, most varieties of arrowroot, pea, bean, wheat, barley, and rye. To the group of facetted grains belong sago, tapioca, Rio arrowroot, rice, maize, and oats.

The unfacetted group includes a sub-group (potato starch and

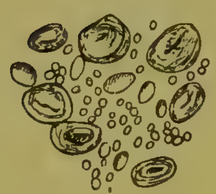

FIG. 39.
Barley Starch.

FIG. 40.
Wheat Starch.

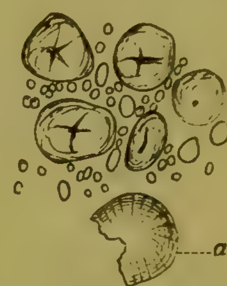

FIG. 41.
Rye Starch. *a*, Crushed Grain.

certain kinds of arrowroot), in which the grain is ovoid in shape, with excentric hilum and with marked lamination. A second sub-group (pea and bean starch) has oval grains with less distinctly marked lamination. A third sub-group (wheat, barley, and rye) presents rounded grains. In rye the hilum is often star-shaped,

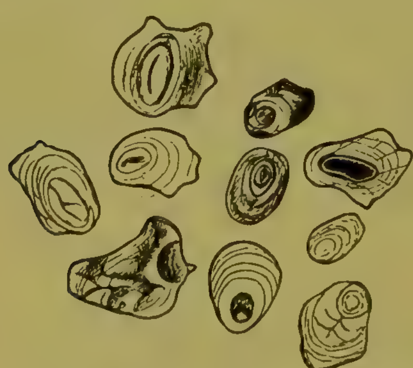

FIG. 42.
Sago Starch.

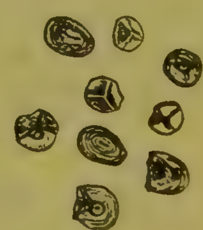

FIG. 43.
Tapioca Starch.

and deeply fissured. Wheat and barley are almost indistinguishable one from another, but wheat contains, as a rule, mainly large and small grains, with but few of intermediate size, while barley has numerous medium-sized grains.

The facetted starches include a sub-group (sago, tapioca, maize, and Rio arrowroot), with partially facetted grains, that is to say, each grain commonly presents a rounded free surface as well as a facet or facets. In another sub-group (maize, oats, and rice) the grains are described as altogether facetted. Maize grains are much larger than oat and rice grains. Oat-starch grains are usually massed in clusters. Tahiti arrowroot resembles maize, but has sharper angles.

Flour may be adulterated by addition of potato-starch, pea, bean,

FIG. 44.
Maize Starch.

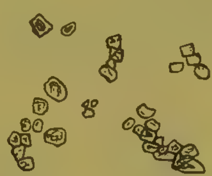

FIG. 45.
Rice Starch.

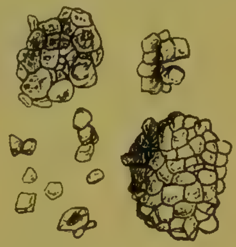

FIG. 46.
Oat Starch.

oats, maize, rice, or barley-starch. The last-named is the most difficult to distinguish on microscopic examination. In addition, however, to the differences already mentioned, it may be noted that the outer coats of the barley grain are more delicate in structure than those of the wheat grain. Moreover, the outline of the barley cells is serrated, while that of the wheat cells is beaded. Buckwheat, which is sometimes added to flour, may also be distinguished by the character of the outer coats, and by the presence of large cellulose spaces enveloping the grains.

Alum and other mineral adulterants may be looked for if the amount of ash exceeds 2 per cent. of the flour. On pouring a fresh decoction of logwood and some solution of ammonium carbonate upon a piece of bread, a blue colour is developed after the lapse of some minutes if excess either of alum or magnesic carbonate be present. The blue colour is permanent, on drying, to a more marked extent in the case of alum than it is in that of magnesic carbonate. With pure bread a pink colour is yielded, which turns brown on drying. Pure bread may contain a small amount of phosphate of alumina, equivalent to as much as 6 to 10 grains of alum in the 4-lb. loaf. Alum enters into the composition of some baking powders, and is also added to inferior bread, with a view to checking fermentative action; this form of adulteration is, however, rarely practised at the present time. It was formerly quite common to find the equivalent of 40 grains of alum, or even more, in the 4-lb. loaf, and when administered in such quantities dyspepsia and constipation were found to be associated with the consumption of the bread.

The presence of various fungi can sometimes be detected on microscopic examination of flour. *Ustilago carbo* (smut) forms a black dusty powder in corn grains ; the spores are smooth, spherical, and light brown in colour. *Tilletia caries* (canker) appears as a moist black powder; the spores are globular, with net-like ridges. *Puccinia graminis* presents characteristic teleutospores, the appearance of which is depicted in Fig. 47. *Mucor mucedo*, *Penicillium*, and *Aspergillus* are also frequently found in decomposing flour. The *Acarus farinæ* (Fig. 48) is sometimes found in

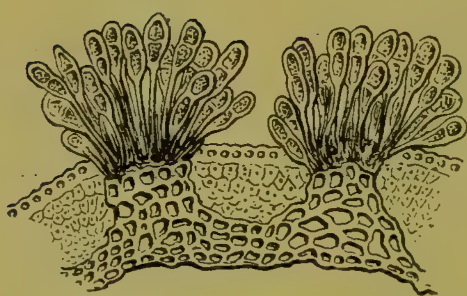

FIG. 47.
Puccinia graminis.

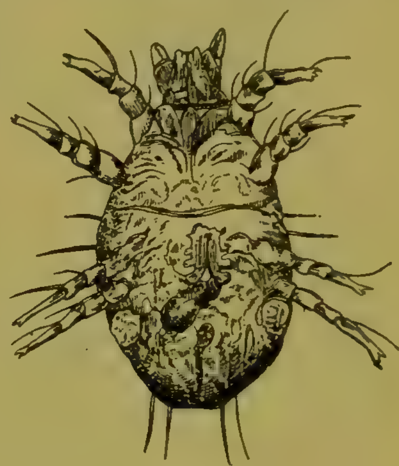

FIG. 48.
Acarus farinæ.

flour, and the weevil, *Calandra granaria*, and the larvæ of other insects may at times be detected. The "ear cockle," *Vibrio tritici*, is a minute, worm-like parasite, sometimes found in damp wheat.

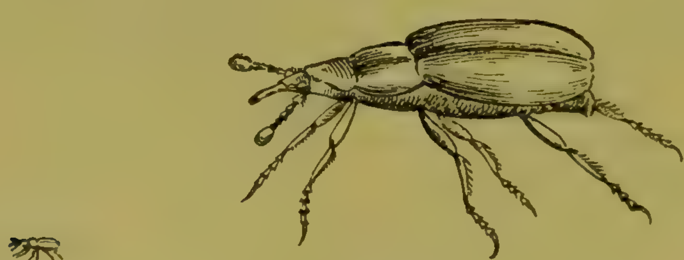

FIG. 49.
Calandra granaria.

Ergotism, a condition accompanied by diarrhœa, vomiting, and in some instances loss of sensation, with paralysis and gangrene of the extremities, was of common occurrence in the Middle Ages, and more particularly on the Continent, as a result of eating black bread made from rye contaminated with ergot. The sclerotium or permanent mycelium, known as ergot, forms dark, horn-like growths, which

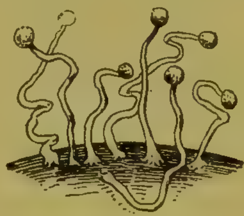

FIG. 51.
Claviceps purpurea.

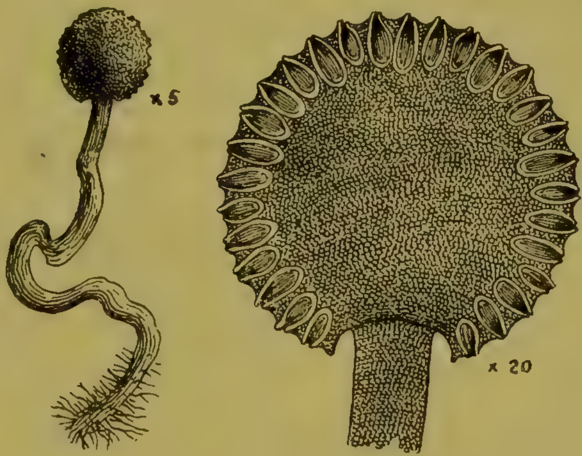

FIG. 52.
Clubbed Heads of *Claviceps purpurea*, magnified one head cut through longitudinally.

project beyond the rye grains. If the dark growth be removed and placed under favourable conditions, it sprouts, forming whitish shoots, terminating in globular heads of a purple colour. This growth is termed *Claviceps purpurea*, and the clubbed head is found on section to present the appearance shown in Fig. 52. At its margin are numerous flask-shaped perithecia, opening externally, each of which contains many fine transparent bladders, packed with needle-like spores. The spores when ripe are discharged, and if they obtain access to the flowering rye, the sclerotium (or ergot) is developed in it. Ergotism is of rare occurrence at the present time; the ergot is carefully col-

FIG. 50.
Spike of Ergotised Rye.

lected when it is found, as its value as a drug is considerable. It is only quite exceptionally met with in flour.

Alcoholic Beverages.—Beer contains from about 3·5 to 7 per cent. of alcohol. It yields, moreover, some 5 per cent. of sugar and dextrin, and is thus capable of supplying carbo-hydrate in appreciable quantity. Malt beers are made by inducing yeast-fermentation of sugar derived from the starch of grain, by the "malting" process. Non-malt beers are obtained by fermenting glucose, and allied substances, obtained by the action of sulphuric acid upon starch.

In November, 1900, Reynolds, of Manchester, suggested that arsenic contained in beer was the cause of an outbreak of arsenical poisoning in that city. The epidemic was not confined to Manchester, but affected other districts in Lancashire, in Staffordshire, and elsewhere; Manchester and Salford were specially involved, and in those boroughs at least 3,000 persons were attacked. A Royal Commission was appointed to inquire into the matter, and in a First Report, published in 1901, the Commissioners state that the "epidemic of sickness has been traced to beer from particular breweries, the latter having been users of brewing sugars supplied by a single firm." In samples of glucose obtained from this firm, amounts of arsenic, as arsenious oxide, were found varying from ·008 to ·131 per cent. (·56 to 9·17 grains per pound); in samples of invert sugar arsenious oxide to the extent of ·02 and of ·062 per cent. (1·4 and 4·34 grains per pound) was found.

The implicated brewing sugars, it was ascertained, "became thus seriously contaminated by arsenic, in course of manufacture, through the use of sulphuric acid supplied by a single firm of acid makers." The last-named firm did not inform the implicated makers of brewing sugars, that acid supplied from February to November, 1900, must have contained arsenic, stating that they did not know the purpose for which it was required; while the manufacturers receiving the acid were under the impression that they were regularly obtaining a pure acid made from brimstone. The amount of arsenic found in implicated specimens of beer was, in exceptional cases, as high as $1\frac{1}{2}$ grains per gallon (in one case 3 grains per gallon was detected), but, as a rule, the quantity of arsenic did not exceed 1, or $\frac{1}{2}$, or $\frac{1}{4}$ of a grain per gallon, or less.

Many of the sufferers were heavy drinkers of beer; but others had taken only quite moderate amounts, and the Commissioners conclude, therefore, that caution is necessary "in comparing the effect of arsenic in small quantities, taken at irregular intervals, along with beer and in uncertain relation to food, with the effect of its medicinal administration under medical supervision." They point out, moreover, that many of those attacked presented symptoms "hardly, if at all, to be distinguished from those of alcoholic peripheral neuritis, which hitherto it has been customary to associate with the consumption of large quantities of alcohol by spirit drinkers." In Manchester and Salford certain medical men had, however, prior to 1900, come to regard this form of disease as one especially affecting beer drinkers. Inquiry was made for the Commission as to the existence of arsenic in beer, before the epidemic, and the Commissioners state that they cannot doubt that beer has in the past contained arsenic, and they add that, since the epidemic, arsenic has been found in beers from certain breweries not using the implicated brewing sugar, "occasionally in quantities such as $\frac{1}{10}$ grain per gallon, and frequently in smaller amounts, such as $\frac{1}{50}$ to $\frac{1}{100}$ grain."

Evidence was forthcoming showing that arsenic may gain access to beer—by way of brewing sugars (in cases in which the mineral acid employed in the manufacture of glucose from starch, or of "invert sugar" from cane sugar, has been arsenical); by way of malt (if fuel which contains arsenic be employed, material quantities of arsenic may be deposited on malt in the process of malting, and so reach beer); and in other ways (by use of chemical substances employed for various purposes).

The Commissioners "are not prepared to allow that it would be right to declare any quantity of arsenic, however small, as admissible in beer or in any food." With regard to beer, they recognise "the desirability of ultimately defining, in terms of a standard quantity of beer and of a standard test, a proportion of arsenic to be regarded as altogether inadmissible," but they propose to institute further inquiry before recommending the standard test which should be imposed. With regard to other articles of food and drink, they state that they have hitherto found no evidence of arsenical contamination, but that they propose to make further inquiry into the matter. They recommend in the meantime that the Board of Inland Revenue should possess, and should exercise, powers enabling them "to specify, in detail, individual ingredients of beer which are liable from their origin, or mode of preparation, to be contaminated by arsenic: to prescribe for every such ingredient and for the materials used in their preparation an adequate test, which should ensure their freedom from arsenic; and to prohibit under penalty the use in a brewery of any material which infringes the prescribed test."

Beer has, in some instances, been found to take up lead from the vessels in which it has been kept, and it has been noted that persons who habitually consumed beer, which had stood overnight in contact with lead and had thus become polluted, were specially liable to be attacked. The Devonshire colic, which was shown by Sir George Baker to be caused by drinking cider, was an instance of lead poisoning on a large scale, in which the medium of conveyance of the poison was an alcoholic beverage.

Wines contain from 7 or 8 per cent. of alcohol (light wines), up to as much as 17 or 18 per cent. (port and sherry). Natural wines made by fermenting grape juice do not, as a rule, yield more than 12 per cent.; the wines with a higher percentage of alcohol are fortified by addition of spirit. Wines contain varying amounts of sugar; vegetable acids, which impart to wine its antiscorbutic properties, are also present.

Spirits are manufactured by the process of distillation; in the case of brandy, fermented grape juice is used; in that of whisky, malted grain; in that of gin, malt with addition of certain flavouring substances (juniper berries, etc.); and in that of rum, molasses is employed. Spirits usually contain about 50 per cent. by weight of alcohol; rather less, as a rule, in the case of gin, and rather more in that of rum. Their chief ingredient is, of course, ethylic alcohol; variable amounts of the higher alcohols, compound ethers, and empyreumatic bodies, such as the substance known as "furfurol," may be also present. Some of the harmful effects of alcohol are probably attributable to such "bye-products." The quantity of "fusel oil" (the name given to the group of higher alcohols) should not exceed ·02 per cent. Furfurol, present in some kinds of whisky to the extent of about ·005 per cent., is said to be specially deleterious, but its amount diminishes as the spirit "mellows" on keeping.

The abuse of alcohol is productive of degenerative changes of the stomach, liver, and nervous tissues, and causes diminished power of resistance to certain forms of acute disease, particularly to pneumonia; the ability to withstand intense cold is also found to be diminished by use of alcohol. It is said that in moderation alcohol may be taken without ill effect, and the equivalent of 1 oz. of pure alcohol daily, is usually given as being the amount which should not be exceeded. Individual susceptibility, however, plays a considerable part in the matter, as in some persons, and certainly in most young people, this quantity of alcohol is productive of harm. The immediate ill effects attendant upon immoderate indulgence in alcohol are sufficiently apparent; the extent to which its habitual use in excess, but to a degree short of causing complete loss of control over the higher nerve centres (the coma and delirium of the drunkard) is responsible for degenerative changes in the brain and nerves is, perhaps, not yet fully appreciated. Alcoholic neuritis and the connection between alcoholic abuse and certain forms of insanity, are subjects to which attention has only been directed in quite recent years. The question as to how far alcohol *per se* is operative in causing degenerative kidney change, has been much debated; the relationship of the various beverages which contain alcohol to gout is also a subject on which there have been differences of opinion. Beer is said to be a great "gout producer." Beer drinkers tend to become obese, and it may be noted that beer, owing probably in the main to the "lupulin" it contains, acts as a depressant upon the nervous system.

CHAPTER VI.

THE COLLECTION, REMOVAL, AND DISPOSAL OF REFUSE.

The problems connected with the collection, removal, and disposal of the refuse of communities have received a great deal of attention in recent years; not only has there been a growing tendency to insist upon a higher standard in such matters on general grounds—the importance attached to cleanliness, and to the prevention of offence to the eyes and nose, being now far greater than it was a century ago—but there has also been increased recognition of the danger to health which results, from accumulations of filth and from the adoption of faulty methods in connection with refuse disposal; and, further, the collection of large aggregations of persons in towns has thrown the evils attendant upon neglect into bolder relief. The nature of the solution of the problems in question depends, to a large extent, upon the character of the material to be dealt with. Refuse matters may be roughly divided into house refuse (ashes and vegetable and animal material), various kinds of animal refuse (*e.g.*, those associated with the keeping and the slaughtering of animals, and with the utilisation of waste animal products), slops and liquid refuse, and human excreta.

I.—House Refuse.

Ordinary London house dust has been found to contain, as a rule, upwards of 60 per cent. of cinders and ashes, some 20 per cent. of fine dust, 4 to 5 per cent. of various vegetable, animal, and mineral matters, about 4 per cent. of waste paper, and some 3 per cent. of straw and fibrous material, while the remaining constituents comprise bottles, broken glass, tins, crockery, bones, rags, and scraps of iron. Both the collection and disposal of these materials were formerly almost exclusively in the hands of contractors, who carted away the dust, caused it to be sorted, sifted, and separated into "hard core" (broken crockery, brickbats, glass, old shoes, bits of rag, etc.), "soft core" (vegetable and animal refuse), and "breeze" (ashes). The sorted materials were sold for various purposes, and whatever could not be disposed of was deposited upon land with the object either of raising the natural level of the ground for building purposes, or of replacing gravel or sand which had been previously excavated from the site. In the neighbourhood of towns the combustible materials obtained from the refuse were, as a rule, utilised in brickmaking.

Much annoyance was experienced under this system, in connection both with the collection and the disposal of the refuse. The infrequency of the scavengers' visits made it necessary to employ large brick or wooden receptacles (dust-bins) for the purpose of storage, and the huge accumulations of material collected in these receptacles were apt to give rise to considerable nuisance. It is now usual to insist, in towns, upon the provision of pails of non-absorbent material, of limited capacity, and furnished with covers so as to prevent rain and moisture obtaining access to their contents; these pails should be emptied at least twice a week, and in some places daily removal is insisted upon; in summer time, especially, frequent removal of the refuse is particularly necessary. Much can be done by the householder in the direction of preventing offensive odours arising from the refuse, if a certain amount of care is exercised in the selection of the materials deposited in the pail; moist vegetable and animal matter should be burnt instead of being allowed to undergo decomposition in the dust receptacle. Nuisance associated with the removal of refuse can, moreover, be reduced to a considerable extent by the use of carts specially constructed for the purpose, provided with covers, and charged in such a way as to prevent unnecessary blowing about of dust.

As regards the subsequent treatment of the refuse, the manipulation, sorting, etc., formerly practised in contractors' yards, were undoubtedly most objectionable, inasmuch as they affected prejudicially not only the persons employed, but also people living in the neighbourhood; moreover, nuisance was continually complained of in connection with the removal of material by barge or by rail; finally the practice of "shooting" the refuse, on land, was attended not only by offence to persons living near the "shoots," but in cases where the sites upon which it had been deposited were afterwards used for building purposes, there was serious risk to the health of those who occupied houses built upon the polluted soil. These drawbacks led to experiments being made as to the practicability of disposing of house dust by burning; and during recent years various types of "destructor furnace" have been invented, some of which dispose of the refuse without causing nuisance. Not only is this the case, but, in a few instances, it has been found possible to utilise the heat developed in the furnaces for generating steam, and thus to obtain power for driving machinery, in connection with electric lighting or other installations.

The appliances used are either "low temperature" or "high temperature" destructors. In the former, in order to prevent nuisance, a "cremator" is sometimes employed through which the fumes from the burning refuse are passed, before being allowed to escape into the outer air. In the high temperature destructor, the principle adopted has been to place the exits, from the furnace to the flue, at some distance from the point at which the material to be burnt is introduced, or otherwise to ensure that all fumes evolved shall be thoroughly exposed to heat before being allowed to escape from the furnace; moreover, a steam blast, or other forced draught, has been employed with great advantage, and a temperature of from 1,500 to 2,000° F. has, by these means, been attained; under such circumstances a destructor can be worked without producing any nuisance.

In high temperature furnaces, ten tons and upwards of refuse can be burnt in a day by each furnace cell; while in the low temperature destructors not much more than half this quantity can be dealt with. The wear and tear is greater in the case of high temperature destructors, but the increased efficiency more than compensates for this. The essential features, from the point of view of nuisance prevention, are that the temperature attained must be considerable, and the arrangement adopted such that all fumes evolved are exposed to great heat for a sufficiently long time to altogether prevent the escape of undecomposed vapour into the chimney-shaft.

II.—Animal Refuse.

The method employed for disposing of cow-dung, horse-dung, etc., is usually that of applying these materials to land as manure. Great nuisance is caused when large collections of dung have been allowed to accumulate, and are then disturbed in the process of removal. Dung receptacles should therefore be of limited capacity, and the emptying of their contents should be effected at frequent intervals; again, it is of importance that they should be constructed of impervious material and protected from the rain, and on no account should they be sunk below the level of the ground. In stables it has become a common practice to use absorbent litter, sawdust, peat-moss, etc., with the object of soaking up urine and thus obviating the necessity of providing for drainage. Serious nuisance is apt to be caused if this plan is adopted, unless removal is effected frequently and with due precautions.

Bones, fat, and offal from slaughter-houses, other waste animal products, and especially fish and game offal, are apt to be a source of great annoyance. The scavenging should be carried out with such frequency as to ensure that decomposition is not far advanced, and effort should be made, by the use of covered receptacles, or, if necessary, of specially constructed tanks, etc., to prevent the escape of effluvia. Offensive animal material and excrement, in places where the water carriage system is not in force, are sometimes conveyed through the streets at night time. This practice is open to objection, for it is desirable that any slopping or spilling which occurs should be at once detected and remedied, and hence removal in the hours of daylight is indicated; it is, however, desirable that a time should be chosen when the streets are not frequented, and by-laws, approved by the Local Government Board, usually specify, therefore, that the operations shall be carried out in the early hours of the morning.

III.—Liquid Refuse.

Household slops, the waste-water from kitchen sinks and from baths, drainage from cowsheds, stables and manufactories, street washings, and urine from public urinals, all contribute to render the liquid waste from communities eminently putrescible, and as a matter of fact it is found that the sewage from midden towns (in which human excreta do not obtain access to the sewers) does not differ materially in composition from the sewage of water-closet towns. The Rivers Pollution Commissioners (1868) published the following table:—

Average Composition of Sewage in parts per 100,000.

	Total solids in solution.	Organic carbon.	Organic nitrogen.	Ammonia.	Total combined nitrogen.	Chlorine.	Suspended matter.		
							Mineral.	Organic.	Total.
Midden towns ...	82·4	4·181	1·975	5·435	6·451	11·54	17·81	21·30	39·11
Water-closet towns	72·2	4·696	2·205	6·703	7·728	10·66	24·18	20·51	44·69

The Commissioners found that "for agricultural purposes 10 tons of average water-closet sewage may in round numbers be taken to be equal to 12 tons of the average sewage of midden towns."

Considerable difficulty is experienced in some instances in dealing with the excess of liquid in the sewers at times of heavy rainfall, and in countries where there is much rain, and under certain other special circumstances, the plan is sometimes adopted of disposing of rainwater and of domestic waste-water independently of one another. Mr. F. O. Ward invented the phrase, "The rainfall to the river and the sewage to the soil." In cases in which a "separate system" of disposal, as it is called, is adopted, the sewers need not be of such large dimensions as would otherwise be necessary, and the amount of sewage to be dealt with at the outfall is smaller and more uniform as regards quantity and composition; again, material derived from road washings does not collect in the sewers, and there is no liability to flooding of basements with sewage in times of heavy rainfall. On the other hand, the separate system entails duplication of pipes, and the rainwater, becoming, as it does, charged with much polluting material, cannot be regarded as clean water—indeed, it is liable to cause complaint and annoyance if permitted to escape without treatment into a stream or watercourse.

Under ordinary circumstances it is usual to discharge liquid refuse into the sewers, and the subject of the construction of drains and sewers for this purpose will be considered in connection with the disposal of excremental matters. In the case of isolated habitations and small villages, where no system of sewerage obtains, liquid waste should be collected in watertight cesspools, constructed of brickwork rendered in cement with a backing of well-puddled clay, properly covered and ventilated, and situated at a sufficient distance (at least 50 ft.) from any dwelling, and at least 80 ft. from any source of water supply.

Cesspools require to be emptied regularly, and in the country, where the nature of the soil is favourable, the plan of applying the slop waters to the land is often adopted. The piece of ground selected for the purpose usually requires to be underdrained; the waste waters are conveyed to it by a system of agricultural pipes with open joints, and in order to secure, as far as possible, distribution of the waste material over the whole extent of the land, it is usual to cause it to be discharged at intervals from a syphon flush tank.

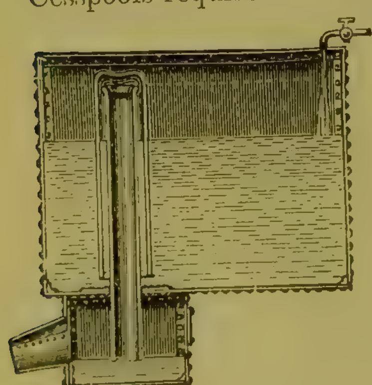

FIG. 53.
Rogers Field's Flush Tank.

For this purpose Rogers Field's "annular syphon tank" is often employed; the upper end of the descending arm of the annular syphon (*See* Fig. 53) has a lip projecting downwards and inwards, so that, when the waste-water reaches the level of the upper end of this descending arm, it is directed towards the centre of the tube by the lip, and, carrying air down with it, causes the syphon to be set in action; this result is satisfactorily attained even when only a small dribble of water is passing into the tank. The syphon, once put in action, empties the whole of the contents of the tank. In cases where such a device is not made use of, the waste-water, owing to the smallness of the amount of the discharge, is apt to penetrate only a short distance into the sub-irrigation pipes; by collecting the liquid, however, until a whole tank-full has accumulated, and then causing the entire amount to be discharged at a given moment into the drains, the waste-water penetrates further into the system of pipes, the proximal portions of which are thoroughly flushed out by the rush of liquid, and the whole area of the plot of land, which has been provided with sub-irrigation pipes, is utilised.

IV.—Excremental Matter.

Advantages and Disadvantages of Various Methods of Disposal.—For the most part, no doubt, in former ages excreta were deposited in pits or dug into the ground, though, even in very early times, the method, of conveyance of liquid refuse by sewers into the nearest watercourse, was adopted in exceptional instances. The plan of covering excreta with earth, employed by some animals from time immemorial, has within recent years been made the basis of a method of practice generally associated with the name of a clergyman, the Rev. Henry Moule (who first advocated the use of earth closets); this method is well adapted, under certain circumstances, for use in the case of isolated habitations (*See* p. 231)

When sewers came into common use for the purpose of carrying off surface water, and when the increasing employment of water for domestic purposes led to its discharge into these sewers, it could not fail to be apparent that here was a means ready to hand for disposing of excreta. Various crude forms of apparatus were from time to time recommended. In 1778, Joseph Bramah, a cabinet maker, patented a water-closet presenting considerable resemblance to the modern valve-closet, and it became a common practice, by means of appliances of this character, to wash excreta and other waste material into cesspools. In 1815 the law prohibiting the transmission of waste products from houses into sewers was repealed, and the convenience of the new system was so obvious, that from 1847 onwards it was made compulsory in many instances.

When this method of water-carriage, largely in consequence of the efforts of sanitary reformers, and notably of Mr. Chadwick, had been commonly adopted, it became manifest that, although great benefit had resulted from getting rid of the objectionable privy or cesspool from close proximity to houses, it was still necessary, in order to avoid nuisance, that much care and ingenuity should be exercised in connection with the construction of sewers. It was gradually recognised, moreover, that there was need for some method of dealing with the sewage carried to the outfall, before turning it into a watercourse or into the sea.

Side by side with the extension of the use of water-carriage, improvements were introduced in some of those centres of population in which the old system of depositing excreta in pits remained in force. The midden privy is not even yet altogether a thing of the past, but already, in the middle of the last century, its faults were beginning to be recognised. Constructed as it was "of porous materials, and permitting the soakage of filth into the surrounding soil, capable of containing the entire dejections from a house, or from a block of houses, for months and even years, uncovered and open to the rain and wind and the sun, and difficult of access for cleansing purposes," it was productive of most serious offence; but the difficulty of dispensing with it altogether led to efforts being made, while retaining the principle, to minimise the attendant danger and annoyance.

Apart from the special difficulties of some localities, and the question of initial expense involved in putting in practice the method of water-carriage, there was this strong inducement in favour of the conservancy system—that the excreta in a dry form were of value as manure. Hence, in a number of cases the "midden" was still employed, and in instances in which public opinion was too advanced to permit of the continuance of the retention of large quantities of excreta under the old conditions, less objectionable types of privy, and "pail systems," were introduced, the tendency being, as the public taste improved, to insist upon smaller and smaller accumulations, and thus necessarily on more and more frequent removal.

Ingenuity continued to be directed towards improvement of conservancy methods, and, on the other hand, difficulty was increasingly experienced in the case of towns, which had adopted the water-carriage system, in dealing with the sewage at the sewage outfall, so that for some time there seemed to be doubt as to whether the water-carriage, or the dry or conservancy method, would ultimately prevail. Of late years, however, the former system has been widely extended, and though much still remains to be done in improving the treatment of sewage at the outfall, and while, in the case of scattered habitations, the earth-closet, or the pail or cesspool, the contents of which are applied directly to the land, must of necessity be employed, conservancy methods seem to have had their day so far as centres of population are concerned. The main cause of the failure of dry methods of excrement disposal appears to be that, where they are adopted, there still remains the problem of disposing of slop water, and, as already noted, the addition of water-closet refuse does not materially affect the composition of town sewage.

Of late years attention has been particularly directed, by Dr. G. V. Poore and others, to the capacity possessed by the "living humus" of surface soil for dealing with excremental matter, and it has been again urged, in the light of modern knowledge, that the water-carriage system involves waste of a "valuable manurial product." The average amount of excrement per unit of population is found to be about 2½ oz. of fæces and 40 oz. of urine, per diem, and it has been calculated, on theoretical principles, that if the nitrogen, phosphates, potash, etc., could be made available, the money value of the excreta of an individual *per annum* should be nearly seven shillings; to this amount the fæces would contribute about one shilling and the urine six shillings. Such calculations are of little importance in practice, as the excreta cannot, as a rule, be collected independently, and the attempt to extract the valuable constituents, after they have been mixed with other substances, is attended with great difficulty.

Earth-Closet.—In the case of the earth-closet, the solid excreta and some portion of the urine are mixed with dry earth, of which an allowance of about half a pound per person daily is usually found to be necessary, where mould, brick-earth, or loamy surface soil can be utilised for the purpose. When suitable material is available, and when it is sifted and dried, and care is exercised in the use of the closet, no nuisance is caused, and the system has proved a most satisfactory means of dealing with excremental matter in the case of isolated houses. Gravel, sand, and chalk are much less efficacious than the other kinds of soil mentioned, and even with the best soils it is necessary to prevent the contents of the pail becoming unduly moist; for this reason the whole of the urine cannot be dealt with in the earth-closet. Charcoal has been employed in cases where suitable earth is not available. When the method of treatment now in question is carefully conducted, under favourable conditions, not only is all smell prevented, but it is found that the pail contents can be again used, after re-drying, for renewed application to excreta. The remarkable thing is that, under such circumstances, the manurial value of the material produced is not great, as the nitrogen, to a large extent, disappears in a gaseous form.

Application to Land.—In cases where there is abundant garden ground about houses, the application of excreta to the surface soil has been practised with advantage; when conducted with scrupulous care, the system has not been attended with nuisance, and the added material has been found to be a valuable fertilising agent. It has been contended that, relying upon the capacity of the "living humus" to render innocuous material deposited upon it, the operations may be conducted in the near neighbourhood of properly constructed surface wells, and that the risk of pollution is then even less than with a water-carriage system and with public supplies of water. Such a method is, of course, quite out of the question in the case of urban communities.

In an interesting discussion on "The Prevention of Enteric Fever," fully reported in the Eighty-first Volume of the *Transactions of the Royal Medical and Chirurgical Society*, this subject was dealt with from various points of view. The decline of enteric fever in this country coincidently with the carrying out of extensive works of sewerage (the mortality from the disease was ·37 per 1,000 in 1871–1875, and ·17 per 1,000 in 1891–1895), and the fall in the death-rate of Glasgow subsequent to the provision of an improved water supply (·51 per 1,000 in 1865–1879, and ·19 per 1,000 in 1887–1897), were referred to in this connection. These and other facts seem to conclusively dispose of the doctrine that the introduction of sewers, water-closets, and public water supplies has led to increased risk of disseminating enteric fever. The contrast between the behaviour of cholera in England in 1848–1849 and in 1893–1894 is, moreover, a particularly striking one. Thus, from the point of view of preventing the spread of water-borne disease, it is certainly not likely that there will be a return to application of excreta to the soil with employment of shallow wells, in substitution for sewerage and public systems of water supply.

A great difficulty in connection with the introduction of water-carriage removal was, of course, the initial outlay involved. This obstacle was to a large extent overcome by the institution of the loan system. Again, the manurial value of excreta, collected under the old conservancy methods, was far greater in the early days, when farming operations were conducted in this country on a much more extensive scale than they are at the present time. Comparison of the acreage of land under cultivation at the time of the accession of Queen Victoria, with that under cultivation at the present day, will show that the importation of food supplies from abroad has, from an economic standpoint, wrought great changes in the conditions of the problem of excrement disposal.

Modifications of the Wet System.—In some places water-carriage is out of the question, by reason of difficulty in obtaining a proper fall, or owing to severity of climate leading to freezing of water, or from insufficient supply of water. Some of these cases have been met by the provision of extraction systems, such as that of Captain Liernur, in which a vacuum is produced by means of an air-pump, and the sewage is thus sucked away in the direction required; or by the use of compressed air, as, for example, in what is known as "Shone's Ejector System," in which the sewage is driven along the course desired.

The Midden or Privy.—In the Northern and Midland towns of this country dry methods were largely used until within recent years, and they are still employed to a lessened extent, not

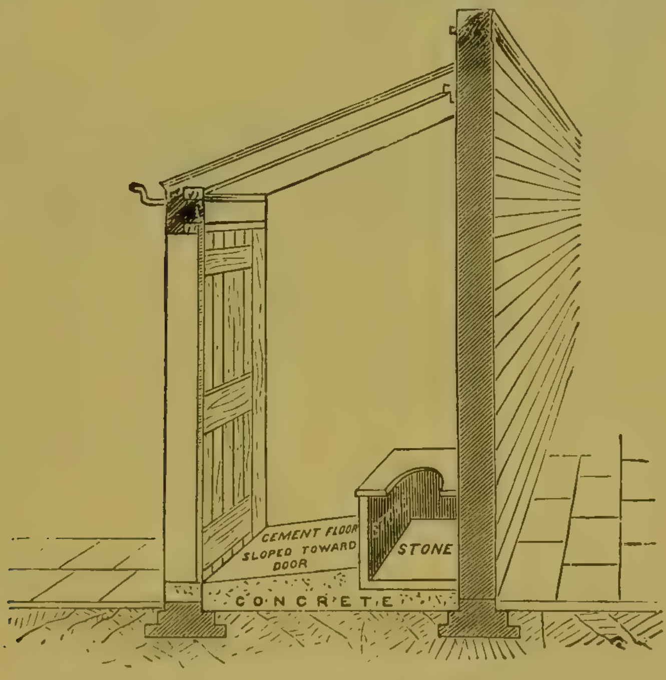

FIG. 54.
A Privy constructed so as to comply with the Model By-laws.

so much because water-carriage has been found impracticable, as with a view to the economic use of the excreta as manure. Again, in many rural districts the cost of water-carriage is found to be altogether prohibitive. The model by-laws prescribe that a midden or privy shall be situated at least 6 ft. from any dwelling, and 50 ft. from any well; that the floor shall be above ground level, and shall incline away from the privy receptacle; the capacity of the latter is limited to 8 cubic ft., and this practically necessitates weekly removal; the receptacle, moreover, is to be of impermeable material, so as to prevent soakage, and it should have a hinged seat to admit of the application of ashes.

Other Conservancy Methods.—The tub or pail constitutes a great improvement upon the fixed receptacle. At Rochdale a wooden

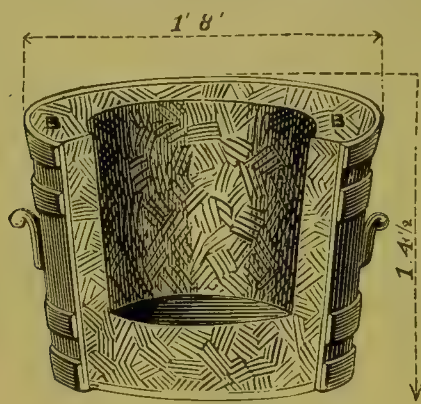

FIG. 55.
Goux Pail.

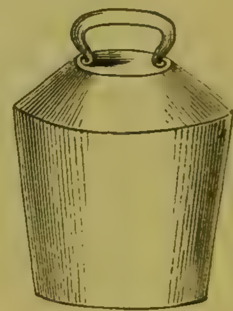

FIG. 56.
Goux Mould.

pail is used; at Birmingham a galvanised iron pail is employed. In Manchester the system of adding ashes by means of a cinder-sifter was adopted at an early date. In Halifax the Goux system was introduced, the pail being lined with an absorbent layer of ashes, street sweepings, factory waste, or a mixture of tan, sawdust, and soot, pressed into shape by means of a mould. Ash-closets are sometimes provided, in which, by a mechanical arrangement, sifted fine ash (Fig. 57, C) is deposited automatically on the pail-contents, while the cinders (Fig. 57, B) are separated for further use as fuel.

The removal of pails is usually carried out at night-time, in specially constructed vans, and the material collected is generally concentrated into smaller bulk by application of heat, and utilised as manure. The plan of drying excreta in a *concretor* was at one time largely practised in Manchester. Somewhat similar methods have been in operation at Rochdale, Birmingham, Glasgow, Leeds, Bradford, and other large towns. In Paris, cesspool sediment has been dried on a large scale, and so converted into what is known as *poudrette*. In the early days of the employment of systems such as the above, it was found that, while none of them paid the cost of collection, they were in some instances more economical than water-carriage removal; but of late years increasing difficulty has been experienced in disposing of the product manufactured, and this fact, together with the necessity for the independent removal of liquid waste, and the objection to the pail system on health

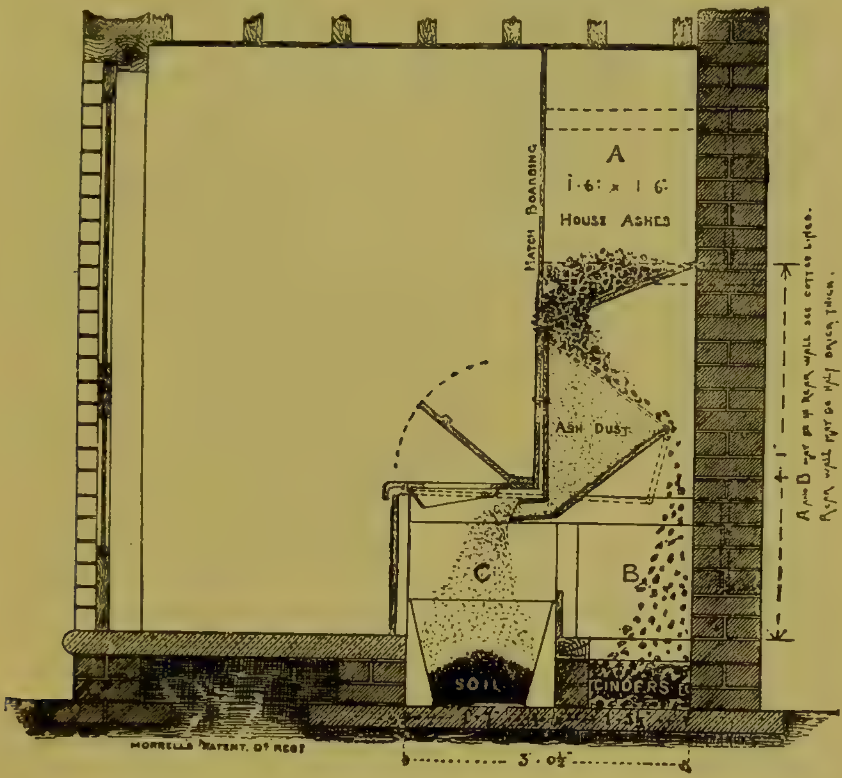

FIG. 57.
Morrell's Cinder-sifting Ash-closet.
The soil pail is removed through a side wall.

grounds, has led to a gradual abandonment of these conservancy methods.

The Water-Carriage System.—The various sanitary fittings used in connection with habitations are disconnected from the drain, which receives the waste material of the house, by means of traps.

Traps.—The principle of the trap will be seen on reference to the annexed diagram, which shows the construction of an ordinary syphon trap. In this trap a bend retains water, and thus serves to disconnect the air of the drain from that of the sanitary fitting to which the trap belongs; the distance A B is called the "seal" of the trap, and this water seal should be at least 1½ in. deep. The air of the drain to some extent obtains access to the interior of the house, even when the seal remains unbroken, for

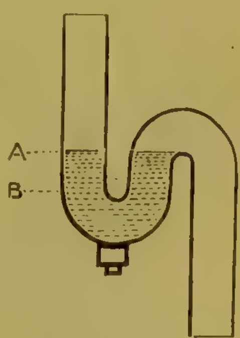

FIG. 58.
Syphon Trap,
with screw-plug for cleansing.
A B, Water seal.

drain air becomes absorbed by the trapping water, and may be given off from its upper surface on the house side.

Dr. Fergus, of Glasgow, who made a series of experiments some years ago, found that substances with characteristic odours, introduced on the drain side of the trap, become perceptible on the house side after the lapse of an interval of time; thus ammonia was found to be taken up by the water in the syphon, and to be transmitted through it to the air on the house side of the trap, in sufficient quantity to become perceptible after the lapse of about fifteen minutes. Moreover, if the contents of the drain be foul, putrefaction may occur in the water of the trap, with bursting of bubbles and discharge of particulate matter into the air on the house side of the trap.

The water seal may become broken from excess of pressure in the drain, if the latter be unventilated. Again, the momentum of discharge may carry the water altogether out of the syphon, or drive out so much water as to cause the trap to become unsealed, particularly if the depth of the seal be insufficient; this is obviated by causing the water-holding part of the trap to be somewhat contracted, and by making the ascending arm large and square in section. Furthermore, the contents of the trap may be sucked out by syphonage; this is particularly liable to occur when the length of pipe on the drain side of the trap is a long one, or when a second pipe communicates with this length of pipe, and the discharge of waste material through this second pipe sucks out the water from the original trap. Syphon-action is specially apt to occur in cases in which a soil-pipe is common to several water-closets, one above another, as, for example, in a block of buildings; it may be prevented by ventilating the top of the trap beyond the seal by means of a 2-in. lead ventilating pipe; such "anti-syphonage pipes," in the case of a vertical row of water-closets, are made to communicate with a common pipe, carried up separately, or taken into the soil-pipe. Finally, the seal of a trap may become broken by the evaporation of the water contained in it.

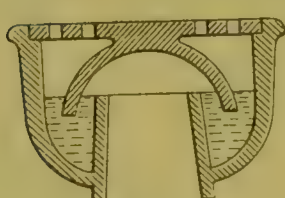

FIG. 59.
Bell Trap.

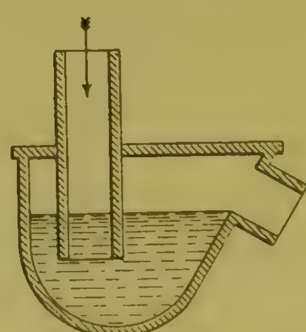

FIG. 60.
D Trap.

A trap, to be efficient, should be self-cleansing, and for this purpose it is necessary that it should be free from all angles and corners which would tend to retain filth. A form of trap formerly largely used is that illustrated in Fig. 59. This trap is apt to become choked from accumulation of deposit; the depth of the seal, usually only about $\frac{3}{8}$ of an inch, is insufficient; the seal is apt to be broken from evaporation of the water; the cover of the bell is often broken, and there is then direct communication with the air of the drain; finally it is a common occurrence, in the case of such traps, to find that the cover, if unbroken, has been removed, or has become displaced. Fig. 60 represents the "D trap," which was at one time largely used in connection with "container water-closets." This trap invariably becomes coated with deposit, and its use is usually prohibited in codes of by-laws.

The trap shown in Fig. 61 is without angles or corners rendering

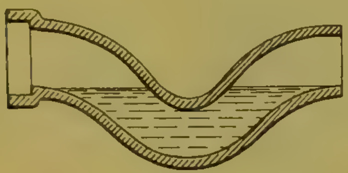

FIG. 61.
A Trap with shallow seal, and without means of access for cleansing purposes.

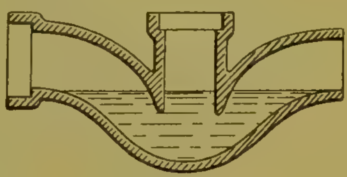

FIG. 62.
Another objectionable form of Trap.

it liable to retain deposit; but its seal is too shallow, and there is no means of access for cleansing purposes. The trap shown in Fig. 62 is objectionable inasmuch as it is especially liable to become blocked; again it is not ventilated, and the opening provided does not offer facilities for clearing the drain beyond the trap.

FIG. 63.
Gully-trap designed for receiving rain-water, etc.

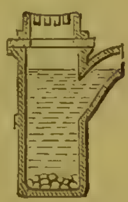

FIG. 64.
Gully-trap designed for yard or road washings.

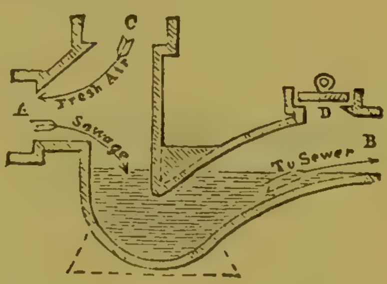

FIG. 65.
Ventilating, Intercepting Trap.
A. Socket for house drain.
B. Connection with sewer.
C. Socket for fresh-air inlet pipe.
D. Cap for clearing purposes.

Fig. 63 represents a self-cleansing gully-trap of the ordinary type. In Fig. 64 is shown a trap designed to prevent solid material passing into the drain; such a trap, of course, requires to be periodically cleansed, as otherwise it is liable to become choked. The form of trap illustrated in Fig. 65, which has means of ventilation, is sometimes used, in cases in which an inspection chamber is not provided, for the purpose of intercepting the house drain from the sewer.

Waste-pipes.—The Model By-law of the Local Government Board requires that "the waste-pipe from every bath, sink (not being a slop sink constructed or adapted to be used for receiving solid or liquid filth), or lavatory, the overflow-pipe from any cistern and from every safe under any bath or water-closet, and every pipe (used for) carrying off waste water," shall discharge in the open air, over a channel,

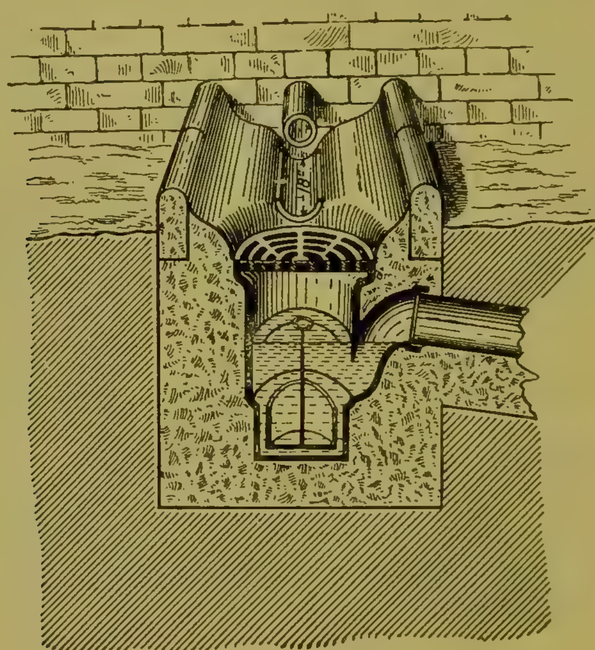

FIG. 66.
Trapped Gully complying with the Model By-law.

leading to a trapped gully at least 18 in. distant; the arrangement contemplated is shown in Fig. 66, and the trap in this instance is fitted with a receiver, provided with a handle, designed to facilitate the removal of any deposit which may collect.

The waste-pipes from kitchen sinks should not only be disconnected from the drain by being made to discharge over a gully in the open air, but they should also be provided with a syphon trap, fitted, at its lowest point, with a screw-cap which can be removed with a view to cleansing the trap. The trap should have a 3-in. water-seal, and should be placed immediately beneath the sink; the collection of greasy material even in a short length of waste-pipe is liable to cause nuisance unless the air contained in the pipe is precluded from escaping at the outlet of the sink. It is a common practice to discharge waste-water from sinks and baths in the upper parts of a house into the heads of rainwater-pipes. This practice is objectionable, inasmuch as it leads to fouling of the whole extent of the rainwater-pipe with grease and soapsuds, and nuisance is likely to be caused by the effluvia which escape from the rainwater-pipe. The waste-pipe from the sink or bath need not, as a rule, be more than 1½ in. in diameter, and it should be carried down to, and made to discharge over, a gully in the open air.

The wastes from bath-safes and the overflow pipes of baths should be trapped, and should be made to communicate with the open air as "warning pipes"; the bath-waste may either be carried down and made to discharge over a gully, or else be connected with a sink-waste which terminates in this manner; it is a good plan to carry a ventilating pipe from the upper end of the pipe receiving one or more bath- or sink-wastes, to a position well above and removed from attic windows. The rainwater-pipe should not be used as a soil-pipe or as a drain ventilator; it should be caused to deliver over a properly trapped gully, and, where practicable, over one which also receives a sink, lavatory, or bath-waste, as a gully which receives the discharge of a rainwater-pipe alone, is apt to become unsealed during dry weather.

Slop sinks are used in large houses, and in some of the Midland and Northern towns, where sufficient water for flushing water-closets is not available. The advantage of the slop sink is said to be that it effects economy in the use of water, inasmuch as the household waste-water can be utilised for flushing purposes. When slop sinks are employed they should be trapped and connected with the soil-pipe, just as a water-closet is; indeed, unless all the precautions deemed necessary in the case of water-closets are also taken with regard to them, they are likely to be a source of danger. Where the closet can be used for the reception of slops it is better to dispense with them altogether; if they are employed they should be provided with a safe having a waste-pipe which discharges into the open air, and it should be seen that they are kept clean and properly flushed.

Water-closets.—The water-closet apartment should be built against an outside wall, and, if possible, it should be provided with a disconnecting lobby, so that cross ventilation can be obtained between the water-closet and the interior of the house. On no account should it be approached directly from a living-room, work-room, or place in which food is stored. The apartment should be well lighted, and should be ventilated by means of a window opening on to a sufficient open space; in addition to this, means of permanent ventilation by an air brick or air shaft should be provided. The floor of an outdoor closet may with advantage be made of cement-concrete, with a fall towards the door. The trap can be embedded in the cement, and there should be no wooden covering in front of it, as in the absence of such covering cleansing is facilitated. The seat of the closet should, moreover, be hinged.

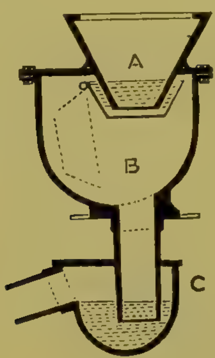

FIG. 67.
Pan Closet.
A, Basin; B, Container; C, D-trap.

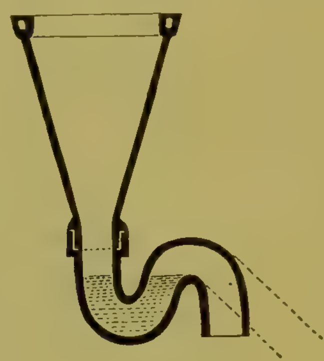

FIG. 68.
Long Hopper Closet.

In Figures 67 and 68 two forms of water-closet, at one time in common use, but now, fortunately, becoming extinct, are shown: the *pan closet*, in which the contents of the water-closet basin were discharged into a "*container*," usually placed in communication with a "D trap," was particularly objectionable. The container and trap invariably became coated with deposit, and the leaden D trap was in some cases actually perforated. When the closet was used, and the pan discharged into the container, the effluvia evolved in the decomposition of the filth on the sides of the container escaped into the house. It was, moreover, a common practice in connection with these closets to take the discharge-pipe, from the leaden safe placed under the water-closet, direct into the D trap, and in this way further opportunity was afforded for the escape of drain air into the house.

The *long hopper* closet is also open to objection, as excreta falling upon the sides of the basin render it foul, and ordinary flushing appliances are, as a rule, found to be quite incapable of cleansing it. Such closets, when furnished, as at one time they not infrequently were, with a "spiral flush," were sources of serious nuisance. The model by-law of the Local Government Board provides "that the water-closet basin shall be composed of non-absorbent material," and be "of such shape, of such capacity, and of such mode of construction as to receive and contain a sufficient quantity of water to allow all filth, which may from time to time be deposited (in it), to fall free of the sides thereof and directly into the water."

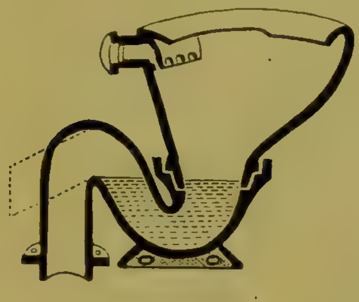

FIG. 69.
Short Hopper or Wash-down Closet.

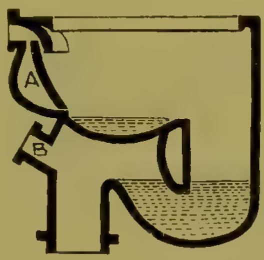

FIG. 70.
Wash-out Closet.
A. After-flush chamber; B, Trap-ventilator.

In the *short hopper* or *wash-down* closet these conditions are generally complied with, though there is considerable difference between the various types of apparatus in common use, in this respect; the back of the basin should be almost vertical, and the area of the contained water should be sufficient to permit of all filth being received directly in it. The junction of the basin and trap, if the two are not made in one piece, should be carefully effected, so that the internal surface is here perfectly smooth, and no projecting edge, such as would favour the collection of filth, is left.

In the *wash-out* closet the area of the water held in the basin is considerable, but the upper part of the syphon trap above the water level is apt to become foul; hence this form of closet is generally productive of more or less nuisance. In the figure, an "after-flush chamber" is shown; this contrivance is designed with the object of receiving some of the flushing water, and gradually allowing it to drain into the basin, so as to ensure that the trap shall be fully recharged in case too much water has been carried out of it by the rush of water which first occurs.

Syphonic closets have been recently introduced; they present the general characteristics of the wash-down type, but the contents of the basin are, in them, drawn out by syphon action in addition to being washed out by flushing. They are said to effect economy in use of water.

The valve-closet has the lower part of the basin closed by a water-tight valve, which can be depressed into a metal box, thus enabling the contents of the basin to be discharged into the syphon trap beneath; an overflow-pipe, which should be trapped, is also made to discharge into the box; as the trap of this overflow-pipe is apt to become unsealed, by evaporation or syphonage, it is the practice, in some instances, to ventilate it to the outer air by means of a "puff pipe," and to adopt an arrangement by which the overflow-pipe is flushed each time the closet is used. It is advisable, moreover, to cause the overflow-pipe to enter the box underlying the valve in such a position, that when the valve is depressed the opening of the overflow-pipe is covered, and choking by paper, etc. thus obviated. The valve-closet possesses the advantage of having a large area of water contained in the receptacle, but the valve is apt to get out of order, and a larger amount of water is necessary for flushing than in the case of other forms of closet, inasmuch as an "after-flush" has to be provided for, in order that the level of the water may rise in the basin after the valve is closed. With a view to supplying this after-flush, a "bellows regulator," consisting of a piston (moving in a cylinder) connected with the handle which serves to open the valve of the closet and that of the supply pipe, is usually employed. When the handle of the closet is lifted the piston of the regulator is raised, but when the handle is released the water continues to be supplied as the piston of the "bellows regulator" gradually falls; the cylinder of the regulator has an air-escape pipe, fitted with a tap, which regulates the escape of air from the cylinder and thus governs the rate of descent of the piston. While the piston is descending, the supply valve remains open, and water continues to enter the closet basin.

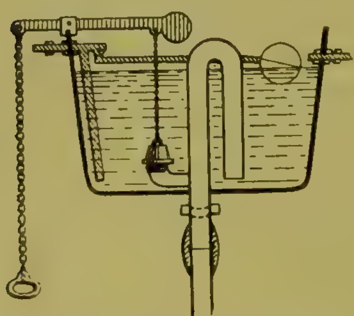

FIG. 71.
Waste-preventing Cistern.

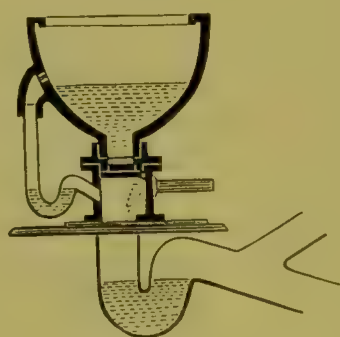

FIG. 72.
Valve-closet.

The water used to flush a water-closet should never be taken directly from a service pipe or from a cistern supplying water for domestic purposes. The form of apparatus ordinarily used for flushing purposes is the "waste-preventing cistern" (Fig. 71), which serves to break the connection between the water-closet and the water-supply pipe.

There are many types of waste-preventing cisterns. The ordinary "valve-cistern," in which water only flows while the chain is held and the valve is thus raised from its seating, is open to objection, for the cistern is not likely to be always completely emptied under such conditions, and the closet may therefore be inadequately flushed.

The "syphon waste-preventer" possesses the advantage that one pull of the chain causes the discharge of the entire contents of the cistern; moreover, no more water is permitted to escape until sufficient time has elapsed to allow the cistern to refill, and the chain is then again pulled. The amount of water in the cistern is often limited to two gallons, and in some waste-preventing cisterns even less is provided. Not infrequently, too, the aperture of the supply pipe of the cistern is made quite small, so as to prolong the process of refilling; under these circumstances no one using the closet is likely to cause the contents of the cistern to be discharged more than once into the basin of the water-closet. When such conditions exist, waste of water is completely obviated, but proper cleansing of the water-closet basin is not so certainly secured. It has been contended that, with suitable appliances and proper flushing arrangements, a two-gallon flush is sufficient to cleanse the basin of the closet and to carry the contents discharged from it into the sewer, provided the drain is properly constructed and laid. The matter has been made the subject of carefully conducted experiments, which show that, under the most favourable conditions, a two-gallon flush is generally sufficient, though there is, as might have been expected, greater security when 2½ or 3 gallons of water are used. There is thus undoubtedly advantage in providing for the waste-preventing cistern to contain at least 2½ or even 3 gallons of water, and the arrangement should, moreover, be such that the cistern rapidly refills, and can be emptied a second time should this be found necessary.

Syphon waste-preventers are set in action either by forcing a body of water over the bend, or by causing water to enter the long leg, of the syphon. In the cistern shown in Fig. 71 the latter method is adopted; when the chain is pulled the valve is raised, water enters the long leg of the syphon, and syphon action is set up. Directly after the valve is raised, a leather plug slips off the lower surface of the valve and closes the orifice, so that when once the cistern has been emptied no more water escapes until it refills and the chain is again pulled.

In all cases water-closet basins should be provided with a flushing rim which directs the water over the whole surface of the basin. The down pipe should be not less than 1¼ in. to 1½ in. in diameter, and the cistern should be placed at least 4 ft., and preferably 6 ft., above the closet basin, in order to obtain a sufficiently forcible discharge.

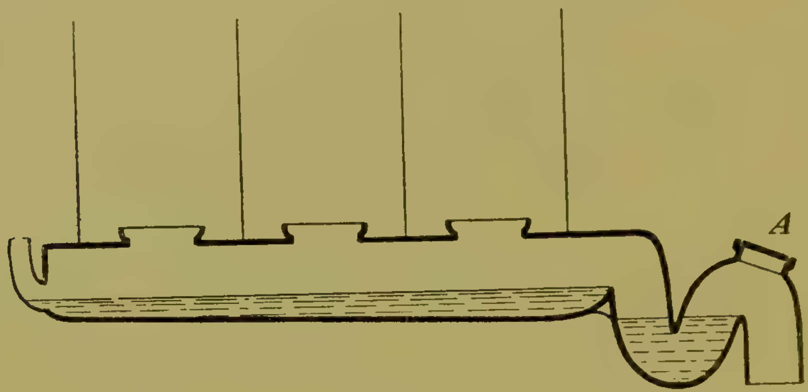

FIG. 73.
Trough Water-closet. *A*, Cleansing Cap.

Trough closets have been recommended in the case of schools and institutions, and in other instances when a number of closets side by side are required. It is said that they are less costly, and are adapted for the use of persons who, from recklessness or sheer mischief, interfere with the working of the flushing or other apparatus of ordinary water-closets. The trough closet can be automatically flushed, and, if the operation is effected at sufficiently frequent intervals, it is contended that nuisance from the accumulation of excreta in the closet will not be experienced. The sides of the trough are liable, however, to become foul from splashing, and if they are not periodically cleansed nuisance must arise from this cause. Improved forms of trough closets, styled "latrines," have been constructed, in which a number of basins, shaped like ordinary water-closet basins, communicate with a trapped discharge pipe common to all of them. These appliances are less open to objection in some respects than the ordinary "trough closet"; but, on the other hand, they do not, as a rule, admit of being properly cleansed. The principle of retaining excremental matter, even if it be for only short periods, before causing it to be discharged into the drain, is undoubtedly objectionable, and even with the most careful management it is practically impossible to maintain such a standard of cleanliness with the trough closet, or latrine, as can be secured where separate water-closet basins are employed. In many places in which trough closets have been tried, they have been found to be a source of considerable nuisance, and in numerous instances it has been found desirable to replace them by ordinary water-closets.

The Soil-pipe should be fixed, if possible, outside the house, and carried up full-bore to a point above the eaves, and well removed from windows. Soil-pipes are usually $3\frac{1}{2}$ or 4 inches in diameter, and they are generally constructed of drawn lead, each length being made in one piece by forcing the molten lead through a round orifice by hydraulic pressure, applied to a piston provided with a core which forms the bore of the pipe. Seamed lead piping must on no account be used, as leakage is apt to occur at the seam. The weight of the lead piping per 10-foot length should be not less than 65 lbs. in the case of $3\frac{1}{2}$-in., and 74 lbs. in the case of 4-in. soil-pipes. The joints should be "wiped" joints. In the case of soil-pipes fixed outside buildings cast-iron pipes are sometimes used; they are inferior to lead pipes, and if employed should be of a uniform thickness of not less than $\frac{3}{16}$ to $\frac{1}{4}$ of an inch; they should be properly tested, and jointed with yarn and molten lead, and the connection with the closet requires to be carefully made in order to secure proper jointing. Even where iron pipes are used as soil-pipes it is advisable to employ lead for the ventilating pipes, as iron, when not washed by sewage, speedily rusts and deteriorates.

House Drains are generally constructed of circular glazed socketed stoneware pipes. These pipes are more durable and less porous than earthenware pipes, from which they are distinguishable by their pale buff colour, their metallic ring when struck with a hammer, and the comparatively small extent to which their weight increases when, after drying, they are submerged for twenty-four hours in water.

They should be carefully laid and jointed with Portland cement in such a way that there is no projection at the site of the joint into the interior of the drain. The absence of such projection is usually ascertained by the use of a "badger," a wooden disc or ball, which can be passed along the interior of the drain. Two wooden discs, edged with india-rubber and connected by a flexible tube, are sometimes employed for the purpose, as this form of badger can be made to closely fit the pipes, and is capable of being drawn through bends in the drain. "Composition rings," cast on the spigot and socket of each pipe, are sometimes used for jointing purposes; when they are employed a fillet of cement is often added in addition to make the joint perfectly secure. It was a common practice in days gone by to make "clay" joints to house drains, but in places in which the laying of drains is adequately supervised, proper joints are, of course, insisted upon. Clay is soon washed out of joints and is perforated by worms and roots of trees; it is, moreover, liable to be squeezed out by pressure.

The house drain is as a rule 4 inches in diameter, and there is great advantage in not using drain-pipes of larger size than this, as the smaller the diameter the greater is the likelihood of the drain being adequately flushed and kept free from deposit. The amount of water necessary to make a 4-inch pipe run full, causes a 6-inch pipe to run less than half full. Cast-iron pipes are generally coated inside and out with Angus Smith's preservative (a mixture of coal tar and coal oil), or with oxide, by the Bower-Barff process (raising to white heat in presence of superheated steam). Those parts of iron pipes which are exposed to ordinary sewage show little tendency to rust, a fact attributed to the contained grease, etc. Cast-iron pipes are often employed for drainage work; they can be manufactured in long lengths, hence fewer joints are necessary, and these can be made in a more reliable way when such pipes are used. Moreover, cast-iron pipes are readily adapted to different varieties of form. They are especially useful when drains have to be carried under houses and under roads used for heavy traffic. It is most important that drain pipes should be laid to a proper fall and on a bed of concrete. In some instances concrete is not insisted upon when the drains are entirely outside the house and the subsoil is "sound." The pipes should be placed with the sockets pointing to the head of the drain, and the gradient should be at least 1 in 40. Maguire's rule is to the effect that a 4-inch drain must have a fall of 1 in 40, a 6-inch drain a fall of 1 in 60, and so on, the diameter of the drain in inches being in each case multiplied by 10.

Drains intended to carry sewage should always be laid on 6 inches of concrete, and the concrete should project on each side to an extent at least equal to the external diameter of the drain. "Hand holes" may be constructed to receive the sockets of the pipes, in order to facilitate jointing and to enable the barrels of the pipes to rest upon the concrete. These hand holes must be subsequently filled in, and the concrete made to cover half the diameter of the drain, or, if the drain pass beneath a dwelling-house, the entire pipe should be encased in concrete 6 in. thick all round. When drains are laid beneath houses, relieving arches in cement should be formed, where the pipes pass under walls, so as to prevent possible damage to the drain from settlement. Iron pipes are best adapted for use in cases where drains pass under buildings, and they may be laid on concrete, or placed in brick channels with concrete floors, so that they are accessible to inspection throughout their entire course beneath the building. Drains should be laid in straight lines, and, if it is necessary to change the direction of the drain, this may best be effected by employing a curved pipe as the means of communication between one run of drain pipe and the next.

An inspection chamber should, if possible, be provided at the point at which each change in the direction of the drain is effected. At the site of the junction of the house drain with the sewer an inspection chamber should be constructed, whenever this is practicable. In the inspection chamber the disconnecting trap, which

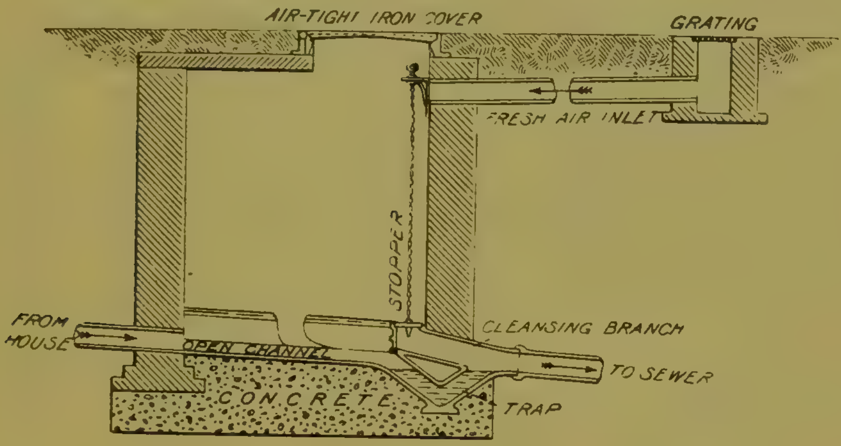

FIG. 74.
Intercepting or Inspection Chamber.

must be provided at the point where the house drain joins the sewer, should be so placed that it can be exposed for purposes of examination. The chamber is generally constructed on a concrete foundation of brickwork lined with cement. The main drain of the house should run across the chamber, in an open channel formed of half-channel pipes, or, if it be deemed necessary, with a view to preventing splashing, three-quarter channel pipes may be used. Branch drains should be made to communicate, where this is practicable, with this open chamber by suitable curved pipes, and the outlets from the drains being thus exposed any obstruction can be readily removed by operating from within the chamber.

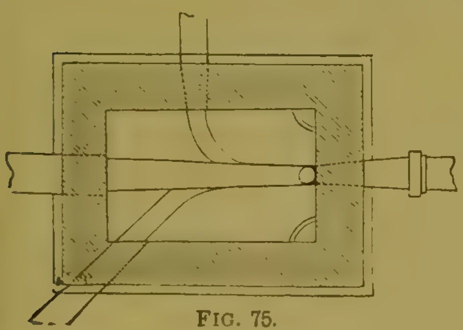

FIG. 75.
Floor of Manhole or Intercepting Chamber viewed from above.

The sewer interceptor should be provided with a raking arm for cleansing purposes. In Fig. 74 an arrangement is shown by which a plug, operated upon by means of a chain, on being raised provides means of escape, for any sewage which may have collected in the chamber, through the raking arm to the sewer. This arrangement is convenient, as it obviates the necessity of baling out sewage from the chamber, in the event of any obstruction occurring in the disconnecting trap, inasmuch as by merely pulling the chain any liquid which may have accumulated in the inspection chamber can be caused to flow away into the sewer. Fig. 74 also shows a fresh-air inlet in connection with the inspection chamber.

It is not unusual to find that the disconnecting trap has been so fixed that its outlet is at a somewhat higher level than its inlet. If this be the case, backing up of sewage occurs, for the contained material necessarily stands in the drain at the level of the outlet of the trap. Again, collections of sewage are caused if the fall of the drain be not carefully regulated. When it is necessary to connect pipes of unequal diameter—for example, a 4-in. and a 6-in. drain—a "taper pipe" should be used. This pipe should be adjusted so that its lower surface, along which the sewage flows, and the corresponding surfaces of the pipes which it connects, present uniformity of slope, while its crown and sides must be so shaped as to effect the necessary tapering; if this is not done the flow of sewage in the drain will be interfered with.

Ventilation of House Drains.—From what has already been said regarding the liability of drain air to become absorbed by the water of traps and to be subsequently given off on the house side of the trap, it will be seen that it is necessary to promote, as far as possible, the circulation of fresh air in the house drain, and to thus prevent the accumulation of gases of putrefaction in it. In order to ventilate the drain a suitable inlet and outlet should be provided, and, with a view to bringing about a flow of air from the one to the other, there should be a difference of level between the inlet and outlet openings; moreover, one of these openings should be placed at the head of the drain, and the other should be situated as near as possible to the point of communication of the drain with the sewer. In this way the air of the whole extent of the drain is continually renewed by ventilation. There is advantage in arranging that the flow of air through the drain shall be in the direction of the flow of the drain contents, if this is practicable.

The model by-laws of the Local Government Board make the provision of two untrapped ventilating openings to the drain compulsory, and require that one of two alternative arrangements shall be adopted:—

(*a*) In the case where there is an open space belonging to the building and in front of it, the first of these two methods can be employed. The arrangement specified is that "one opening, being at or near the level of the surface of the ground adjoining such opening, shall communicate with the drains by means of a suitable pipe, shaft, or disconnecting chamber, and shall be situated as near as may be practicable to the trap . . . . provided between the main drain, or other drain of the building and the sewer. . . . Such opening shall also in every case be situated on that side of the trap which is the nearer to the building. The second opening shall be obtained by carrying up, from a point in the drains, as far distant as may be practicable from the point at which the first-mentioned opening shall be situated, a pipe or shaft vertically to such a height and in such a manner as effectually to prevent any escape of foul air from such pipe or shaft into any building in the vicinity thereof, and in no case to a height of less than 10 ft." This second opening can be provided, in those cases in which the soil-pipe is situated at the head of the drain, by carrying such soil-pipe well up above the eaves of the building, in a position removed from attic windows.

(*b*) The alternative arrangement, which can be adopted where the front of the building actually abuts upon the street, is described as follows:—"One opening shall be obtained by carrying up from a point, as near as may be practicable to the (intercepting) trap, ... a pipe or shaft, vertically, to such a height and in such a manner as effectually to prevent any escape of foul air from such pipe or shaft into any building in the vicinity thereof, and in no case to a less height than 10 ft. Such opening shall also in every case be situated on that side of the trap which is the nearer to the building. The second opening, being at a point in the drains as far distant as may be practicable from the point at which such last-mentioned pipe or shaft shall be carried up, shall be at or near the level of the surface of the ground adjoining such opening, and shall communicate with the drains by means of a suitable pipe or shaft." In giving effect to this alternative arrangement it is sometimes possible to use a soil pipe carried up above the eaves, as already described, for the first ventilating opening, while the second ventilating opening may be formed by an untrapped gully in a back yard.

The model by-law also provides that the pipe or shaft used, in connection with either of these arrangements, as a ventilating pipe, shall have a sectional area "not less than that of the drain with which it communicates, and not less in any case than the sectional area of a pipe or shaft of the diameter of 4 in." It further specifies that "no bend or angle shall (except where unavoidable) be formed" in any such ventilating pipe, and it provides that a grating or cover, for the purpose of preventing any obstruction, shall be placed over every ventilating opening, such grating or cover to be so constructed and fitted as to secure the free passage of air, by means of a sufficient number of apertures, of which the aggregate sectional area shall be not less than that of the pipe or drain.

Having regard to the extent to which bends or angles in ventilating pipes interfere with the passage of air, it is obvious that such obstructions to ventilation should, as far as possible, be avoided. Again, the necessity of providing a ventilating pipe of calibre equal to that of the drain which it ventilates, is apparent. It was, a few years ago, no unusual thing to find ventilating pipes of ridiculously insufficient size fitted in connection with house drains. It is a common practice for the lower or inlet opening to a drain-ventilating system to be provided with a mica flap, with a view to preventing the escape of drain air from the opening, while permitting fresh air to enter the drain; these flaps are, however, in practice, often found to be out of order, and if the ventilating opening be sufficiently remote from the windows of living rooms, and placed in a situation in which the escape of drain air is not likely to cause complaint, it is probably better to omit the flap.

Drain-testing.—Drains are best tested by applying the water test, the outlet of the drain being first plugged and the drain then filled with water to the level of the highest gully or other inlet; any intermediate opening at a lower level will, of course, also require to be plugged. The drain must be allowed to remain charged with water for at least half an hour. In laying new drains this test should be applied from time to time, as the several lengths of drain are completed. In testing a house-drainage system the lower end of the drain may be plugged at the point where it enters the disconnecting chamber, if there is one, or it may be necessary to open up the ground in order to expose the drain. Drain bags made of india-rubber or waterproof canvas are best adapted for plugging drains. The pneumatic test, in which compressed air, supplied from a force pump, is employed, possesses the advantage that the pressure applied is uniform; whereas, in the water test the lower part of the drain is subjected to greater pressure than the upper part. The smoke test is often used, a smoke machine being employed to pump smoke, from oily cotton-waste or other material, into the drain. In employing this method comparatively little pressure is brought to bear upon the drain, and the test is not, therefore, sufficiently searching, at any rate for drains laid within buildings. Defects in old drains may be detected by means of certain olfactory tests, *e.g.*, by pouring oil of peppermint down the highest water-closet, and then flushing with hot water, or by the use of "grenades," etc., charged with a mixture of asafœtida and phosphorus, which gives rise to a readily appreciable odour on being brought in contact with water. Such tests ought not to be applied to new drains, as they only reveal gross defects.

Properly laid stoneware drains should stand a pressure of 4 to 5 lbs. to the square inch; sometimes in applying the water test the level is found to slowly sink, although no actual defect can be discovered. This may be due to imperfect plugging of the drain, to the fact that the pipes are not wholly impervious to water (such "sweating" pipes should not be used), or to the occlusion of air in branch pipes or drains, as the drain is filled with water, and subsequent absorption of this intercepted air. This last-named contingency may be provided against by passing a bent pipe through the trap, which prevents the air escaping, so as to ensure the whole length of the pipe tested being filled with water.

Sewers.—The brick sewers originally constructed were designed to drain the subsoil as well as to carry away sewage; hence they were not made of impermeable materials, and not only did subsoil water enter them, but sewage matter was also able to escape from them. Further, they were, as a rule, square in section or otherwise constructed in such a way as to favour the accumulation of deposit.

FIG. 76.
Egg-shaped Brick Sewer (shown in section).

Modern sewers, up to 18 in. in diameter, are generally made of well-glazed stoneware or iron pipes, and are circular in section. A sewer of more considerable dimensions is, as a rule, constructed with well-burnt impervious bricks set in Portland cement. The larger sewers are generally egg-shaped in section, as this form offers great resistance to external pressure, and possesses the manifest advantage that, when the volume of sewage is small, a maximum scouring effect is secured, there being less contact of the liquid with the containing walls, than would be the case if the sewer were circular in section. The floor of the sewer should be perfectly smooth and suitably curved. Stoneware blocks are often employed in this part of the sewer; these blocks are sometimes made hollow, with a view to providing means of draining off subsoil water, but this plan is found to be attended with certain disadvantages, and in particular it interferes with the stability of the sewer.

The gradient of the sewer should be designed to give a velocity of not less than $2\frac{1}{2}$ ft. per second in sewers up to 24 in. diameter; for larger sewers, a velocity of 2 ft. per second is considered sufficient. The larger the sewer the less is the gradient required to produce any particular velocity. Baldwin Latham pointed out that "A sewer 10 ft. in diameter having a fall of 2 ft. per mile; a sewer 5 ft. in diameter having a fall of 4 ft. per mile; a sewer 2 ft. in diameter having a fall of 10 ft. per mile; and a sewer a foot in diameter, with a fall of 20 ft. per mile, will all have the same velocity of flow; but the volume of sewage in the 10-ft. sewer must be 100 times, in the 5-ft. sewer twenty-five times, and in the 2-ft. sewer four times the volume of sewage in the 1-ft. sewer." In each of the instances given it will be noted that the product, of the diameter of the sewer and the fall in feet per mile, is the same.

A simple formula for calculating the discharge from sewers is

$$V = 55\sqrt{2DF}.$$

Where V = velocity in feet per minute.
D = hydraulic mean depth.
F = fall in feet per mile.

If A be the sectional area of the fluid, $V \times A$ gives the discharge in cubic feet per minute. The "hydraulic mean depth" to which reference is made above is the sectional area of the current of fluid divided by the wetted perimeter. In the case of circular pipes the "hydraulic mean depth" is equal to one-fourth of the diameter, whatever be the sectional area of the fluid running in the pipe. In egg-shaped sewers the "hydraulic mean depth" varies according to the level of the sewage flowing in them. In the case of sewers constructed on the ordinary plan, in which the transverse diameter is two-thirds of the vertical diameter, the "hydraulic mean depth," when the sewer is running full, is ·2897 multiplied by the transverse diameter; when running two-thirds full, ·3157 multiplied by the transverse diameter; when running one-third full, ·2066 multiplied by the transverse diameter.

The junction of small sewers with larger ones should always be made in such a way that the sewage enters the larger sewer in the direction of flow; moreover, the points of junction of drains with sewers, or of small sewers with large sewers, should be so arranged as to prevent the "backing up" of sewage into the smaller pipes when the large sewer is running full.

Ventilation openings should be provided at frequent intervals. In the case of openings in the roadway it is commonly stated that the distance between the ventilators should not exceed 100 yards. In many streets these openings are placed in the middle of the road, directly over the sewer; in streets in which there is much traffic access to manholes is often provided from the pavement; in narrow thoroughfares, and at the dead-ends of sewers, ventilating shafts, carried up so as to permit of escape of the sewer air at a point sufficiently removed from windows, may be employed instead of surface ventilators.

Sometimes sewer ventilators are connected with factory chimneys; pipes have also been carried up through street gas lamps, with a view to exposing the sewer air to the gas flame. In cases where the first-named expedient has been adopted it has been found that the aspirating effect of the chimney is only appreciable for a short distance in the sewer, for while much air is sucked in at openings in the near neighbourhood of the chimney, the effect produced has only been quite local. Again, this method of ventilating sewers is likely to lead to suction of water from the traps of house-drains near the chimney. Deodorising materials have also been recommended in cases where nuisance is experienced in connection with sewer ventilators, but they, too, cannot be regarded as a satisfactory means of disposing of the difficulty in question. Where the sewers are well constructed, properly flushed, and have a sufficient fall, these various devices are unnecessary, and in any case their adoption only palliates and does not go to the root of the mischief.

It has been suggested that sewers should be ventilated by means of the soil-pipe ventilators of house drains; this would involve the abolition of the trap disconnecting the house drain from the sewer, and the method is open to great objection. Again, it has been proposed to carry a ventilating pipe up the side of the house from a point just beyond the disconnecting trap, and on the sewer side of it. In times of heavy rainfall, however, when ventilation of the sewer is most required, such pipes would, in many instances, be put out of action, by reason of the fact that the level of the sewage, in the sewer, rises to such an extent as to close the opening by which the pipe enters; moreover, owners of houses naturally object to affording facilities, for the ventilation of the public sewer, which may involve some risk of nuisance being caused upon private premises.

The flow of air in sewers is in part determined by the flow of the sewage, which, to some extent, draws the superincumbent air along with it. Again, the difference in the temperatures, inside the sewer and in the roadway, tends to produce interchange of air through sewer ventilators. In summer time the sewer air is cooler, as a rule, than the outside air; in winter time it is warmer, and on this account, and because it is saturated with moisture, the sewer air tends to rise through ventilating openings in the roadway, while the colder external air enters the sewer. Further, the discharge of warm liquids into the sewer, and variations in the volume of sewage at different times of the day, and especially during periods of rainfall, favour the displacement of sewer air. Finally, variations of barometrical pressure, and the aspirating effect of winds blowing into or over openings communicating with the sewer, are factors which influence sewer ventilation.

The air of well-ventilated sewers differs little in chemical composition from that of the ordinary atmosphere. It has been shown, by Laws and Andrewes, that the bacteria of sewer air are for the most part those of the surrounding atmospheric air, and that there is little tendency for the bacteria of the sewage to obtain access to the air of sewers. In ill-ventilated sewers, however, the contained air, on chemical analysis, has been found, in particular instances, to present marked deviation from the constitution of the ordinary atmosphere. In certain instances men, who have entered foul sewers, in which there was much putrefying sediment and in which the absence of ventilation had brought about accumulation of gases of decomposition have been attacked with acute symptoms of poisoning (headache, vomiting, purging, etc.), and a fatal result has in rare cases been known to occur. When death has been caused by entering foul sewers, it seems to have been due either to poisoning with sulphuretted hydrogen gas, or to asphyxiation caused by replacement of the oxygen in the sewer air by carbonic acid. The air of a choked sewer in Paris was found to contain nearly 3 per cent. of sulphuretted hydrogen and only 13·8 per cent. of oxygen.

Sewage Disposal.

1. *Discharge into the Sea or into the Estuary of a Large River.*—This method has been adopted in some cases, and provided that the outfall is below low-water mark of the lowest tide, that the local currents are such as to carry the sewage out to sea, and that the discharge is effected at suitable times, the system has not been productive of complaint. Float observations have been made, in particular instances, with a view to determining the direction of the local currents, and the point at which the sewage outfall may with advantage be placed. Difficulty is experienced, of course, from the fact that the sewage is continually flowing, and that it can only be discharged at certain states of the tide. To meet this difficulty storage reservoirs have, in some instances, been employed. The risk attendant upon adoption of the method of disposal in question is, of course, much greater, where tidal estuaries are concerned, than it is in places situated on the sea shore, as in the former case the tendency usually is for the sewage to be brought back by the incoming tide, and for a contaminated "sewage zone" to be formed in the estuary.

2. *Precipitation Methods.*—Many chemical substances have been employed for the treatment of sewage. Lime, sulphate of alumina, and protosulphate of iron enter into the composition of most of these. In the "lime process" thoroughly slaked pure lime is employed in the proportion of 1 ton of lime to each 1,000,000 gallons of sewage; insoluble carbonate of lime, and compounds of lime and organic matter are precipitated, and collect on subsidence, constituting "sludge." If the sludge and effluent become too markedly alkaline, putrefaction is favoured. Sulphate of alumina, when added to sewage, is decomposed, and a flocculent precipitate of hydrate of alumina is formed, which tends to carry down with it the suspended organic matter in the sewage. Protosulphate of iron has also been used, generally in connection with lime treatment; here, too, a flocculent precipitate, in this case of hydrated protoxide of iron, is thrown down, carrying with it the suspended organic matter. In the treatment of the metropolitan sewage, lime 3·7 grains, and protosulphate of iron 1 grain, per gallon of sewage, have been largely employed; after precipitation, manganate of soda and sulphuric acid have been added to diminish offensive smell. The sulphate of iron checks putrefaction, but its use is attended with the disadvantage that the

effluent is likely to produce an unsightly black deposit of sulphide of iron.

The "A B C process" consists in the addition to the sewage of a mixture, the chief ingredients of which are alum, clay, and charcoal; in some instances a small quantity of blood is also added. The sludge obtained in this process, having been pressed in filter-presses and dried, can, it is said, be readily sold as manure, but the effluent is liable to undergo secondary decomposition, and the cost is greater than when lime alone is employed. In the "Ferrozone and Polarite process" the material called ferrozone (which consists largely of protosulphate of iron) is used for precipitation purposes, and the effluent is then filtered through polarite (magnetic oxide and carbide of iron with silica, lime and alumina). In the "Amines process" a mixture of lime and herring brine is employed, the trimethylamine contained in the latter is said to produce a "soluble gas antagonistic to micro-organisms."

The "Hermite process" may be here referred to, as, though not, strictly speaking, a precipitation method, the principle resembles that adopted in the chemical processes of treatment, in that deodorisation and sterilisation of the sewer contents are the objects aimed at. The system depends on the employment of electrolysed sea-water for flushing water-closets, etc., and as the liquid used possesses some disinfecting powers, in virtue of the presence of chlorine, or of some chlorine-containing body, it is found that the number of micro-organisms in the effluent shows marked reduction, and that the tendency to decomposition is materially influenced. Soap and domestic waste, however, appear to prejudice the activity of the liquid, and the discharge of an effluent containing free chlorine into rivers is open to objection. Moreover, the process is expensive.

"Webster's process" consists in directly electrolysing the sewage, which is made to pass through channels containing the necessary appliances. At the positive pole (the electrode used is an iron plate), chlorine and oxygen enter into combination with iron, and the iron salts formed in the solution are said to act as carriers of oxygen, and thus to oxidise the organic matter of the sewage, while deodorisation is facilitated by absorption of sulphuretted hydrogen, probably by the carbonate of iron present. The number of micro-organisms in the effluent is greatly reduced, but the method is a costly one.

In connection with all these methods difficulties are experienced both as regards securing a sufficiently purified effluent and devising an economical means of disposing of the sludge.

The Rivers Pollution Commissioners laid down the following standards as being those with which a sewage effluent discharged into a river should comply:—

MAXIMUM IMPURITY IN PARTS PER 100,000.

Dry mineral matter in suspension.	Dry organic matter in suspension.	Colour.	In solution.					
			Organic carbon.	Organic nitrogen.	Any metal except calcium, magnesium, potassium, or sodium.	Arsenic.	Chlorine.	Sulphur as H_2S or sulphate.
3	1	Any colour in one inch stratum in a white vessel	2	0·3	2	·05	1	1

The "organic ammonia" is often appealed to as a test of a good effluent; it should not exceed ·15 per 100,000. The "oxygen absorbed" in four hours at 80° F. ought not to amount to more than 1·5 parts per 100,000. The percentage of dissolved organic pollution removed, expressed in parts of permanganate of potash reduced, is a criterion now commonly applied. A satisfactory effluent should be devoid of fæcal odour, and not be liable to undergo secondary decomposition. The study of sewage effluents from the bacteriological side has only recently been commenced. Houston has drawn attention (*British Medical Journal*, December 21st, 1901) to the delicacy and importance of certain bacteriological tests. The significance of the presence of *streptococci*, as an indication of recent pollution by animal organic matter, has been clearly demonstrated by his experiments. Numerous analyses given by the Rivers Pollution Commissioners showed that the chemical methods in use at the time of their report only removed, on an average, about 90 per cent. of the suspended matters of sewage, and 36 per cent. of the organic nitrogen dissolved in it. (The organic nitrogen in sewage is generally about 2 parts per 100,000. *See* p. 227.) Thus, the adoption of these methods implied of necessity some system of dealing with sludge, and, as a rule, application of the effluent to land, with a view to further purification, before allowing it to be discharged into a watercourse.

The sludge question has been termed the "*bête noir* of all precipitation systems." The attempt has been made to partially separate the water from the sludge, as, for example, by the use of a "filter press," and to then dry it, or mix it with ashes producing a compost which can be sold as manure. Again, the sludge has been burnt in a destructor (at Ealing), it has been proposed to make it into cement, and it has been dug into the land. The value of the sewage manures obtained from sludge is small; they contain, as a rule, a considerable percentage of substances of no manurial value, and the nitrogen, for the most part, is not present in them in readily assimilable form. The sewage cement process, too, has been found to be financially impracticable. The sludge from the metropolitan sewage has been pumped into specially constructed steamships, and carried for some distance down the Thames estuary and there discharged.

3. *Filtration through Land.*—The system of "intermittent downward filtration" consists in "the concentration of sewage at short intervals on an area of specially chosen porous ground, as *small* as will absorb and cleanse it, not excluding vegetation, but making the produce of secondary importance." The land is drained to 6 or 8 ft., *i.e.*, to a greater depth than where "broad irrigation" is practised; the drains, too, are placed at more frequent intervals than is usual in broad irrigation; the soil, moreover, must be light and well broken up. In the application of this system the Rivers Pollution Commissioners estimated that one acre would be necessary for the sewage of 2,000 persons. If the sewage has been subjected to previous treatment, a smaller quantity of land, in proportion to population, may suffice. On the other hand, the estimate is a low one for untreated sewage; one acre for 700 persons has been suggested as a limit, and probably one acre per 1,000 persons may be taken as nearer the mark than one acre per 2,000. The filtration should be intermittent, in order that the interstices of the land filter may be again and again aerated. It has been found that the filter speedily becomes clogged unless some of the suspended matter of the sewage is removed in the first instance. As a rule it is not desirable to attempt to grow crops on the land. An important point to be borne in mind in connection with this system of sewage treatment is that the surface of the land filter should be frequently turned over in order to revivify it.

4. *Broad Irrigation* consists in "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." For successful sewage farming the soil must be of suitable character and properly prepared and underdrained; the sewage should undergo preliminary straining, and should be applied as fresh as possible. On an average about one acre per 100 persons is found necessary for the practice of irrigation; at Croydon, one acre per 200 persons; and at Berlin, one acre for about 150

persons is allowed. In the case of Berlin the area of land covered by the sewage works exceeds thirty square miles, though only about half this area is actually laid out for irrigation; ryegrass is chiefly cultivated, but wheat, barley, oats and roots are also grown. Sewage farming is extensively practised in the neighbourhood of Paris, the farm at Gennevilliers having been at work for many years with considerable success; the area of land under cultivation has, moreover, been recently greatly extended.

The main difficulty in connection with irrigation is that of securing a satisfactory effluent during rainstorms; in some instances a part of the farm has been laid out as a closely drained filter bed, with the object of rapidly dealing with excess of storm water. The configuration of land and the favouring conditions of soil necessary for successful sewage farming are, of course, only found in certain localities, and, where pumping has to be extensively resorted to, the expense is greatly enhanced. A stiff clay soil is eminently unfavourable for treatment by irrigation; the best soil is said to be a friable loam, and porous soils generally are to be preferred to retentive soils; in the case of chalk soils, more particularly, there is risk of sewage obtaining access to fissures and so polluting water supplies.

The subject of risk of spread of disease in connection with sewage farms has received much attention. Enteric fever has in a few cases been attributed to effluvia from these farms, but in one or two instances, in which the question has been carefully inquired into, it has transpired that the probable source of infection was the consumption, by the persons attacked, of sewage-contaminated water. Dysentery has also been attributed to effluvia from sewage-irrigated land. The population living in the neighbourhood of well-managed farms does not appear, however, to suffer from these diseases, or from other diseases which could be thought of as being caused by sewage effluvia. The experience of the Berlin sewage farms may be specially referred to as pointing in this direction. In the early days of sewage farming it was anticipated that tape-worms and round-worms would obtain access to the human alimentary canal, to an increasing extent, as the result of the application of liquid sewage to land. Instances of infection traced to this source have not, however, been forthcoming, and this fact has been attributed to the alkalinity of the sewage, for the ova of these parasites naturally undergo development in an acid medium. In no instance has the consumption of vegetable produce from sewage farms, in this country, been definitely found to have produced disease in man, and even where cattle have been pastured on sewage farms, and their milk subsequently distributed, no harmful result appears to have been observed. An epidemic of "entero-colitis," which occurred at an asylum in France, was attributed, in 1889, to *Trichocephalus*, which was supposed to have been communicated by consumption of vegetables watered with sewage water. The risk of contamination of water supplies derived from formations, in which the existence of fissures may lead to pollution of deep wells, is one carefully to be borne in mind; such contamination is said to have occurred in at least one instance.

5. *Biological Purification.*—In what is termed the biological treatment of sewage, the aim is not to arrest but to favour decomposition; endeavour is made to so control the sequence of changes, however, as to prevent nuisance, and yet attain the desired purification. The discovery, in 1877, by Schlösing and Muntz, of the fact that nitrification is accomplished by the agency of bacteria, first directed attention to the necessity of studying the behaviour of micro-organisms in relation to putrefaction; but it was not until a series of experiments was conducted by the State Board of Health of Massachusetts, in 1888 and succeeding years, that the subject of bacterial growth in connection with the purification of sewage was seen to be assuming especial importance. In 1891, Scott Moncrieff attempted to solve the question of producing liquefaction of the solid matters in sewage by bacterial agency, and in 1892 he introduced his "cultivation tanks," in which sewage was allowed to enter at the lower part of a filter bed filled with flint, coke, and gravel. The suspended matters in the sewage were held back by the filter, and to a large extent "peptonised," the effluent sewage escaping, from the upper part of the tank, being practically free from suspended matter. With a view to further improving this effluent by oxidisation and the action of micro-organisms, it was passed down a series of "nitrification channels." More recently, Scott Moncrieff has attempted to secure greater aeration of the effluent by various devices. Dibdin, in 1891–95, made a series of experiments with regard to the downward filtration of sewage through coarse filter beds; he experimented with the metropolitan sewage, and at Sutton his method of treatment was put in practice on a large scale, and it has since been adopted elsewhere.

In 1895, Mr. Donald Cameron, the City Surveyor of Exeter, introduced what is known as the "septic tank." He applied the principle of subjecting sewage to preliminary treatment in a receptacle covered to exclude the light and, as far as possible, the air. The incoming sewage was delivered below water level, and the outlet was also submerged; the passage of material through the tank was, moreover, slowly accomplished, and disturbance of the upper layers of the liquid was, as far as possible, avoided. Under these circumstances it was found that no sludge collected in the tank, only a thin layer of black earthy matter being formed. A scum develops on the surface of the sewage; and here aerobic micro-organisms are, no doubt, actively at work, while, in the deeper layers in the tank, anaerobic organisms may be assumed to be carrying on the process of liquefaction of suspended matter. On leaving the septic tank, through an opening placed, so as to exclude the surface scum, somewhat below the level of the sewage in the tank, the effluent is made to flow in a thin stream into an "aerator," and thence, by means of automatic alternating gear, it is turned on to first one, then another, of a series of coke-breeze filters. By this method not only is the suspended matter practically entirely removed, but the septic tank treatment alone is found to give "29 per cent." purification as against the Rivers Pollution Commissioners' mean result, of 28·4 per cent. removal of organic carbon, by all the best-known chemical methods; the filters, moreover, "yield 73 per cent. purification on the tank effluent."

It has been pointed out that this anaerobic treatment of the sewage is really a development of the old cesspool system; for it is well known that the amount of deposit which collected, during a long period of time, in the old underground cesspool was quite small in proportion to the total quantity of suspended matter in the sewage discharged into the cesspool.

Colonel Ducat, in 1897, devised an "aerated bacterial self-acting filter." In this appliance, it is sought to secure liquefaction and purification of sewage by a "continuous filtration" process. The walls of the filter are constructed with agricultural drain-pipes, having a slight fall towards the interior; thus the wind can blow through the pipes and aeration is promoted, the idea of an anaerobic treatment of the sewage being quite abandoned; the material through which the sewage percolates is coarse at the top and fine at the bottom; a method of warming the filter in winter has been also devised.

A number of experiments with regard to filtration of sewage have been conducted by Clowes and Houston at the Metropolitan Outfalls. A single coke bed was used, and experiments were also made in which the effluent from one coke bed was afterwards subjected to further treatment in a second coke bed. Clowes, in reporting on operations conducted in the summer of 1898, concluded that "by substituting a single coke treatment for chemical treatment the effluent sewage discharged into the river would be completely free from suspended impurity, and would possess a purity as regards dissolved putrescible matter of 51·3 per cent. as compared with 16·9 per cent. in the present effluent, representing an improvement of 67·1 per cent.; if discharged after double treatment in the coke beds, the percentage improvement on the chemical effluent would be 75·6."

In these experiments gas coke in pieces about the size of walnuts was employed. Some reduction in the capacity of the coke bed was found to occur with continued use; this reduction of capacity "appears to be mainly due to fragments of straw and chaff, apparently derived from horse-dung, and to woody fibre derived from the wear of wood pavements." As regards the quantity of sewage dealt with, this originally amounted to 550,000 gallons per acre per day for the 4-ft. coke bed, and to 832,500 gallons per acre per day for the 6-ft. coke bed; these amounts were reduced after ten months' working to 370,000 and 637,400 respectively. It was found that rather more than 1½ million gallons per acre per day were dealt with when the 6-ft. coke bed was filled twice daily. Moreover, experiments were later made with coke beds of greater depth (in particular with a 13-ft. bed), and Clowes writes: "If the satisfactory working of the 13-ft. bed is maintained, it will treat a volume of sewage equal to at least 3½ million gallons per day."

Houston carefully investigated the effect of the method of treatment adopted from the bacteriological point of view. He selected *Bacillus coli* and *Bacillus enteritidis sporogenes* as types specially suited for the purpose of his inquiry, and he found that the number of colonies of these organisms, obtainable from the effluents, was very nearly as large as in the case of the crude sewage. His researches led him to the conclusion that "it is doubtful if any bacterial process, in practical operation at the present time, 'treats' or 'detains' the sewage for a sufficiently long period to allow of the complete destruction of all the pathogenic germs by bacterial agencies." He ascertained that a microbe which he called the "sewage Proteus" passed through the filter in practically undiminished numbers; he further isolated from the coke bed effluent "a highly virulent strain of *Bacillus pyocyaneus*." He found, moreover, that bacilli indistinguishable morphologically from the tubercle bacillus were present, in the deposit on the coke fragments, and could be demonstrated by centrifugalising large quantities of crude sewage and effluents, staining with carbol-fuchsin, and then decolourising with nitric acid. Inoculation experiments gave a positive result in only one instance, and it was concluded "that even if some of the 'acid-fast' bacteria collecting in the coke beds are those of the tubercle bacillus, they have for the most part lost their infective power."

Houston points out that "in certain cases it may be imperative to obtain an effluent bacteriologically sound, but it does not follow that a similar result is urgently called for in other cases, as, for example, where an effluent is turned into a watercourse, which is not used for drinking purposes, and which already may contain practically all the bacteria that are found in sewage." He adds: "No doubt the question will eventually have to be faced—Are the advantages gained by chemical purification sufficiently great to outweigh the possible danger arising from the discharge of an effluent bacteriologically unsound into the river Thames?"

In 1898 a Royal Commission was appointed to make inquiry concerning methods of treating and disposing of sewage which may properly be adopted. The Commissioners prepared an interim report in 1901. In the first place, with reference to the alleged unsuitability of certain sorts of land for the purification of sewage, they arrived at the conclusion, while doubting whether any land is entirely useless, that peat and stiff clay lands are generally unsuitable. Secondly, as regards artificial processes, they found it was practicable, by their use, to produce "effluents which will not putrify, which would be classed as good according to ordinary chemical standards, and which might be discharged into a stream without fear of creating a nuisance"; they concluded, therefore, "that there are cases in which the Local Government Board would be justified in modifying, under proper safeguards, the present rule as regards the application of sewage to land." Thirdly, they held the general protection of rivers to be a matter of such grave concern as to demand the creation of a separate Commission, or a new department of the Local Government Board, which should be a Supreme Rivers Authority, with powers to act in default of local authorities.

CHAPTER VII.

DWELLINGS, SCHOOLS, AND HOSPITALS.

The conditions which influence the healthiness of the habitation are—(*a*) Those of its site and surroundings, with which may be included such arrangements of streets and neighbouring houses as affect the lighting and ventilation of the dwelling. (*b*) The structural details of the habitation itself, including among these not only questions of stability and of dryness of foundations, walls, and roofs, but also means of sewerage, refuse disposal, and water supply, and those points of construction which have concern with the prevention of fire. The provision of adequate means of escape for the occupants, in the event of fire occurring, is a point, too, which needs consideration in connection with building regulations.

Site and Surroundings.

Sites.—The subject of soil in relation to houses has been already referred to. In the country, especially, it is important that attention should be directed to drainage of the subsoil of the site, and a situation on rising ground and in the neighbourhood of trees, but not unduly obstructed by them, is to be preferred, as presenting especially favourable conditions in this respect. Other things being equal, it is best to have an east or south-east aspect for the front rooms, as in that case the maximum effect of sunlight, on the front and back of the house, is secured.

The character of the soil underlying the house needs to be particularly attended to; the model by-law of the Local Government Board prohibits the erection of a new building "upon any site which shall have been filled up with any material impregnated with any animal or vegetable matter, or upon which any such matter may have been deposited, unless and until such matter shall have been properly removed, by excavation or otherwise, from such site." Land which has been used for the deposit of such material is wholly unfit for building purposes, and effluvia, which can sometimes be appreciated by the sense of smell, are given off from such sites for a considerable period. Burdon-Sanderson and Parkes made a number of experiments, some years ago, with the object of determining the effect of time upon organic matter and cinder refuse which had been used to fill up inequalities in the ground. They found that decay of the most easily destructible matters was completed in about three years, but in the case of more resistant materials, such as wood and woollen cloth, the process was more prolonged.

In any case the site of the dwelling should be properly asphalted, or covered with a layer of good cement concrete, rammed solid, and at least six inches thick; the object of this precaution being to prevent the passage of moisture and ground air, from the soil beneath, into the interior of the dwelling. Where the rooms in the lowest storey have boarded floors, it is the practice to require that there shall be provided, between the under side of the floor joists and the upper surface of the asphalt or concrete, a clear space of three inches at the least, in every part; this space should be thoroughly ventilated by air bricks, or in some other effectual manner. In some codes of by-laws covering with concrete is not insisted upon, provided the site is dry and the subsoil unpolluted. In such cases the model by-law of the Local Government Board prescribes that the ventilating space beneath the floor boards shall be at least nine inches in depth; this involves fully two or more additional courses of bricks in the walls of the building, and thus very little saving is effected by the omission of the concrete.

Open Space about Buildings.—In towns more particularly, the question of the amount of open space provided in front and at the rear of dwellings is apt to assume importance, inasmuch as, where building land is especially valuable, there is a natural tendency to cover the ground to the greatest extent permitted, and thus to interfere with the proper lighting and ventilation of houses. The desirability of adequately lighting inhabited rooms has been long recognised. There is an old proverb to the effect that where the sun never enters the doctor always does, and modern knowledge concerning the circumstances which favour the development of micro-organisms, and the way in which exposure to sunlight destroys disease germs, has led to increasing recognition of the value of light as a disinfecting agent. It is not merely necessary that living-rooms should be adequately lighted (some attempt to secure this result has been made in the past for obvious reasons), but staircases, bedrooms, and indeed any part of the house which may afford opportunity for the communication of impurity in the form of dust to the atmosphere of the dwelling, should also, as far as practicable, be exposed to the action of light. Just as it is necessary to avoid dark enclosures and corners, so it is important that circulation of air should, as far as possible, be secured, and that completely circumscribed "shafts" and "wells" which would permit of the collection of stagnant columns of air, and such arrangement of tenements as would interfere with the proper renewal and interchange of the air of the rooms, should be avoided.

In the past but little attention was paid to such questions; it was common to form culs-de-sac, dead-ends, which prevented air movement, and led to more or less stagnation of the air in front of the houses approached from the cul-de-sac. Again, it was a frequent practice to cause a court to be entered by a narrow passage-way overarched by a portion of a house fronting upon a main street. Such courts were themselves, in many instances, far too narrow, and often ended blindly, so that the air contained in them was practically almost stagnant. In towns, where land was especially valuable, but little space was left at the rear of buildings, and workshops or cottages have been in numerous instances erected upon the ground originally intended to be the back yard of a house; in many cases such back cottages not only possessed no means of through ventilation, but they were dependent for their air-supply upon the well of stagnant atmosphere situated between them and the front house, and by their presence they materially interfered with the ventilation of the latter. Moreover, the back rooms of the front building and the rooms of the cottage at the rear were mutually darkened by the close proximity of the two buildings to one another.

As regards the *space in front* of houses, the model by-laws prescribe a minimum width of 36 feet for a street more than 100 feet in length, or one which is used as a carriage-way, while in any circumstances it is required that a street forming the principal approach or means of access to a building shall be at least 24 feet in width. The London Building Act, 1894, empowers the County Council to refuse to sanction plans for streets formed for carriage traffic of less width than 40 feet clear, and for those formed for foot traffic of less width than 20 feet clear. Moreover, the width of certain new streets, not within two miles of St. Paul's Cathedral, may be required to be 60 feet.

With the object of securing adequate open space in the front of new domestic buildings, the model by-laws prescribe that throughout the whole line of frontage of any such building there shall be an open space extending to a distance of 24 feet at least, free from any erections (other than porticoes, steps, etc., not exceeding 7 feet in height). This clause secures, on the re-erection of domestic buildings in streets of less than 24 feet in width, the widening of such streets. It has been found, however, that the clause presses unduly upon the first person who reconstructs on one side of a narrow street, as he has to set back so as to secure the 24 feet of open space, while his opposite neighbour, if he rebuilds at a later date, is not required to set back at all. In order to meet this objection, the by-law is sometimes worded so that it devolves upon the first person, who rebuilds on a narrow street, to set back one-half as many feet as the difference between the width of the street and 24 feet, and then, when the opposite neighbour rebuilds, he is in his turn required to set back to a like extent, so that the ultimate result is that a street of 24 feet in width is formed.

As regards *space at the rear*, the model by-laws provide that at least 150 superficial feet shall be kept free from any erection above the level of the ground, with the exception of a water-closet, earth-closet, privy, or ashpit. This space must extend the whole length of the building, and at no point must it be less than 10 feet across to the boundary of the premises opposite. If the height of the building is 15 feet, the distance across must be at least 15 feet; if the height is 25 feet, the distance must be 20 feet; and if the height is 35 feet or more, the distance across must be at least 25 feet. These requirements do not secure much space at the rear of houses, and in country districts a much larger amount of back yard, or garden ground, is usually provided. In large towns, however, even the limitations referred to above are not always insisted upon.

In London, in the Act of 1894, the principle that the amount of open space at the rear shall be proportionate to the height of the building is accepted, the height being limited by the requirement that it shall not exceed twice the distance from the rear of the building to the boundary of the open space provided. In other words, an imaginary horizontal line is first drawn at the level of the pavement, running at right angles to the centre of the front of the building, and is prolonged to the boundary of the open space at the rear of the building, and then, at the point where this line intersects the rear boundary, an imaginary diagonal line is drawn, in the same vertical plane as the horizontal line, and making with it an angle of $63\frac{1}{2}°$; the diagonal line, thus defined, controls the height of the building, no part of which, except chimneys, dormers, gables, turrets, or other architectural ornaments, must extend above this line. While this is the general principle held in view, certain exceptions are made; moreover, the special circumstances of basement rooms below pavement level have to be considered. Thus, as regards habitable basements, the Act requires that all domestic buildings possessing them, which are erected after 1894, shall have a space of 100 square feet, free from any erection above the level of the pavement, provided at the rear, for the purpose of giving light and air to the basements. The detailed application of the general principle referred to, and the exceptions admitted, remain to be referred to.

If a domestic building be erected, abutting upon a *new* street, it must have, at its rear, an open space of at least 150 square feet extending throughout its entire width, and at least 10 feet across in every part; but where there is a basement storey lighted and ventilated by the 100 square feet space already mentioned, or where there is no basement storey and the ground storey is not intended to be inhabited (as, for example, when it is used for business purposes), the open space of 150 square feet may be provided above the level of the ceiling of the ground storey, or a level of 16 feet above the adjoining pavement. The height of the building is controlled by the 63½° angle, as already described. Special sub-sections deal with the particular case of a building at a corner abutting upon two streets, or abutting upon one side on a street and on another side upon an open space not less than 40 feet wide, and permanently secured. In these and other exceptional cases, the Council must be satisfied that due access of light and air is not interfered with. It may be noted that the model by-laws of the Local Government Board contain special clauses dealing with the way in which such particular cases may be met.

As regards domestic buildings abutting upon *old* streets, a modification is made, the horizontal line being directed to be drawn not at pavement level, but 16 feet above this, and the 63½° angle is then applied as before. Moreover, the 150 square feet of open space, 10 feet across at every part, may be provided above the level of the ceiling of the ground storey, or 16 feet above the level of the adjoining pavement. An important exception is made, however, in the case of houses adapted to be inhabited by persons of the working-class, as in such houses the open space must be provided from pavement level upwards.

Again, if domestic buildings (other than dwellings inhabited or adapted to be inhabited by persons of the working class) are *erected on old sites* abutting upon a street, the original conditions can be again reproduced, but no more ground must be occupied by the new buildings than was occupied by those previously existing. In other words, the conditions must not be made worse than they originally were. It will be obvious that in such a state of the law it is possible to newly erect, upon old foundations, buildings which will be very inadequately provided with rear space.

A very important section of the Act is that which relates to the provision of open space about dwelling-houses, adapted to be inhabited by persons of the working-class, and which do not abut upon a street. In the case of such dwellings plans must be submitted to the London County Council, and the Council may refuse its sanction to such plans if the open space, or spaces, provided are found not to be equivalent to the open space, or open spaces, which would have to be provided if the dwelling-house were erected abutting on a street or way formed or laid out before the commencement of the Act. This provision gives a most important, though somewhat limited, power of control over the erection of working-class dwellings upon "back land."

The law in London with regard to limitation of the *height* of the building, in proportion to the width of the street upon which it *fronts*, is to the following effect:—No building (other than a church or chapel) may be erected in a street of less width than 50 feet, formed or laid out after 1862, to a height exceeding the distance from the nearest external wall of such building to the opposite side of such street. The position of the front of new buildings, with reference to streets, is controlled by a section which specifies that no part of the building and no forecourt shall, without the consent of the London County Council, be at a distance less than the *prescribed distance* from the centre of the roadway. (The "prescribed distance" is defined as being 20 feet from the centre of a roadway used for carriage traffic, and 10 feet from the centre of a roadway not so used.) In the case of working-class dwelling-houses, it was newly provided in 1894 that such houses should not be erected, within the "prescribed distance," to a height exceeding the distance of the front of such building from the opposite side of such street; further, no building could be converted into such a dwelling-house, within the "prescribed distance," so as to exceed such height. In practice, difficulty was experienced in determining the way in which this proviso should be interpreted in certain instances, and, in order to remove this difficulty, an amending Act of 1898 substituted for the expression "prescribed distance," in this particular proviso, the words "a distance of 20 feet from the centre of the roadway."

Another important section of the London Building Act of 1894 is that concerned with the lighting and ventilation of rooms opening into the *internal courts* or shafts, which are so common in block buildings, and in dwellings constructed to be let in flats. Where such a court is enclosed on every side, and where its depth, measured down to the ceiling of the ground storey, exceeds its length or breadth, adequate provision for its ventilation, by means of a communication at its lower part with the outer air, must be made and maintained; moreover, a habitable room which has no window, other than one opening into such a court, must comply with the condition (subject to slight modification in exceptional circumstances) that the width of the court, from the window to the opposite wall, shall be equal to at least half the depth of the sill of such window below the eaves or parapet of the opposite wall.

There are several important provisions which relate to *habitable rooms*. Such rooms must be at least 8 feet 6 inches high, though in the case of attic rooms it is only necessary that a height of not less than 8 feet, over an area of at least one-half the area of the room, shall be secured. Habitable rooms must also have one or more windows opening directly into the external air or into a conservatory, and providing window space equal to at least one-tenth of the floor area of the room; moreover, the windows must be so constructed that a portion, equal to at least one-twentieth of the floor area, can be opened, and so that they extend to at least 7 feet above floor level. There is, however, a modification of this requirement in the case of "a room having no external wall or a room constructed wholly or partially in the roof." Again, there is a provision in the Act of 1894 that habitable rooms above the level of the ground storey, having no window other than one opening into a court open on one side (the depth of which court measured from the open side exceeds twice the width), must comply with the condition, that the distance, to the opposite wall of the court, shall be not less than half the depth, below the top of the wall, of the sill of the window. The question at issue here is the need of securing the adequate lighting of rooms which are overshadowed by back additions extending from a main building.

The Act further contains important provisions relating to the *lighting and ventilation of staircases*: it requires, in the case of houses let in separate tenements to more than two families, that the principal common staircase shall be ventilated on every storey above the ground storey by windows or skylights opening directly into the open air, or shall otherwise be adequately ventilated; in every instance it requires that the principal staircase of a dwelling-house shall be ventilated by at least one such window or skylight.

The importance of such regulations as those just referred to is very great, they tend to limit or prevent "closeness, and bad arrangement," and interference with access of light to, and circulation of air about, habitations. Farr many years ago directed attention to the way in which the mortality of districts is raised in correspondence with increasing density of population. He was even led to express the relation by means of a formula to the effect that the mortality varied as the sixth root of the density. He later (Supplement to the 35th Annual Report of the Registrar-General) modified his formula, ·11998 being substituted for one-sixth, so that, m and m' being the mortalities, and D and D' the densities in two places, $m' = m\left(\frac{D'}{D}\right)^{0\cdot11998}$ *i.e.*, the mortalities vary approximately as the eighth roots of the densities.

Ogle found on examination of the death-rates in districts in England and Wales in 1871–1880, that if there were less than 400 persons per square mile, density appeared to have little influence; but when, on the other hand, the closeness of aggregation of persons upon area was increased beyond this limit, the mortality also steadily increased. Thus while death-rates of from 14 to 20, per thousand persons living, were found in the more sparsely populated districts, rates of 22 to 24 were observed in districts with from one to two thousand persons to the square mile, and the death-rate rose with increasing density, until, in districts with upwards of 6,000 persons to the square mile, rates of 27 to 28, per thousand persons living, were recorded. Tatham, dealing with the decennium 1881–1890, found that the relationship in question was too complex to admit of being expressed by such a formula as that of Farr, but he noted that mortality steadily rose with increase of density.

The result of an investigation concerning the vital statistics of occupants of Peabody Buildings, made by Newsholme in 1888–1890, was given in a paper printed in the *Journal of the Royal Statistical Society* in 1891. This investigation showed that the death-rate in these buildings was about two per thousand lower than that of London, for the twelve years ending with the year 1885. The infantile mortality was much lower in the Peabody Buildings than in London as a whole. The death-rate from phthisis and other tuberculous diseases was slightly higher, and diseases of a specially infectious character, and particularly whooping-cough and measles, were found to be more fatal than in London generally.

The occupiers of the dwellings referred to are, it must be borne in mind, to a large extent specially selected, and care requires to be exercised in drawing conclusions with regard to the mortality experienced by them. While this is the case it must be admitted that the results of housing large numbers of persons upon a limited area, provided due regard is paid to the question of arrangement of the buildings and of their sanitary condition, are not so serious as the investigations concerning density of population, made by Farr half a century ago, led him to assume that they would be. On the other hand, there is a certain amount of evidence pointing to the conclusion that diseases, due to direct infection, tend to show increase when persons are housed in large numbers in blocks of buildings, even when care is devoted to designing the arrangement of the rooms in such blocks. Newsholme considers that the "essential element in testing the true density of population is a statement of the number of persons living in each occupied room." This test, he thinks, combined with a determination of the population on a given area, would give the most trustworthy estimate of density, and "the two together would determine the probabilities of the incidence of the diseases connected with overcrowding, and of the rapid spread of infectious diseases."

The question of the need for *open spaces* is one which, especially in recent years, has received some amount of attention in large towns. The formation of squares and gardens, the provision of cross streets at frequent intervals, and the desirability of so dealing with the land at the corners of streets, as not to interfere unduly with circulation of air, are matters which have received some consideration in connection with building schemes on large estates. Instances of this are afforded, for example, in the Grosvenor and Bedford estates in London. Again, the need for laying out public parks has not been altogether lost sight of, and the Metropolitan Open Spaces Acts of 1877 and 1881 provided for the acquirement of disused burial-grounds and their maintenance as open spaces. (For the extension of these powers to places outside London, *see* p. 534.)

The evils of close aggregation of dwellings may be specially illustrated by consideration of the question of *back-to-back houses.* Tatham, when Medical Officer of Health of Salford, collected statistics relating to the registration districts in that borough, for the five years 1879–1883, which showed in a striking way how mortality increases in correspondence with the extent to which back-to-back house construction prevails. Thus, in the Regent Road registration district, a portion of the area containing no back-to-back houses, showed a mortality of 26·1 per thousand; in a portion of the area with 18 per cent. of back-to-back houses, the mortality was 29·1 per thousand; and in a third portion with 50 per cent. of back-to-back houses, a mortality of 37·3 per thousand was recorded. Similarly, in the Greengate registration district, three portions (enumeration districts), with 0, 23, and 56 per cent. respectively of back-to-back houses, showed death-rates of 27·5, 29·2, and 30·5 per thousand.

A joint report, prepared by Barry and Gordon Smith, dealing with the subject of back-to-back houses, was published by the Local Government Board in 1888; one of the conclusions arrived at, as a result of this inquiry, was to the effect that the want of through ventilation, *per se*, had probably had an unfavourable influence upon health, and had given rise to an increased mortality from pulmonary disease, phthisis, and diarrhœa. Further, it was found that "the difference in the cost of construction of a through house and of a back-to-back house respectively, each affording the same accommodation and built equally well, is very slight indeed, the advantage, such as it is, being with the back-to-back house." It was submitted, as the general outcome of the investigation, that the Board should refuse to sanction any by-laws which would permit the erection of back-to-back houses, and should discourage, by all the means at their command, the erection of such houses.

Further inquiries have since been made concerning the mortality statistics of back-to-back houses by Niven in Manchester, and by Evans in Bradford, and recent Building Acts and codes of by-laws contain, as a rule, provisions, the intention of which is, no doubt, to make the erection of such houses illegal. So far as cottage dwellings are concerned, the desired end is, as a rule, attained, but it does not appear that the possibility of reproducing objectionable types of construction of dwelling-rooms, in the case of block dwellings, is adequately guarded against.

J. F. J. Sykes has pointed out that "each accretion to the room, the dwelling, the house, and the block demands correspondingly amplified building restrictions, or, in the complications resulting from the heaping of Ossa on Pelion, the methods of construction prohibited in the simplest type, are reproduced in other and more aggravated forms in the larger and more complicated pile." He observes that in order to prevent the construction of what are practically back-to-back houses in blocks of dwellings, it is necessary that there should be a requirement "that in every dwelling consisting of two or more communicating rooms, at least one of the rooms shall possess a window opening on the opposite side of the building to that in which the window of the other room, or one of the other rooms, is situated."

In some sets of "flats," the block is not limited by being only two rooms deep, but is designed to admit of the construction, not merely of rooms lighted from its front and rear, but also of intermediately placed rooms; such internal rooms are made to abut upon a central well, or are lighted by means of windows opening upon courts, which penetrate into the depth of the block, from its front or its rear aspects. These central wells are apt to contain more or less stagnant air, and the rooms opening into them, in the lower storeys of the block, are likely to be much darkened. Again the court which passes into the depth of the block from the front or rear of the building is often narrow, and thus much overshadowed, and rooms opening upon it are far less favourably placed, so far as ventilation is concerned, than if they abutted upon the front or rear walls of the building; moreover, if they are on the lower storeys and near the dead end of the court, they are likely to be dark and gloomy. Building regulations which will adequately control abuses of this kind are obviously necessary for preventing the construction, in the types of block dwellings referred to, of rooms quite unfit for purposes of habitation.

Structural Details.

(i.) Under ordinary circumstances the external or party walls enclosing new buildings should be formed only of "good bricks, stone, or other hard and incombustible materials, properly bonded and solidly put together" with suitable mortar and cement. The "proper bonding" is usually effected by one of two methods—either, as in what is termed Flemish bond, each course contains "headers" (bricks laid transversely) and "stretchers" (bricks laid longitudinally) placed alternately, or, as in English bond, courses of "headers" alternate with courses of "stretchers." Walls so bonded must be at least the length of a brick in thickness (9 in. brickwork). When walls exceed 25 ft. in height or 30 ft. in length they are generally required to be of greater thickness, and codes of by-laws usually prescribe in detail the circumstances under which 13½ in., 18 in., or greater thicknesses of brickwork shall be used. Hollow walls are, as a rule, permitted, provided proper bonding ties are inserted. In some cases, in detached houses, half-timber walls are permitted, under appropriate restrictions, designed mainly with the object of securing stability and reducing to a minimum the risk of spread of fire.

(ii.) The footings of walls should rest upon solid rock or upon a sufficient foundation of concrete. It is usual in building regulations to prescribe the width, height, and arrangement of the footings.

(iii.) Prevention of dampness: The walls should be provided with "a proper damp course of sheet lead, asphalt, or slates laid in cement, or of other durable material impervious to moisture." The damp course should be placed "beneath the level of the lowest timbers, and at a height of not less than 6 in. above the surface of the ground" adjoining the wall. The insertion of a damp course is necessary to prevent moisture being absorbed by the bricks. Such "ground dampness" ascending in an unprotected wall leads to rotting of woodwork and staining of the paper placed upon walls; it favours development of mould, and produces a musty and unwholesome condition of the air of rooms.

In old houses, the walls of which are unprovided with a damp course, it is a common thing to find basement and ground-floor rooms "match-lined," with a view to concealing the unsightly appearances caused by damp walls. Where the match-lining does not extend to the ceiling, evidence of dampness can often be detected above the woodwork. Such covering up of walls, while it removes the cause of offence to the eye, does not, of course, prevent the damp brick-work causing pollution of the atmosphere of the room.

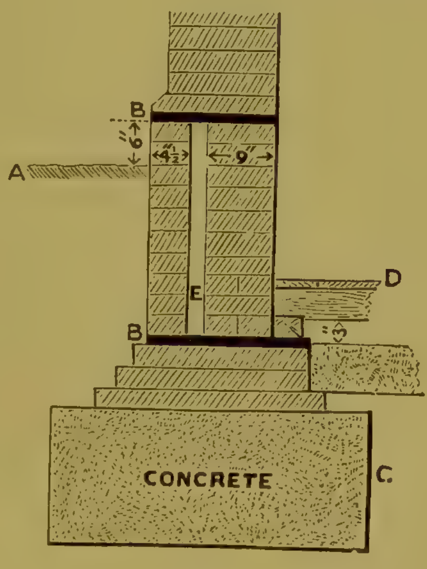

FIG. 77.

Double Damp-course.—*A*, Ground Level. *B*, *B*, Damp Courses. *C*, *C*, Concrete. *D*, Floor. *E*, Cavity between walls.

In the case of basement rooms an area should, if possible, be formed to keep the ground away from the wall, or the outside of the wall should be covered with impervious material. Codes of by-laws often prescribe the adoption of the device shown in Fig. 77. A hollow wall is constructed and two damp courses are provided, one at the base of the wall below the level of the floor boards, the other above the ground level and at the top of the cavity of the hollow wall.

Paving the ground adjoining walls is often productive of marked benefit in preventing dampness. Moreover, care requires to be taken that sink wastes, rain-water pipes, etc., do not discharge in such a way as to favour such a condition by splashing or otherwise. Leaky gutters and down-pipes are common sources of dampness. In exposed situations, driving rain is apt to cause trouble, and it may be found necessary to line the walls externally with impervious materials, or to construct hollow walls. Leakage through defective roofs is one of the most common sources of penetration of moisture into living-rooms. In old houses, after stormy weather, the ceilings of top-floor rooms often yield evidence that a slate or tile has been displaced, and, in dilapidated and neglected houses, it is no uncommon thing to find ceilings stained and discoloured with the marks of many a storm.

Roofs should not only be weather-tight, but should be so constructed as to protect the upper rooms from external heat and cold. Thatch is objectionable; it tends to undergo decomposition, harbours vermin, and is a source of danger in case of fire. Slates laid on boarding and felt are very generally used for roofing purposes; if the slates are merely laid upon laths the rooms are not sufficiently protected against heat and cold, and will be unduly hot in summer and cold in winter. Tiles afford better protection against extreme conditions of temperature, but do not so readily facilitate the escape of rain as slate does, hence the slope of the roof is usually made much more steep when tiles are employed. Eaves-gutters and rain-water pipes may with great advantage be kept an inch or two away from the face of walls, with a view to preventing dampness, in the event of blocking or leakages occurring.

(iv.) Certain precautions should be adopted to prevent the spread of fire. Party walls should be continued above the roof, forming parapets, as otherwise flames blown across the roof may split the slates, exposing the roof timbers, and the spread of fire from one building to another may be thus favoured. Moreover, roofs, gutters, and down-pipes should be made of incombustible materials. Again, building regulations generally control the making of openings in party walls, with a view to limiting risk of spread of fire, and they often prohibit the use of timber in party walls and deal with the mode of constructing chimneys and flues.

In block buildings it is usual to construct floors and staircases of fireproof materials, and solid floors are also to be preferred from the standpoint of health. In passages, stone and tiles are often used. Wood is warmer for living rooms; oak and teak are fire-resisting but expensive. The ordinary deal floor tends to wear unevenly, but much can be done, as regards preventing the formation of crevices, by careful laying with properly grooved and tongued joints. "Shag felt" may be used with the object of deadening sound; ordinary "pugging" (sawdust, plasterer's rubbish, etc.), which is often employed, is objectionable; indeed, all possibility of collection of organic dust and *débris*, likely to favour the growth of germs beneath floor-boards and in crevices, should be carefully guarded against. In the case of lofty buildings it is especially necessary that attention should be paid to the question of providing alternative means of escape in case of fire, so that, if the principal staircase becomes blocked by smoke, there shall be no possibility of persons being caught, as it were, in a trap, and exposed to risk of being burnt to death. The London Building Act makes the adoption of special precautions compulsory in the case of public buildings (this expression includes *inter alia*, lodging-houses, blocks of dwellings, etc., in which more than 100 persons sleep).

Particular details of construction which relate to the lighting and ventilation of rooms, to methods of removal of waste water, sewage, and refuse, and to means of supplying water, are referred to elsewhere (chapters ii. and vi.). It remains to describe the peculiarities of special types of dwelling.

Artisans' Dwellings.—Ample space should be provided both in front and at the rear of each block; the height of the building should be limited to three, or at most four storeys, unless the distance across the open space to the front and rear be unusually great; the length of each section should also be restricted so as to promote circulation of air. Blocks should not be connected at a right angle or an acute angle. The need of such arrangement of rooms as will favour through ventilation has already been insisted upon.

Staircases should be built against outer walls; the dark and inadequately ventilated "central" or "internal staircase" constitutes an especially objectionable feature in many old houses. Moreover, the staircase should be sufficiently wide; a width of 3 feet 6 inches has been proposed and adopted in some instances as the minimum permissible. There is great advantage in "open staircases" from the point of view of ventilation. Baths and washhouse accommodation are now often furnished in connection with block dwellings. Again, a good cupboard or larder, ventilating into the external air, should be provided in each tenement. Water-closets should be practically outside the dwelling, and should therefore, if possible, be placed so that they are entered through a disconnecting lobby furnished with means of cross-ventilation. Dust shoots, if provided, need special contrivance, by means of double doors opening and closing together, or by some other means, to prevent nuisance. If possible, their use should be avoided.

Block dwellings are frequently constructed with balconies running the whole length of the building on each floor. Under these circumstances rooms, more particularly those on the lower floors, are apt to be much darkened. There is advantage in not constructing rooms of too small dimensions. The smaller the room, the more difficult it is, other things being equal, to secure its being properly ventilated, and tenements consisting of small rooms are especially likely to be overcrowded. The London County Council in 1889 fixed 144 square feet as the minimum for living-rooms, and 96 square feet as the minimum for bedrooms, to be constructed in blocks erected in connection with clearance schemes. Later these limits were raised to 160 square feet and 110 square feet respectively, but the necessity of keeping down rents led to the minimum sizes specified in 1889 being again reverted to. In a Memorandum, on the provision and arrangement of dwellings, issued by the Local Government Board in 1894, it is suggested, as regards separate houses or cottages, that the living-room should have a floor area of some 200 square feet, with a clear height of from eight to nine feet, and that bedrooms should be of the same height, that for the parents being at least 120 feet in area, while for children's rooms a minimum of 80 feet is specified.

Stable Dwellings.—In towns it is a common practice to construct rooms, intended to be inhabited, over stables in "mews." Such rooms, in addition to being exposed to stable effluvia, often exhibit other serious defects (the "mews" may be a *cul de sac*, and the dwellings without through ventilation, etc.), and it is not surprising that the statistics of stable dwellings should show excess of mortality among the persons living under these unfavourable conditions. Sykes has investigated the question so far as the stable dwellings in St. Pancras are concerned. He found the death-rates from pulmonary disease and from zymotic disease (particularly diarrhœa and diphtheria) notably in excess, as was also the infant mortality. The London Building Act contains a special section dealing with the protection of habitable rooms which are situated over stables.

Cellar Dwellings.—In large towns there are still many persons who live and sleep in basement rooms. The extent to which the law controls the use of cellar dwellings will be considered later.

Tenement Dwellings.—The Customs and Inland Revenue Act of 1890, Sec. 26 (2), provides that landlords of houses, let in tenements at rents not exceeding seven shillings and sixpence a week for each dwelling, may be exempted from inhabited house duty, provided a certificate of the medical officer of health of the district, or some other medical practitioner appointed for the purpose, is produced stating that "the house is so constructed as to afford suitable accommodation for each of the families or persons inhabiting it, and that due provision is made for their sanitary requirements." Sykes, in his Milroy lectures on "The Influence of the Dwelling upon Health," enumerates certain minimum requirements, which he suggests the medical officer of health should have in view in issuing such certificates. These requirements give an indication of the standard of accommodation which is regarded as necessary in tenement dwellings.

In new buildings, "originally built" to be occupied in separate dwellings, the points to which attention should be directed are as follows: (1) That the buildings are constructed in conformity with the Building Act and By-laws, especially as regards damp courses, concreted basements, etc. (2) That the water supply and (3) that the drainage are in conformity with the Acts and By-laws regulating such matters. (4) That the common staircase is permanently ventilated, at each floor level, or by through ventilation, so as to break the common air connection. (5) That each dwelling is so arranged as to have through ventilation. (6) That each of the habitable rooms is at least 8 feet 6 inches in height and 96 square feet in area, and has a fireplace and chimney flue. (7) That there is at least one draw-tap and sink with a constant supply of water for every twelve occupants or less on each floor. (8) That there is at least one water-closet, properly and efficiently supplied with water, for every twelve occupants or less on each floor, disconnected aerially from any dwelling in the interior of the building. (9) That on each floor a sufficient space, or open lobby, is provided, accessible to and for the use of each family on each floor, for the deposit of refuse, etc. (10) That accommodation for clothes washing is provided sufficient to enable each family to occupy the washhouse or appliances one day in each week.

In the case of existing buildings "adapted by alterations" to be occupied as separate dwellings, the standard must necessarily be a less satisfactory one. The points to which attention should be directed are: (1) That the common staircase is amply and permanently ventilated into the open air. (2) That the dwellings are ventilated through, from one point to another. (3) That the water supply is in conformity with statute. (4) That a draw-tap and sink are provided on each floor for every twelve persons or less. (5) That the drainage is in conformity with statute. (6) That clothes-washing accommodation is provided for each family on at least one day a week. (7) That there is water-closet accommodation, for every twelve persons or less on each floor, properly disconnected, aerially, from the dwelling. (8) That there is an open lobby space, or balcony, on each floor, available as a place of deposit for the dust receptacle and offensive refuse.

In many old houses the ground-floor rooms are below the level of the street or adjoining pavement; under such circumstances the walls of these ground-floor rooms are frequently found to be damp; this state of things is aggravated, more often than not, by the absence of a damp course. Another common defect is want of ventilation of the space beneath the floor boards, the joists being laid directly upon the earth. When these conditions exist the wood will be specially liable to be affected with "dry rot," and the effluvia given off by the decaying wood, together with emanations from the soil beneath the house, will, of course, be apt to be drawn up into the dwelling. In old cottages the staircase sometimes leads directly from the living-room into the bedroom, and in that case vitiated air from the living-room escapes into the bedroom, instead of fresh air being supplied, as it should be, from a well-ventilated passage or staircase. G. V. Poore has pointed out that in many old houses "the staircase oscillates between water-closet doors and bedroom doors, getting darker and darker as it ascends," and, as he says, it is often the case that "the internal channels of communication, instead of serving for the supply of fresh air, merely facilitate the exchange of foul air."

In cases in which the ground-floor rooms of buildings are used for commercial purposes, the dwelling-rooms above are liable to be exposed to the influence of a much polluted atmosphere. The site on the ground storey is often entirely covered with buildings, and proper ventilation is rendered impossible; moreover, the ground-floor rooms are generally dark, and artificial light is therefore likely to be frequently resorted to; contamination from products of combustion then results. In the case of eating-houses and restaurants the smell of cooking is apt to pervade the upper rooms, and the extent to which contamination of the upper floors is often brought about is very clearly demonstrated by the condition of the atmosphere frequently observed in the bedrooms of old inns, and, indeed, it may be added, of ill-designed modern hotels.

Common Lodging-Houses.—A house, before being registered as a common lodging-house, must be "inspected and approved for the purpose by some officer of the local authority." The rules which should guide the inspecting officer in his examination are laid down in a Local Government Board Memorandum, which may be quoted as indicating the standard of fitness regarded as necessary in such cases:—

"The house should (1) possess the conditions of wholesomeness needed for dwelling-houses in general; and (2) it should further have arrangements fitting it for its special purpose of receiving a given number of lodgers.

"1. The house should be dry in its foundations and have proper drainage, guttering, and spouting, with properly laid and substantial paving to any area or yard abutting on to it. Its drains should have their connections properly made, and they should be trapped, where necessary, and adequately ventilated. Except the soil-pipe from a properly trapped water-closet, there should be no direct communication of the drains with the interior of the house. All waste pipes from sinks, basins, and cisterns should discharge in the open air over gullies outside the house. The soil-pipe should always be efficiently ventilated. The closets or privies, and the refuse receptacle of the house, should be in proper situations, of proper construction, and adapted to any scavenging arrangements that may be in force in the district. The house should have a water supply of good quality, and, if the water be stored in cisterns, they should be conveniently placed and of proper construction to prevent any fouling of water. The walls, roof, and floors of the house should be in good repair. Inside walls should not be papered. The rooms and staircases should possess the means of complete ventilation; windows being of adequate size, able to be opened to their full extent, or, if sash windows, both at top and bottom. Any room proposed for registration that has not a chimney should be furnished with a special ventilating opening or shaft, but a room not having a window to the outer air, even if it have special means of ventilation, can seldom be proper for registration.

"2. The numbers for which the house, and each sleeping-room, may be registered will depend partly upon the dimensions of the rooms and the facilities for ventilation, and partly upon the amount of accommodation of other kinds. In rooms of ordinary construction, to be used for sleeping, where there are the usual means of ventilation by windows and chimneys, about 300 cubic feet will be a proper standard of space to secure to each person; but in many rooms it will be right to appoint a larger space,* and this can only be determined on inspection of the particular room. The house should possess kitchen and day-room accommodation, apart from its bedrooms, and the sufficiency of this will have to be attended to. Rooms that are partially underground may not be improper for day-rooms, but should not be registered for use as bedrooms. The amount of water supply, closet or privy accommodation, and the provision of refuse receptacles should be proportionate to the numbers for which the house is to be registered. If the water is not supplied from works with constant service, a quantity should be secured for daily use on a scale, per registered inmate, of not less than ten gallons a day where there are water-closets, or five gallons a day where there are dry closets. For every twenty registered lodgers a separate closet or privy should be required. The washing accommodation should, wherever practicable, be in a special place, and not be in the bedrooms, and the basins for personal washing should be fixed and have water-taps and discharge pipes connected with them."

This Memorandum was issued in 1877, and since that time the type of building used for common lodging-house purposes has, in large towns, undergone material alteration. In numerous instances houses adapted for many hundreds of lodgers have been erected, and in these cases the conditions to be regulated are more comparable to those presented by block dwellings, which have been already mentioned, than to those of ordinary dwelling-houses. In the Memorandum issued in 1894, and already referred to on page 278, it is stated that it is desirable to limit the size of any building intended for occupation as a lodging-house, so that it may not accommodate more than some 200 lodgers. The desirability of providing a dayroom with floor area affording some 15 square feet to each lodger is pointed out; sleeping-rooms, it is noted, should be of moderate size, holding not more than about twenty lodgers each; each bed, it is suggested, should have some 5 feet lineal across it, 40 square feet of floor area, and from 300 to 400 cubic feet of space. Water-closets in the proportion of one closet for every fifteen to twenty lodgers, and fixed lavatory basins in the proportion of one basin to every ten lodgers, are recommended. A properly contrived hot-closet for drying the wet clothes of lodgers is also stated to be a desideratum.

* By-laws recently brought into operation in London for controlling seamen's lodging-houses fix the standard at 400 cubic feet.

The lighting of rooms, and the need for securing adequate through ventilation, require to be particularly attended to in large houses. The practice of partitioning rooms off into cubicles, while it affords privacy to lodgers, is likely to be attended with serious interference with both lighting and ventilation. The "open dormitory" system possesses, therefore, great advantages over the cubicle system from a health point of view. Dormitories are sometimes heated by hot-water pipes, and special arrangements for the extraction of foul air, or the supply of fresh air, have, in some instances, been made. Huge sleeping-rooms, in which the air space allotted to each individual bed is in communication with the general atmosphere of the dormitory, are attended with the disadvantage that in the event of a case of typhus, small-pox, etc., occurring, the whole "common atmosphere" of the dormitory falls under suspicion of being possibly contaminated. In large buildings, the question of providing means of escape in case of fire assumes special importance. The standard of cleanliness, too, has been raised of late years, and in many modern lodging-houses baths are provided; the requirements of the inmates are thus not altogether limited, as in former days, to "basins for personal washing."

Schools.—The Code of Regulations of the Education Department (1900) for day schools contains (Schedule vii.) "Building rules," study of which indicates the extent to which attention is devoted to health questions in the planning and fitting up of public elementary schools. These rules are, no doubt, primarily intended to secure the best results attainable from a purely educational point of view, and health considerations are only incidentally touched upon. Thus it is stated that "in planning a school, the first thing is to seat the children in the best manner for being taught." Space not used for providing seating accommodation is spoken of as "wasted space," though, as has been pointed out, inasmuch as this space "tends to increase the otherwise very small quantity of cubic space available for each child, the term is hardly a desirable one."

The rules specify the manner in which classes may be arranged, both in large *school-rooms* and in *class-rooms* not providing accommodation for more than sixty children. In the former, a width of 18 to 22 feet is recommended, and it is prescribed that "In a room 18 feet wide, groups of long desks, three deep, should be used; where four rows are used, the depth should be 21 feet 6 inches, and if the width is 22 feet, dual desks, five rows deep, are most suitable." Again: "Accommodation in school-rooms for elder children is calculated by the number of children seated at desks and benches, subject to a minimum of 10 square feet per child being provided." Further, there is a provision that "no school-room lighted from one side only can be approved." Class-rooms "are calculated at 10 square feet, if not providing accommodation for more than sixty children, and six rows of dual desks, or five rows of long length desks, are permissible in such class-rooms." As regards the method of seating-arrangement, "benches and desks, graduated according to the ages of the children, should be provided for all the scholars, and placed at right angles to the light. The benches should be fitted with backs. An allowance of 18 inches per scholar at each desk and bench will suffice (except in the case of the dual desk), and the length of each group should therefore be some multiple of 18 inches, with gangways of 18 inches between the groups *and at the walls.* A desk for one child needs no gangway next the wall." In the case of the dual desk the usual length is 3 feet 4 inches, the gangway being 1 foot 4 inches. Further, it is stated that the desks should be inclined at an angle of about 15°; again, long desks should not exceed 12 feet in length when arranged three rows deep, and 9 feet in length when arranged four rows deep, and in school-rooms with more than sixty children, the number of rows of benches and desks should not exceed four, even when the width is more than 21 feet 6 inches.*

In infant class-rooms the accommodation is calculated at only 9 square feet for each child; such rooms, it is noted, should not, "as a rule, contain more than sixty" infants. Thus 10 square feet and 9 square feet are the limits fixed for elder children and infants respectively in *new* schools; it may be observed, however, that under certain circumstances (Article 85) in schools already receiving grants, and in neighbourhoods where there is deficiency of school accommodation, 80 cubic feet and 8 square feet are the limits adopted. Even those limits cannot be considered absolute minima, as Article 85 merely prescribes that "no room may be habitually used for a larger number of scholars than that for which it is passed by the Department."

The insufficiency of these standards, from a health point of view, has been increasingly realised during the last few years. That each child should have its own desk has, at any rate in the case

* Here at least there appears, *primâ facie*, to be some indication that the rules are intended to glance, if it be only obliquely, at health requirements, but on reading further it transpires that the requirement is made because "in proportion as the depth is increased the teacher must raise his voice to a higher pitch; and this becomes exhausting, etc., etc."

of upper classes in well-managed schools, long been regarded as desirable, but that due separation of young children is also necessary, and that the provision of sufficient floor space for this purpose should be made, has been rendered particularly evident since study has been made of the extent to which close aggregation of children in class-rooms favours the spread of certain forms of infectious disease. Again, the principle, the importance of which is admitted, of providing desks "graduated according to the ages of the children," can only with difficulty be carried into effect in cases where one long desk is made to accommodate several pupils. The desirability of providing for each child a desk, the dimensions of which are adapted to its individual requirements, is great, from the point of view of preventing stooping, etc., and neglect of such considerations, and of proper lighting of the schoolroom, have undoubted influence in promoting development of myopia and possibly other eye defects.

C. E. Paget, in his "Handbook on Healthy Schools," suggested 400 cubic feet per child as a minimum for elementary schools, and 800 cubic feet for public schools. Between 400 cubic feet and the 80 cubic feet of the Code there is a vast difference from the point of view of seating accommodation, and while it is clear that 80 cubic feet are quite inadequate, it is unlikely that, at any rate under existing circumstances, 400 cubic feet can be generally provided.

The inquiries of Carnelley, Haldane, and Anderson, already referred to, led these observers to the conclusion that the best results were obtained in schools having a system of mechanical ventilation by propulsion, and in instances quoted by them between 800 and 1,400 cubic feet per head were supplied hourly. W. N. Shaw, in a report upon the ventilation of class-rooms in Poor Law schools, suggests that a minimum supply of 1,500 cubic feet per head per hour should be required. He arrives at this figure as the limit by allowing, in the first place, for the fact that the school-rooms can be aired after an hour's use, and hence a supply at the rate of 2,000 cubic feet per hour would be sufficient to keep the impurity within De Chaumont's limits, assuming each person to contribute ·6 cubic foot of CO_2 per hour; again, he also takes into account the fact that he is dealing with children and not with adults.

The "Building Rules" of the Code prescribe that light shall, as far as possible, "be admitted from the left side of the scholars," but when "left light" is impossible, "right light is next best." It has already been seen that the windows should not be limited to one side of the room only; "other windows in class-rooms," should, however, be "regarded as supplementary, or for summer ventilation." The sills of the windows should be placed about

4 feet above the floor, but the windows should extend to within a few inches of the ceiling, as "large spaces between the window-heads and the ceiling are productive of foul rooms." Paget states that 15 square feet of window space should be provided for every 1,000 cubic feet of room space. Apart from open windows and doors, there should be special inlets and outlets for purposes of ventilation; the rules of the Code prescribe that "inlets should provide a minimum of 2½ square inches per child, and outlets a minimum of 2 inches;" they further particularly direct that "rooms should in addition be flushed with fresh air from windows about every two hours."

As regards warming, a temperature of from 56°—60° should be maintained, and "a thermometer should always be kept hung up in a school." The rules of the Code contemplate the use of hot-water pipes or of open grates, but only approve the use of stoves under certain conditions.

Water-closets should be outside the main building. The following table is given in the Building Rules already referred to as indicating, approximately, the number of closets needed:—

	For Girls.	For Boys.	For Infants.
Under 30 children	2	1	2
" 50 "	3	2	3
" 70 "	4	2	3
" 100 "	5	3	4
" 150 "	6	3	5
" 200 "	7	4	6
" 300 "	8	5	7
		Urinals in proportion.	

These figures relate, of course, to day schools; in residential schools more liberal provision is necessary. In Poor Law schools, ten closets, with urinals in addition, per 100 boys, and fifteen per 100 girls, have been prescribed. The rules in the Code further contain provisions as to drainage-construction in schools.

Ophthalmia, etc., in Residential Schools.—In residential schools, the influence of the establishment upon the health of the children is, of course, likely to be much more pronounced than in the case of day schools. In the latter, overcrowding and defective ventilation, until evidence of spread of infection was forthcoming in recent years, for the most part escaped criticism, for the tendency, as a rule, was, in the event of headaches, anæmia, and other signs of ill-health being noticed, to explain the phenomena as being due to educational "over-pressure." In the Poor Law schools, in which children lived continuously, it became apparent years ago that certain ill effects were associated with life in the schools. Repeated outbreaks of ophthalmia especially drew attention to this matter, and in 1875 the subject was fully considered by Nettleship in his "Report on Ophthalmia in the Metropolitan Pauper Schools."

Nettleship found the disease in question had caused great trouble in these schools, and he drew attention to the need of recognition of the fact that outbreaks of similar forms of eye-malady, affecting other residential schools, had from time to time occurred. He held that ophthalmia must be regarded as "the touchstone of the general healthiness of an institution," and that "where many persons are herded together, their eyelids show sooner and more certainly than any other part if the conditions of vigorous health are not complied with." The tendency of late years has been to regard the aggregation of large numbers of children in "barrack schools" as a mistaken policy, and with a view to giving effect to the principles of subdivision, the "cottage home" system, as opposed to the large institution system, has in some instances been adopted, or in other cases small independent houses have been erected in place of a continuous pile of buildings, and as far as possible the collection of large numbers of children in common living or sleeping rooms has been avoided.

Much has been done to prevent the spread of infection, from child to child, by setting apart a brush, towel, etc., for the use of each individual. Of late years, with a view to avoiding possibility of conveyance of infection by use of common basins, etc., the "spray system" of washing has been introduced. Where this method is in operation, each child washes under a jet or spray of water, instead of using a basin, and it is thus made impossible to employ, for the purposes of ablution, water previously used by another child. By the adoption of such precautions, there is no doubt that much has been done to limit the spread of disease. Again, the fact must not be ignored that some of the ill effects produced by life in institutions have been due, in the past, to errors of diet, and to rigid adherence to ill-regulated and insufficiently varied diet-scales.

Questions of the kind above referred to have been brought into special prominence in connection with detailed investigation made into the working of two sorts of schools. The Industrial and Reformatory School System was made the subject of inquiry by a

Departmental Committee of the Home Office, which reported in 1896, and the Poor Law schools were reported upon, by a Departmental Committee appointed by the Local Government Board, at about the same time. Both these inquiries led to emphasis being laid on the evils of aggregation of large numbers of children in institutions. The Departmental Committee concerned with Poor Law schools particularly called attention to the ill effects of such aggregation upon the health, and mental and moral development, of the children. As regards health, after alluding to the spread of such ailments as ophthalmia, ringworm, and skin complaints generally, the Committee refer to "conditions of defective health and vitality due to imperfect ventilation, overcrowding, poor diet, lack of exercise, massing together of children in large groups, and so forth." This Committee recommended that the subject of ventilation and warming of the schools should be investigated by an expert. Dr. W. N. Shaw was asked to undertake this duty, and in 1897 he presented his Report, which is particularly instructive, dealing as it does with the problem of securing adequate ventilation and warming under very varying conditions, as will be seen from the following summary :—

Dormitories.—It was found that cross ventilation was mainly relied upon in the schools; this system answered fairly well for the narrower dormitories (the windows being opened some 8 inches at the top, and the opening having a perforated zinc screen in front of it) but needed to be supplemented by hot-water radiators under the windows. Special provision was also necessary for ventilation in calm weather, and for this purpose an arrangement for differentiating the windows into inlets and outlets was suggested. In dormitories exceeding 24 feet in width similar arrangements were recommended, with a larger window opening (1 foot instead of 8 inches), and it was suggested that the allowance of cubic space per head should be increased. Additional means of ventilation were found to be required in dormitories exceeding 30 feet in width, and the employment of mechanical ventilation, or ventilation by a wide factory chimney, was suggested.

Day Rooms.—Here open flues were recommended, supplemented by steam or hot-water pipes, so as to bring the whole room to a minimum of 56°. The heating should be concentrated under the windows, so that incoming air may be warmed when the windows are opened for the purpose of ventilation. Cold air openings at the floor level may also be provided, with doors that may be closed in very cold weather and opened when no artificial warming is required.

Dining Rooms.—The temperature should be raised to between 57°

and 59° F. before the commencement of a meal, and the ventilation should be sufficient to prevent the temperature rising more than 3° F. during the half-hour of meal times.

School-rooms.—Warmed air should be supplied mechanically at the rate of 1,500 cubic feet per hour per child, during school hours, at a temperature of from 55° to 57°, the existing openings for ventilation being retained as outlets for the air.

Infirmaries.—Open fires are mainly to be relied upon. In wards occupied by day and by night the number of beds should not exceed five for each open fire (or other motive power), capable of extracting 20,000 cubic feet per hour. In wards occupied by night and only partially by day, in which a larger number of persons than that just indicated is accommodated, the open fire ventilation must be supplemented by providing cased hot-water or steam coils under windows on opposite sides, and separate extraction flues must be provided.

Influence of School Attendance on Spread of Other Infectious Diseases.—The spread of certain forms of infectious disease, other than ophthalmia, ringworm, etc., in schools requires to be now more particularly referred to.

The influence of school attendance in connection with diphtheria prevalence was demonstrated, in 1876, at Brailes, by W. H. Power; and Thorne Thorne, in 1877, noted that in an outbreak of diphtheria at Coggeshall, children at school age had been specially affected. Power, in 1882, investigated an outbreak of diphtheria which occurred at Pirbright, and showed, from consideration of the behaviour of the disease during periods of school closure, and again during periods when the school was open, that "conditions of school attendance played an important part in the speciality of the incidence of grave illness on children three to twelve (years of age) in Pirbright." Other outbreaks were from time to time investigated by inspectors of the Local Government Board, and it was found "that apart from age and susceptibility, 'school influence,' so-called, tends to foster, diffuse, and enhance the potency of diphtheria, and this, in part at least, by the aggregation of children suffering from that 'sore throat' which commonly is prevalent, antecedent to and concurrently with, true diphtheria." The suggestion was made that, under certain favouring conditions, there might "be a progressive development of the property of infectiveness" (Thorne Thorne).

In 1884 an Article was inserted in the Code of Regulations of the Committee of Council on Education dealing with the question of school closure, and a Memorandum on the subject of "School closure and exclusion from school of particular scholars as means for controlling spread of infectious disease" was issued, in the same year, by the Local Government Board. This "School Memorandum" was re-issued in 1890. Article 88 of the Day School Code of 1900 (which is the revised form of the Article first issued in 1884) prescribes that the managers of a public elementary school "must at once comply with any notice of the sanitary authority of the district in which the school is situated, or any two members thereof, acting on the advice of the medical officer of health, requiring them, for a specified time, with a view to preventing the spread of disease, or any danger to health likely to arise from the condition of the school, either to close the school or to exclude any scholars from attendance; but after complying they may appeal to the Department if they consider the notice to be unreasonable."

The School Memorandum of 1890 may be summarised as follows:—After pointing out that the diseases principally requiring action are those which spread by infection directly from person to person, such as scarlet fever, measles, diphtheria, whooping-cough, small-pox, and rötheln, reference is made to the fact that two alternative lines of action are indicated in Article 88 of the Code, inasmuch as it is assumed that it may be necessary either (*a*) to cause particular scholars to be for a specified time excluded from attendance, the "less severe measure"; or (*b*) to require the school to be closed for a specified time, "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 Memorandum lays down the universal principle that all children suffering from any dangerous infectious disorder should be excluded from school until they have ceased to be infectious. Furthermore, all children of an infected household should be excluded, and sometimes the attendance of children from a particular street or hamlet may with advantage be prohibited; school interests may, of course, be more particularly considered in the case of diseases involving little or no danger to life, such as mumps and skin diseases.

The closing of a school is a much more serious matter than the exclusion of particular scholars. "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."

In Articles 9, 10, and 11 of the Memorandum, the subject of alternative powers is thus discussed :—

"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."

"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 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."

"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 inter-communication 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 infectious disease was prevalent, there are many places where schools would hardly ever be open."

A number of other points are touched upon in the Memorandum: the importance of mutual aid being rendered by school authorities and health officers is alluded to—the fact that a time should be specified during which scholars are to be excluded from attendance is mentioned—and the absence, under Article 88 of the Code, of power of control over Sunday and private schools is pointed out.

Further Study of School Influence.—Numerous outbreaks of illness have been dealt with from time to time on the lines laid down in the Memorandum—at first mainly in rural districts, but in more recent years, and particularly since increasing use has been made of the information afforded by notification certificates, also in towns. Shirley Murphy has repeatedly commented, in annual and special reports, upon the extent to which school influence has operated in favouring the spread of scarlet fever and diphtheria in London schools. In 1891 and 1894 he had already noted the fact that there had been an increased incidence of diphtheria mortality in recent years upon the age 3 to 10 years, as compared with the incidence upon all ages. This new departure was more noticeable in London than in other parts of the country, and, having regard to the time of its appearance, was "suggestive of a fresh factor of diphtheria at ages 3 to 10 years becoming operative in the decennium 1871–80, the increased tendency of children from 3 to 10 years of age to die from diphtheria having manifested itself somewhere between the two periods, 1861–70 and 1871–80." A closer examination pointed "to the year 1871 as that in which this increased incidence first became conspicuous," and it was noted that "the Elementary Education Act first became operative in that year." The question as to how far altered nomenclature was responsible for the behaviour of the figures obviously required to be considered; it was found, however, that on inclusion of croup with

* It is to be observed, however, that the close aggregation of children in the class-rooms of public elementary schools does not, as a rule, find any parallel in the conditions of home or street life.

diphtheria, similar results to those afforded by the diphtheria figures alone were still obtained.

Moreover, in 1894, Shirley Murphy called attention to the fact that the influence of schools, in giving opportunity for the communication of infectious disease from person to person, was being manifested in another way. "It might be expected," he said, "that any interruption in school life would be indicated by a diminution in the amount of prevalence," assuming that school influence was at that time operative. He was led to look, therefore, for "some evidence of the influence of longer holidays," and the existence of a "marked August holiday depression" was, as a result of his inquiries, demonstrated in the curves showing the cases of diphtheria and scarlet fever notified week by week.* But it was argued, "the closing of schools ought to be attended by some difference in the age-incidence of the disease, if it is associated with diminution in the amount of disease caught at school." On grouping the cases (of scarlet fever or of diphtheria) into three age-periods—under three years of age, above three years of age and under thirteen years of age, and above thirteen years of age—it was found that the children from three to thirteen years of age enjoyed a larger immunity during the holidays than did persons at other ages; in other words, the holiday depression was especially marked in the case of persons of school age. It was noted that it was of course "possible that other influences, such as the migration of population from London," might have contributed to the August depression. To meet the requirements of the case, it would be necessary, however, to assume "that this migration was of very notable extent, and that children at school age migrated very much more largely than persons at other ages."

In a report, entitled "Diphtheria and Elementary Schools," bearing date July, 1898, the evidence upon the subject was re-stated by Shirley Murphy, and further figures which had then become available were made use of. It was found that in London, and in England and Wales generally, there had been a notable increase of relative incidence of diphtheria mortality on the ages 3—4, 4—5, 5—10, and 10—15. The extent to which this increased incidence might be attributable to changes due to differences in nomen-

* The depression did not precisely correspond with the period of closure; thus it commenced about a week after the schools closed ("allowing two or three days for the incubation of the disease, two or three days for the disease to become recognised, and perhaps for a little delay in the notification"), and was most conspicuous in the four weeks terminating about a week after the schools had re-opened. Cases of enteric fever showed no August depression.

clature, to changes due to actual behaviour of disease, or to changes due to some varying social conditions of the community, was then carefully considered.

As regards nomenclature it was felt that the only safe course to adopt, in considering variations in prevalence of diphtheria, was to group together croup and diphtheria deaths. The question of transference, from scarlet fever to diphtheria, also needed consideration in connection with the altered age-incidence of diphtheria; here the figures were found to suggest that some such transference had taken place. The fact, however, remained, that "irrespective of all questions of change in nomenclature, there is increased incidence on the ages 3—4, 4—5, and 5—10, when the figures relating to diphtheria, croup, and scarlet fever are all combined." The hypothesis that this increase was caused by the aggregation of children at school appeared "most likely to be correct," and when careful study was made of the behaviour of other diseases (measles, scarlet fever, and whooping-cough), nothing was found which could be held to militate against this hypothesis.

As regards the August depression, additional evidence, supplied by the figures available for more recent years than those previously dealt with, was now forthcoming, and it was clear that there was a close correspondence in point of time between the diminution of prevalence and the closing of the schools, allowance being made for incubation and a little delay in notification. It was further noticed that the depression in the curves relating to the age-period 0—3 generally occurs somewhat later than in those relating to the age 3—13, suggesting "a lessening of the infection of the younger by the older children."

Shirley Murphy concludes, as the result of his inquiry, that a substantial balance of the increased incidence, of diphtheria mortality, upon children at the school age, is due to "greater opportunity of infection at school," and he says: "This change in the age-incidence of mortality had its beginning about the time that compulsory attendance at school had its beginning, has affected the country as a whole, and has not only been maintained ever since, but has steadily grown in proportion until the present time. Examination of the figures supplied by the notifications of diphtheria points in the same direction. The very striking difference in the age-incidence of notified cases when schools are in operation, and when school attendance is suspended for the summer holidays, is in agreement with the hypothesis that the age-incidence of diphtheria mortality has been affected by attendance at school. Again, this behaviour of the figures supplied by notification, is not limited to those of London, but is shared by the figures of other large towns."

In connection with the investigation of school influence, it has been found, in some instances, that particular classes in the school have suffered to a disproportionate extent; again, in schools containing boys' and girls' and infants' departments, one of these departments only has been especially attacked. The infants' department, as might be expected, has been more particularly involved in numerous instances. Such limitation of disease to classes or departments of a school has, of course, important bearing upon the question of school closure. The increasing amount of attention which has been directed to the risk of spread of infectious disease by school operations has led to the system of periodical medical inspection of scholars being adopted in several instances. By this means cases of illness, which might otherwise not be recognised and might cause much mischief, can be detected and prevented from giving rise to further cases.

Hospitals.—A hospital has been described by Sir John Simon as "an establishment which never rests from fouling itself," hence its construction and surroundings require to receive, in a special degree, the attention with regard to matters of lighting, ventilation, aspect, etc., which has already been noted as necessary in the case

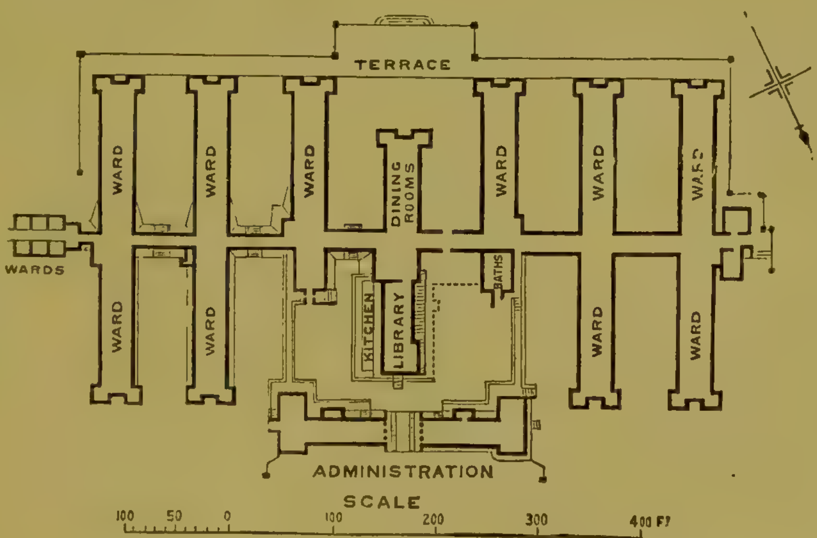

FIG. 78.
General Plan of the Herbert Hospital, Woolwich.
(*After Galton.*)

of dwelling-houses generally. The site should be dry, not bleak or exposed, and yet not unduly sheltered. The wards should, if possible, face east and west, or, if any deviation from this is permitted, it should be with a view to obtaining a south-east and north-west aspect. Lofty structures of many storeys should be avoided as far as practicable, and the buildings should be detached. Tenon, in 1788, drew attention to the evils of free intercommunication between hospital buildings, in connection with the old Hôtel Dieu in Paris, a vast pile designed to accommodate upwards of 3,000 persons, having the most infectious departments placed in the middle of the building, and constituting practically a huge ward. Such a pile was, as this writer said, more fit "to destroy than to establish and preserve health." Tenon urged that intercommunication between wards should be as far as possible prevented.

In modern hospitals, with a view to attaining this object, what is

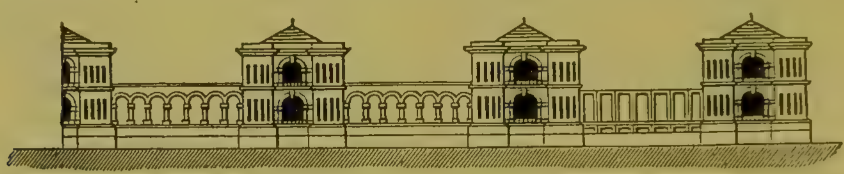

FIG. 79.

Sketch of the End of Southern Pavilions of the Herbert Hospital, showing the Elevation of the Corridor. (*After Galton.*)

is known as the "pavilion system," the main features of which are indicated in Figures 78 and 79, is usually adopted. The elevation shows pavilions two storeys high and united by a corridor; the administrative buildings are centrally placed, but are detached, as they should be, from the ward blocks. Buildings only one storey high have been, in many instances, erected, and they present special advantages, but expense will, as a rule, preclude the adoption of such a plan of construction. In any case, however, the space between the blocks should be such as to allow of adequate lighting and ventilation of the wards. Even where the cost of land is great, the essential principle of separating wards and administrative buildings should still be observed: the operating-room should be disconnected from the wards; the mortuary should be removed from other buildings; the laundry and out-patient departments should not be in aerial communication with wards, and the medical and surgical wards should be kept apart from one another.

The ward unit is usually rectangular in shape, 24 to 30 feet wide, and from 30 to 100 feet in length. The floor space per bed should be at least 100 square feet, and this amount may, with advantage, be increased in wards in which special cases are treated, or in wards in which clinical teaching is carried on. The cubic space should be at least 1,200 cubic feet per patient, and when acute cases only, or infectious cases are dealt with, 1,500—2,000 cubic feet should be provided.

Nursing arrangements are best facilitated with wards containing from 24 to 28 beds. In Fig. 80 the ward contains 24 beds, each of which is placed, as is desirable, between two windows; the intervening space between the windows extends, it will be seen, rather more than a foot on each side of the bed. In some instances windows are so arranged that two beds can be placed in the space between them, but this method of planning is less satisfactory. In Fig. 80 the spacing between the beds is equal throughout, each bed having about 10 feet of wall space allotted to it, while the interval between the beds is about 7 feet. This arrangement affords some 145 square feet of floor space per bed. In no case should the interval between beds be less than 5 feet, and in wards for acute, or for infectious cases, the interval should be increased to 10 feet. It will be noted that in the figure the end beds have a window on each side of them, and this arrangement is desirable, as otherwise the space occupied by the end beds would be less favourably circumstanced, as regards ventilation, than that in the neighbourhood of other beds.

The total area available for lighting purposes should be in the proportion of 1 foot to 60 – 80 feet of cubic space, and the windows should extend, from 2 to 2½ feet from the floor level, to within as short a distance as possible of the ceiling. The heating may be effected by ventilating stoves situated in the centre of the ward, with flues passing under the floor—open fireplaces, or coils of steam or hot-water pipes are often used. Inlets for admitting warmed air are sometimes placed beneath the beds; the patient then breathes pure air, and the exhaled air, driven upwards in the act of being breathed out, is carried off by the outlets in the upper part of the ward. In some modern hospitals for the treatment of infectious cases, special extraction shafts carry away the air of the ward, and convey it through a furnace, with the object of destroying any infective properties it may possess. In any case, ventilation should be provided for, to the extent of at least 3,000 cubic feet per head per hour. In this country reliance is, as a rule, mainly placed upon the ventilation afforded by open windows, as it is found that "on about 300 to 330 days in the year it is possible to open the windows of a hospital ward without injury to the patients." In the more recently constructed hospitals, cross ventilation is secured: the windows are fitted with double-hung sashes, and a deep fillet at the sill is often provided, with a view to the admission of air between the upper and lower sash, without causing draught at the sill level. In addition to such window ventilation, it has, however, been found desirable to arrange for the admission of warmed air by ventilating stoves, and by openings so situated that the entering air is warmed by steam or hot-water pipes. As regards exhaustion of air, fireplaces are mainly relied upon, and in addition vertical shafts in which an upward current of air is produced, by coils of steam or hot-water pipes, have also been provided in some instances.

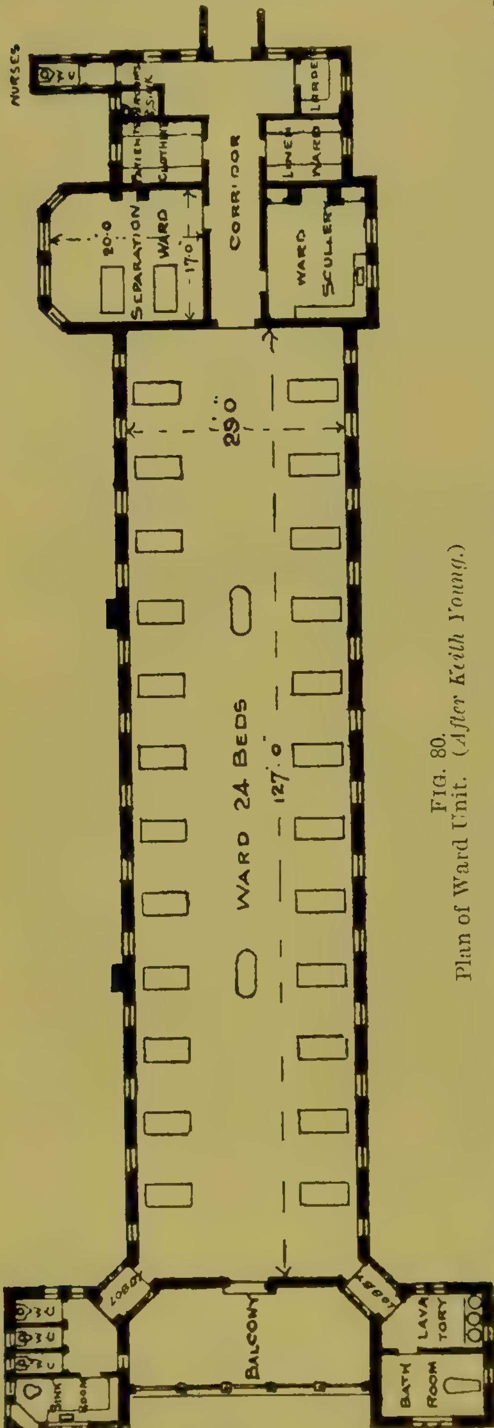

FIG. 80.
Plan of Ward Unit. (*After Keith Young.*)

The water-closets and lavatories should be disconnected, by cross-ventilated lobbies, from the ward. The walls of the ward should be impervious, and capable of being washed, all crevices in which dust might lodge being avoided, and in place of corners and angles, rounded surfaces should be provided. Glazed bricks or tiles are sometimes used, or a cemented surface covered with varnish may be employed. Sometimes the lower part of the walls is covered with a cement dado, painted and varnished, while the upper part is finished with plaster and distempered. The varnished surface can be washed, and the distemper should be renewed at least once yearly. The floors should be of fireproof material, formed by iron joists embedded in concrete, and with the wooden floor laid solid upon the concrete surface, no intervening space capable of harbouring dust or germs being left; the boards should be stained and polished, so as to obviate need for continual washing. In Fig. 80 a separate room is shown at one end of the main ward. Such provision for the isolation of cases which may prove to be infectious is requisite in a hospital, though not necessarily in connection with each ward.

Isolation Hospitals.—In the eighteenth century, and indeed before that period, isolation of infectious cases seems to have been practised in certain instances in lazarettos in connection with quarantine arrangements, but it was not until the latter half of the nineteenth century that isolation hospitals were provided on any considerable scale. The growth of the isolation system in the latter part of that century will be appreciated by reference to the history of infectious hospitals in London. Until the year 1867 the London Fever Hospital and the Highgate Small-pox Hospital were the only existing special isolation hospitals, and they were primarily devoted to the treatment of paying patients, no other special hospitals being available for the poorer members of the community suffering from infectious disease; thus the persons specially needing to be provided for were dependent upon the workhouse or the general hospital, while, to a large extent, owing to the insufficiency of the accommodation available, such persons were of necessity treated in their own homes, practically no attempt at their isolation being made.

The evils attendant on this system became so manifest that in 1867 the Metropolitan Asylums Board was constituted and empowered to make the necessary provision. At first it was thought that it would be sufficient to construct two permanent fever hospitals, together with two permanent small-pox hospitals, and two sites (Homerton and Stockwell) were secured, and the erection of a fever and small-pox hospital on each site was commenced. A third site, at Hampstead, was also shortly afterwards acquired. An outbreak of relapsing fever, in 1869, necessitated the erection of temporary huts on the Hampstead site and in the grounds of the London Fever Hospital, and in 1870 and 1871 the great small-pox outbreak occurred, and, as result, all available accommodation was absorbed, and a hospital ship, moored off Greenwich, was fitted up and used. Later epidemics of small-pox, in 1876 and subsequent years, led to the acquirement of additional sites. It was now noted, however, that small-pox was apt to become especially prevalent in areas surrounding the hospitals in which small-pox patients were aggregated.

Aerial Diffusion of Small-pox.—Power's investigations with regard to the behaviour of small-pox, in the neighbourhood more particularly of the Fulham Hospital, in 1881 and years immediately preceding, directed special attention to this matter. He found that, dealing with fortnightly periods in the years 1877–81, no sooner did the number of recorded admissions to the institution exceed 35 or 40, than the influence of the hospital upon the surrounding population began to manifest itself. The relation between use of the hospital and manifestation of excessive small-pox in its neighbourhood was not, however, demonstrable when the hospital was employed for convalescents only. A "special area," included in a circle of one mile radius, having the hospital as a centre, was selected; this area was divided up into four others by concentric circles of a ¼-mile, ½-mile and ¾-mile radius respectively, each of these circles also having the hospital as a centre. The facts admitted of being tabulated as follows:—

Admissions of Acute Small-pox to Fulham Hospital, and Incidence of Small-pox upon Houses in Several Divisions of the Special Area during Five Epidemic Periods.

Cases of acute small-pox admitted.	In epidemic periods since opening of hospital.	Incidence on every hundred houses within the special area and its divisions.				
		On total special area.	On small circle 0–¼ mile.	On first ring ¼–½ mile.	On second ring ½–¾ mile.	On third ring ¾–1 mile.
327	March, 1877, to end of 1877	1·10	3·47	1·37	1·27	·36
714	Jan., 1878, to Sept., 1878	1·80	4·62	2·55	1·84	·67
679	Sept., 1878, to Oct., 1879	1·68	4·40	2·63	1·49	·64
292	Oct., 1879, to Dec., 1880	·58	1·85	1·06	·30	·28
515	Dec., 1880, to April 2, 1881	1·21	3·00	1·64	1·25	·61
2,527	Five periods.	6·37	17·34	9·25	6·15	2·56

The "very exact and very constant" gradation in the intensity of incidence upon houses, at increasing distances from the hospital, was found not to be explicable as a result of "recognised communications of the establishment with the outside world." Thus, "houses upon the chief lines of human intercourse with the hospital" had not suffered more than other houses, and the ingoings and outgoings of various classes of persons did not suffice to explain the phenomena. Power was led to conclude that direct atmospheric agency had been operative in promoting spread of the disease, and his report (published in the Tenth Annual Report of the Medical Officer of the Local Government Board) refers to "weather circumstances" which appeared to have favoured such atmospheric conveyance of infection, and to certain other problems arising on examination of an hypothesis of aerial diffusion of small-pox. These inquiries led to the appointment of a Royal Commission in 1881, to consider "the conditions and limitations under which the hospitals provided by the Managers should be continued"; and among the recommendations made by the Commissioners were the following:—The provision of hospital accommodation for infectious disease should be entirely disconnected from the poor-law; cases of infectious disease should be notified to the medical officer of health of the district in which the patient resides; small-pox should be treated in hospitals established in isolated situations on the banks of the Thames, or in floating hospitals on the river itself; and convalescent hospitals should be established at some distance in the country.

At the moment, however, and as an experimental measure, it was suggested that severer cases, too ill for long journeys, should have provision made for them in a few groups of small wards, within the Metropolis, to hold not more than thirty or forty patients in each group. Power continued the while his inquiry, and, in the Fourteenth Annual Report of the Medical Officer of the Local Government Board, his extended experience up to 1884, is given. He found that "excess of small-pox in the neighbourhood of the hospital was quite and specially remarkable at a time when the total admissions to hospital had not exceeded *nine*." He, moreover, pursued his investigations with regard to "weather states," and noted that two weeks prior to an outburst in June, 1884, atmospheric conditions, for a period of some days, were of such sort as might be thought of as specially favouring (1) escape upwards into the atmosphere of small-pox infection derived from the wards of the hospital; (2) suspension and retention in the atmosphere, above and over the neighbourhood of the hospital, of infection-material which had been contracted from the hospital wards; and (3) subsequent descent, mainly upon the special area, and fairly equably on all sides of the hospital, of infection-material previously aerially sustained and spread abroad in the atmosphere of the hospital neighbourhood.

In the Fifteenth Annual Report of the Medical Officer of the Local Government Board, the result of further observation of the influence exerted by the Fulham Hospital is given. Diagrams showing the "indifference of direction of distribution of small-pox in the special area" were prepared. Power divided up this area into quadrants by drawing two diameters running N. to S. and E. to W., and showed that the gradation of incidence of small-pox was closely similar in each of these quadrants; the same fact was demonstrated when a different quadrature, by diameters running N.E. to S.W. and N.W. to S.E., was taken. In spite of improvements in hospital administration, the disastrous ability of the hospital to spread small-pox was still apparent; it had not been extinguished "by the regulation of methods of transit or by the removal of opportunities for personal communication with patients in hospital." Moreover, there was further evidence supporting the hypothesis that "the potency of small-pox to spread resides mainly in the acute cases," and thus pointing to the conclusion that aggregation of exclusively acute and severe cases might have in it some new form of danger of its own.

Further, the Sixteenth Annual Report of the Medical Officer of the Local Government Board contains, in a "series of chapters," the outcome of Power's investigations as to the behaviour of small-pox in London registration districts from 1875–85 in its relation to small-pox hospitals. These inquiries raised a strong presumption that the Fulham experiences did not stand alone, but that at Hampstead, Homerton, Stockwell, and Greenwich, in which localities hospitals were at one time or another in use, small-pox infection had been also distributed over considerable areas, most conspicuously at the commencement of epidemic periods.

Since Power's observations were made, Barry at Sheffield, Shirley Murphy in St. Pancras, Niven at Oldham, Evans at Bradford, and other observers have collected evidence of a similar kind. Further, the marked diminution of small-pox in London since 1885, in which year the system of removal to the hospital ships at Darenth was inaugurated, affords striking confirmation of the correctness of Power's views. On the other hand, instances of the non-occurrence of the phenomena observed at Fulham in 1881 have been cited, but, of course, mere negative evidence in this connection is beside the mark. The argument has been advanced that proximity to a small-pox hospital means difference in character of population of such a sort as to favour prevalence of the disease; this suggested explanation, however, cannot be regarded as meeting the large body of evidence collected by Power and others. The objectors to aerial dissemination limit themselves, nowadays, for the most part, to rejecting the possibility of such dissemination over long distances, that is to say, they accept, as a rule, the hypothesis that the disease can spread in the near neighbourhood, but look upon excessive incidence of small-pox, at greater distances from the hospital, as being bound up with questions of human intercourse, ambulance traffic, and the like. A certain number of cases have come before the courts in which it has been sought to obtain an injunction, preventing the use of a particular hospital for the treatment of small-pox, on the ground of danger to health. In the instances of hospitals at Withington in 1893, at Guildford in 1895, and at Ossett in 1898, injunctions thus applied for were refused.

To return, however, to the recommendations of the Commission of 1881. As regards the first, an Act of Parliament was passed removing all civil disabilities attaching to admission to hospitals of the Metropolitan Asylums Board. To the second recommendation effect was not given until 1889, when notification was tentatively introduced; its adoption was (except in London) made in the first instance permissive throughout the country generally. The system had previously been introduced in a few towns under local acts; it was made compulsory in London in 1889, and throughout the country in 1896. As regards the third of the above recommendations, three floating hospitals were ultimately established in Long Reach, some seventeen miles below London Bridge, and a temporary camp (and later permanent accommodation) was provided in an isolated situation at Gore Farm, near Darenth. Convalescent hospitals have also been constructed, in accordance with the last of the recommendations already referred to. The removal by water to the hospital ships was effected in special ambulance steamers, and the land ambulance system was soon developed and extended to the removal of cases, other than small-pox, to the ordinary hospitals of the Board.

In 1887 an Order of the Local Government Board empowered the Asylums Managers to receive all persons suffering from small-pox or fever, whose removal was applied for by any "duly qualified medical practitioner" (the regulations made under the Act of 1867 originally made it necessary for the Poor-Law officers to sign the admission orders), and in 1889 the Managers were empowered by Act of Parliament to admit ("subject to such regulations as the Local Government Board from time to time made") any person "reasonably believed to be suffering from fever, small-pox, or diphtheria;" finally the Public Health (London) Act, 1891, threw the cost of maintenance of non-pauper patients upon the county rate. The effect of thus completely removing the "stigma of pauperism," of making the treatment gratuitous, and of extending the facilities afforded to diphtheria, would in any case have been marked; the changed conditions coincided, however, with the introduction of notification. The great advantages incidental to hospital treatment speedily appealed to the public, and the cases admitted to the hospitals rapidly multiplied. Prior to 1887 the number of fever patients admitted in one year had not exceeded 2,867, in 1887 it rose to 6,537, and in 1899 it exceeded 25,000. This increase was due in the main, not to greater prevalence of disease, but to an augmented proportion of admissions. For the years subsequent to 1890 the percentage of admissions to notifications is known, and it appears that whereas, in the case of scarlet fever, in 1890, only 43 per cent. of the notified cases were admitted to hospitals of the Board, 74 per cent. were admitted in 1899, while, in the case of diphtheria, the percentages for the same years were 18 and 70; the corresponding figures for enteric fever were 22 per cent. and 41 per cent. respectively.

In 1900 the hospitals, erected and in use or in course of construction for London inhabitants, were designed to afford accommodation for some 6,000 acute and convalescent cases of fever and diphtheria, and for 700 acute and 1,192 convalescent cases of small-pox, a total number of nearly 8,000 cases. This large extension of the employment of isolation hospitals has considerably exceeded the anticipations which were made at the time of the Commission of 1881. It was thought, in the early days of isolation, that powers of compulsory removal to hospital would need to be exercised. Experience has shown that such powers are in practice rarely necessary, the advantages of removal of the infectious sick having made themselves so apparent, that objection on the part of parents and friends has not proved a serious obstacle. The carrying out of the isolation system has been greatly aided by the satisfactory working of ambulance arrangements, and the fears at first entertained that serious injury would result, from conveyance of sick persons from their houses to the hospitals, have been found, in the light of actual practice, almost wholly groundless. Moreover, the development of the system of telephonic communication has greatly facilitated the operations of the Asylums Managers.

Isolation has not made quite such rapid progress throughout the country considered as a whole. In many large urban centres a good deal of attention has been given to the subject; thus, in Glasgow the first municipal hospital was opened as early as 1865, and already in 1881 the Local Authority resolved "that all classes of the citizens suffering from infectious disease should be treated in hospital without any charge being made therefor." Section 131 of the Public Health Act of 1875 authorised the provisions of hospitals by sanitary authorities generally.

An important report on the use and influence of hospitals for infectious diseases was prepared by Thorne Thorne, in 1880–81, for the Local Government Board (Supplement to the Tenth Annual Report of the Medical Officer of the Board); in the course of the inquiry, detailed particulars as to the isolation hospital accommodation then in existence throughout England and Wales were obtained. About seventy hospitals constructed by urban, rural, and port sanitary authorities were visited and reported upon. Attention was specially directed to the fact that if isolation hospitals are to be of use their accommodation must be ready beforehand. Numerous instances were encountered in the course of the inquiry in which epidemics had "evidently been prevented by the isolation of first cases of infectious disease." On the other hand, the "hospital hastily run up, when small-pox or fever was making head in the district," had proved an undoubted failure. The finding of the report with regard to the emergency hospital is as follows:—"It is often not ready for occupation until the immediate cause of its erection has passed by; it provides accommodation of a very indifferent sort; it fails, almost without exception, to meet the permanent requirements of the district, even when in amount it turns out to be more than the district needs; and thus the object of the hospital, as a part of the sanitary defences of the district, is often attained in a very imperfect manner and at a needlessly large cost." Another notable result of the inquiry was the elicitation of the fact that there was no evidence to show that fevers (scarlet, typhus, and enteric) or other infectious disease spread from the hospital to the surrounding neighbourhood; this experience was in marked contrast to the phenomena already referred to as having been observed in connection with the isolation of small-pox.

Memorandum on Provision of Isolation Hospitals.—A Memorandum issued by the Local Government Board in 1888 (re-issued in 1895), sets out the general principles which should be held in view by all authorities about to establish isolation hospitals for their districts. This Memorandum states that: "For a town the hospital provision ought to consist of wards in one or more permanent buildings, with space enough for the erection of other wards, temporary or permanent. Considerations of ultimate economy make it wise to have permanent buildings sufficient for somewhat more than the average necessities of the place, so that recourse to temporary extensions may less often be necessary. In any case, it is well to make the administrative offices somewhat in excess of the wants of the permanent wards, because thus, at little additional first cost, they will be ready to serve, when occasion comes, for the wants of temporary extensions."

As regards the number of cases for which permanent provision should be made, the Memorandum states that no fixed standard can be laid down; much "must depend upon various considerations, among which the size and growth of the town, the housing and habits of its population, and the traffic of the town

20

with other places, are the most important." A rough rule has been formulated to the effect that at least one bed for every 1,000 persons should be provided: it may be noted, however, that the provision in London during recent years has been considerably in excess of this standard; while, on the other hand, in sparsely populated districts, and particularly in places where the population is largely well-to-do, it may be found that one bed for every 1,500 or 2,000

FIG. 81.

Small Isolation Hospital. Designed to accommodate two patients of each sex. A caretaker's cottage is also shown.

inhabitants, provided temporary extension can be made if needed, will prove sufficient.

The Memorandum referred to is accompanied by plans illustrating the sanitary requirements of small hospitals for infectious diseases. The simplest form of hospital should comprise at least (1) an administration block; (2) a block for patients; and (3) a wash-house, mortuary, and disinfection-house block. In Fig. 81 the ward block provides for the accommodation of only four persons, two of each sex.

A somewhat larger hospital building, providing for ten patients, and admitting of isolation of two distinct diseases, as well as of separation of the sexes, is also shown, Fig. 82, and Fig. 83 is a plan of a small pavilion, adapted to receive six male and six female patients, suffering from one and the same form of infectious disease.

In Fig. 81 an earth-closet, E.C., is indicated as the means of excrement disposal (earth-commodes are suggested for the wards); water-closets are, of course, to be preferred where efficient sewers are available. In any case, the Memorandum prescribes that an interval of 40 feet shall be interposed between every building used for the reception of infected persons or things, and the boundary of the hospital site; moreover, "this boundary should have a close fence of not less than 6 feet 6 inches in height, and the 40 feet of interval should not afterwards be encroached upon by any temporary building, or other extension of the hospital. In the construction and arrangement of such temporary buildings, as may at times be wanted in extension of the permanent hospital, the same principles should be held in view."

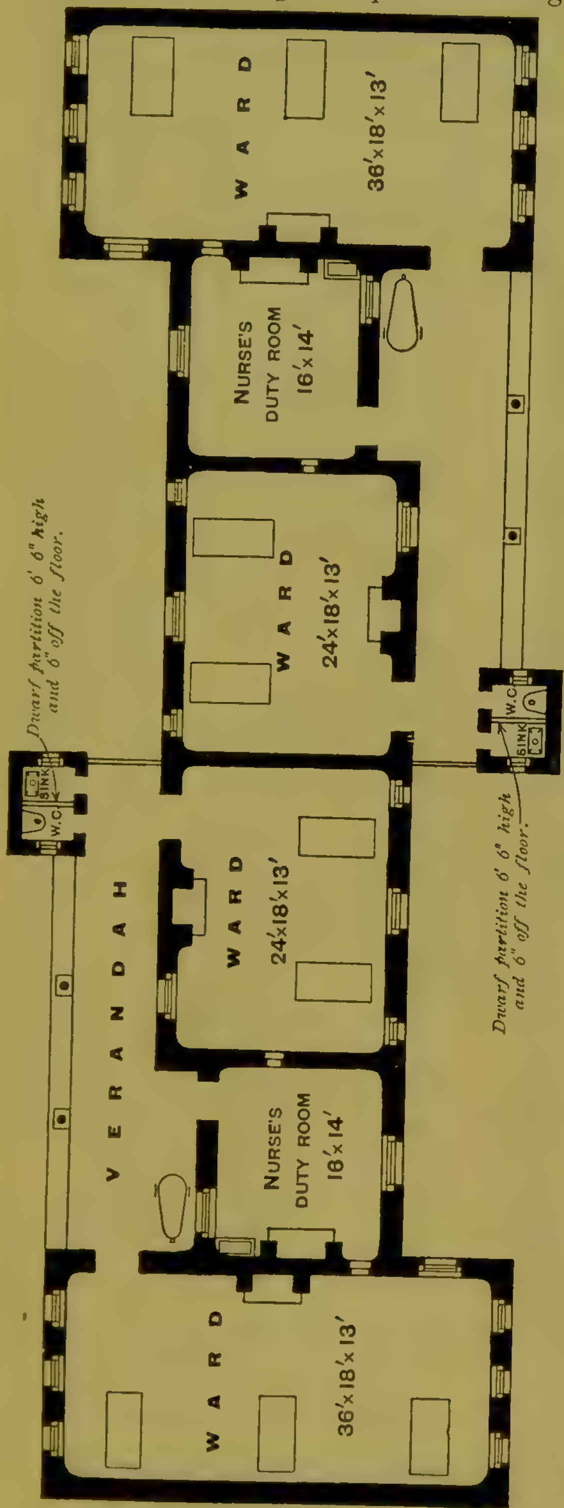

FIG. 82.
Plan of a Block for Ten Beds.

While the provision of a 40 feet interval is deemed to afford sufficient security in the case of buildings devoted to the reception of cases of infective fevers other than small-pox, the case is far different, when the disease last named has to be dealt with. The Memorandum prescribes "with a view of lessening the risk of infection," that a local authority should not contemplate the erection of a small-pox hospital:—

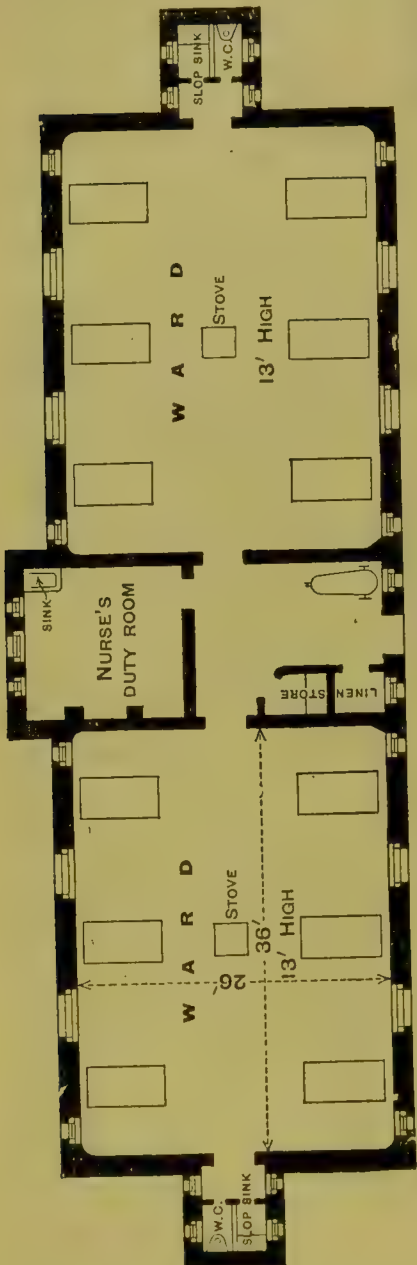

FIG. 83. Plan of a Ward Pavilion for Twelve Beds.

"1. On any site where it would have within a quarter of a mile as 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.

"2. On any site where it would have within half a mile of it as centre, a population of 500 to 600 persons, whether in one or more institutions, or in dwelling-houses. It must also be understood that even where the above conditions are strictly fulfilled, there may be circumstances under which the erection of a small-pox hospital should not be contemplated. Cases in which there is any considerable collection of inhabitants, just beyond the half-mile zone, should always call for especial consideration."

It will be seen that these conditions preclude the provision of buildings for the isolation of small-pox on the same site as that on which an isolation hospital for other forms of infectious disease is constructed, and this need of providing dual sites has led to difficulty, especially in the case of small districts. Under the Isolation Hospitals Act, 1893, County Councils were empowered, on representation being made to them, to combine sanitary districts into Hospital Districts, and to contribute out of the County Rate towards the expenses of an isolation hospital. In recent years some progress has been made, as regards provision, under this Act, of isolation in small urban and rural communities, though much still remains to be done in this direction.

The Report of 1882, already referred to, showed that the average cost per bed, excluding cost of site, incurred in connection with provision of isolation hospitals, in a number of urban centres, was rather more than £200. In more recently constructed hospitals the cost has been greater than this, and in the hospitals of best design, erected in recent years, £400 to £500 per bed, exclusive of the cost of land, has been a more usual average; of course, much depends upon the special circumstances in each individual case. Where temporary buildings must be provided at short notice to meet an emergency, wooden huts or galvanised iron structures have been utilised; tents have been erected in summer time, and portable hospitals constructed of what is known as Doecker's material (a leather-like waterproof material) have also been employed. The temporary fever hospital at Tottenham, which was completed in 1892 for the Metropolitan Asylums Managers in six weeks, consisted of wooden structures upon brick piers, raised upon concrete platforms, in most cases extending about six feet beyond the walls. These buildings were thus described: "The floors are in double thickness, with a layer of felt between; the walls are of timber framing, filled and weather-boarded outside, and match-lined inside; and the roofs are match-lined, boarded, and covered with galvanised corrugated iron. The whole of the buildings are warmed by steam pipes or radiators worked by the central boilers, which also supply steam to the kitchen laundry."

The proposal was made by Dr. Richardson in 1881, that the air of an infectious hospital should be deprived of all injurious property by being passed through fire, and the details of a plan for applying this principle to small-pox hospitals were submitted to the Royal Commissioners appointed in that year. The scheme contemplated the erection of wards in the form of a ring, "with the chamber from which the air is directly extracted in the centre of the ring." The ward was intended to communicate with the outside only by the opening from the corridor, by which it was approached, and to have no openings save those designed for ventilation; the beds were to be arranged against the internal wall, and each bed was to be placed "between two of the septa or screens which passed to a certain distance out from the internal walls into the annular space; so that the head of each bed would be included in the space between each two neighbouring septa." The space within the ring (*i.e.*, the central extraction chamber) was to communicate with the annular space answering the purpose of a ward, by the extraction openings, and also with an extractor, preferably a fan. "The fan would collect the air from the ward, and at once discharge it into a chamber where it could be subjected to a high temperature, so as to destroy all organic matter it might contain." This scheme of dealing with the air of small-pox wards has not hitherto found favour, and the method as originally designed is open to several objections. The patients faced the light, "which would be extremely unpleasant in the acute stage of small-pox," there was insufficient space about the beds, the central shaft was unnecessarily large, and it was seen that difficulties would be experienced in connection with ventilating the wards.

Circular wards have been constructed in a few modern hospitals not designed for the reception of infectious cases, and this form of ward undoubtedly presents some advantages. It is used in the city hospital at Antwerp, and a somewhat similar "octagon ward" is employed at Baltimore; in both instances the beds are arranged against the outer walls, having the heads towards the windows. A circular ward has been constructed at the Great Northern Central Hospital in London. Professor Marshall originally advocated this form of ward, on the ground that it afforded (*a*) freedom of frontage to all points of the compass; (*b*) great accessibility to light and air; (*c*) greater area, contained within a given length of wall, in a circle than in a rectangle; (*d*) superior ventilability; and (*e*) more equal warming. The circular form of ward also facilitates cleansing. Objection has been taken to it on various grounds, the main difficulty being the question of cost. If it is assumed that each ward should hold at least 28 or 30 patients, the circular form is undoubtedly costly; at the Great Northern Hospital the ward accommodates 20 beds only. The idea of depriving the air of small-pox hospitals of infectious property has much to recommend it, and if the circular ward continues to find favour, it may be that the plan of exhausting and consuming air from small-pox wards may be again considered in connection with its use.

Finally, it remains to note as regards infectious hospitals that it is especially important that all dressings, poultices, etc., should be so dealt with as to avoid spread of infection, and that infected clothing should be adequately disinfected. Proper disinfecting apparatus should therefore be available, and a destructor furnace for burning refuse material is a desideratum. Careful supervision requires to be exercised over visiting arrangements. Visits should only be permitted to patients who are dangerously ill, and then only in the case of near relatives and intimate friends, and due precautions are necessary in connection with the discharge of patients. Care should be exercised, moreover, with regard to tradesmen's visits, and indeed all necessary intercourse with the outside world.

CHAPTER VIII.

PARASITES—INFECTION—IMMUNITY.

"Of recent years," as Hirsch has observed, "few departments of medicine have grown so much as that of parasitology." Very early records, however, yield suggestions of the existence of parasitism. Thus it has been surmised that the "fiery serpents" which afflicted the Israelites in the desert were "Guinea-worms" (*Dracunculus medinensis*), and it is at any rate probable that the history of "dracontiasis," as the dracunculus disease is called, dates back to Plutarch. The plagues of Egypt afford ground for much speculation; the murrain of beasts and the plague of boils and blains may perhaps have been manifestations of anthrax. Again the "very great destruction" which smote the Philistines who carried the ark (*See* p. 402) has been regarded as having been bubonic plague. The division of animals into clean and unclean under the Mosaic code may have been, to some extent, based on the presence or absence of parasites. Some of the tape-worms have been long known, and the parasitic nature of itch was recognised by the Arabian physicians.

Steady progress was not, however, made until the eighteenth century, when the foundations of the science of helminthology were first laid down by Linnæus and his followers. During the last half-century advance in knowledge concerning the relation of parasites to infective processes has been remarkably rapid, and the establishment of the "germ theory" of disease has specially focussed attention upon certain minute forms of life, and particularly upon the bacteria. Before alluding further to these lowly organisms, it will be well to briefly refer to the more highly organised parasites.

Higher Parasitic Forms.—In addition to micro-organisms (Protozoa, Bacteria, etc., *see* p. 320) associated with disease, there are upwards of fifty more highly organised animals belonging to the Insecta, Arachnida, Suctoria, Nematoda, Cestoda, and Trematoda, which occur parasitically in man. Leuckart says of them: "The outer skin of the body and the alimentary canal seem, on the whole, to contain the greatest number, and this because they are more easy of access; in man more than three-fourths of the total number of parasites are found in these two localities."

Among parasitic INSECTA, fleas, bugs, and lice are well known in this country, and the jigger or chigoe (*Pulex penetrans*) is excessively troublesome in certain parts of the tropics. Myiasis (μυῖα, a fly), the condition in which dipterous larvæ are met with as accidental parasites, needs to be mentioned; the larvæ may be lodged in the human skin and grow there. The larvæ of the bot fly (*Œstrus hominis*) and of species of lucilia, dermatobia, etc. (some of the anthropophagous larvæ await identification), are not infrequently encountered in the tropics—thus, *Lucilia macellaria*, the "screw-worm," occurs in parts of America; *Dermatobia noxialis*, the "ver Macaque," in Central America; and *Ochromyia anthropophaga*, the "ver du Cayor," in the Cayor district of Senegambia. The larvæ of certain dipterous insects, more particularly in tropical countries, may be hatched in the alimentary canal, notably that of *Musca vomitoria*, the bluebottle fly. The larvæ of beetles, *e g.*, *Blaps mortisaga* and *Tenebrio molitor*, and occasionally also those of some species of moth have been found in human excreta. The *rôle* played by mosquitoes and the tsetse fly in spreading disease has only quite recently been demonstrated.

Among the ARACHNIDA, the mites (*Acaridæ*), ticks, and pentastomes are parasitic. *Acarus scabiei* is well known; a few ticks infest man in the tropics; *Pentastomum denticulatum*, said to be an immature form of *Linguatula caprina*, has been found in the liver and lungs of Europeans; and an allied larval form, *Pentastomum constrictum*, has not infrequently come under notice in Africa. Among the SUCTORIA the leeches of tropical jungle lands require mention.

The Nemathelminthes include the Nematoda and the Acanthocephali, distinguished from the Nematoda by the absence of an alimentary canal. To the Acanthocephali belongs *Echinorhynchus gigas*, a common parasite in the pig, and this or allied forms have in rare instances been observed in man. The NEMATODA (νῆμα, a thread) include the common thread-worm (*Oxyuris vermicularis*); the common round-worm (*Ascaris lumbricoides*); the whip-worm (*Trichocephalus dispar*); *Trichina spiralis* (*See* p. 182); the Guinea-worm (*Dracunculus medinensis*); *Anchylostoma duodenale* (*Dochmius duo-*

denalis) the cause of the disease, of which anæmia is a marked symptom, known as anchylostomiasis; *Rhabdonema intestinale* (*Anguillula stercoralis*), described as occurring in Cochin China diarrhœa; and the various forms of Filaria, of which Manson mentions six, found in human blood. Among the embryo nematodes last named, *Filaria nocturna* must be specially referred to. It was styled by Lewis, in 1872, *Filaria sanguinis hominis*, but now that other blood filariæ have been discovered, and as this particular filaria is mainly found in the peripheral circulation at night time (filarial periodicity), the term *Filaria nocturna* has been applied to it. *Filaria nocturna* is the embryonic form of *Filaria Bancrofti*, which lives in the lymphatic system. In 1879 and 1883, Manson argued that the filaria was introduced into its human intermediate* host by mosquito bite. The importance of the bearing of this discovery upon more recent inquiries concerning malaria will be obvious, but, apart from this, "filariasis" itself is a disease of no little consequence. Manson enumerates the following conditions as possible results of the presence in man of *Filaria nocturna*:—"Abscess; lymphangitis; varicose groin glands; varicose axillary glands; lymph scrotum; cutaneous and deep lymphatic varix; orchitis; chyluria; elephantiasis of the leg, scrotum, vulva, arm, mamma, and elsewhere; chylous dropsy of the tunica vaginalis; chylous ascites; chylous diarrhœa; and probably other forms of disease depending on obstruction or varicosity of the lymphatics, or on death of the parent filaria." Again, he says: "The subjects of filariasis should be regarded as dangers to themselves and to the community, and be compelled to sleep under mosquito nets." He has, moreover, suggested that *Filaria perstans*, another embryonic form, may be concerned in the production of African lethargy, the "sleeping sickness of the Congo," and possibly in causing one of the forms of African "craw-craw." *Filaria loa* is a mature sexual form whose habitat is the connective tissue; it is met with on the West Coast of Africa. This brief reference to the Nematoda may be concluded by noting that Manson enumerates in all twenty-five species of human parasites belonging to this class.

The Platyhelminthes (πλατὺς, flat), the remaining class of parasitic worms, include the Cestoda (κεστὸς, a girdle) or tape-worms, of which Manson refers to twelve species as occurring in man, and the Trematoda (τρῆμα, a pore) or flukes, with ten species described as being occasionally parasitic in man. Many of the species,

* The *definitive* host is that which harbours the sexually mature parasite; the *intermediate* host harbours the immature form.

both of Nemathelminthes and Platyhelminthes, occur only in the tropics, and truly, as Manson says, "He who would properly qualify himself for medical work in warm countries must acquire something more than a smattering of helminthology." Indeed, the Entozoa, or internal parasites (the term Epizoa is applied to external parasites), are, in the main, worms. A curious point concerning them is, as Leuckart says, that the embryos do not resemble their parents; "even in the nematodes which are commonly said to go through no metamorphosis, the resemblance of the young to the adult is more apparent than real. In the majority of cases (in the cestodes, distomidæ, echinorhynchus, and pentastomum) the differences are so great that there is hardly any point of similarity between the young and the fully formed worm." He adds, that "sexual maturity and generation take place in most parasites during the time of their parasitic life."

At one time it was supposed that bladder-worms were pathological forms, the germ of the tape-worm having "lost its way," *i.e.*, arrived at some place unsuited for its requirements. The resemblance existing, for example, between the head of the bladder-worm of the mouse and the tape-worm (*T. crassicollis*) of the cat was, however, at length noted, and, in 1852, Kuchenmeister, by the method of feeding, demonstrated that bladder-worms were really an immature stage of tape-worms, and his researches paved the way for the study of alternation of generations in one and another species of animal. "The host of the young parasite," says Leuckart, "is frequently an animal which serves as food for the definitive host: thus the mouse yields to the cat not only its flesh but its parasites, and the like happens with the rabbit and dog, the fish and the seagull." He continues: "If one animal select as its food a certain other animal, it evidently follows that the latter is best suited to its nutritive requirements, hence the conditions of nutrition in both must be somewhat similar, and a parasite capable of living in one would probably also find the other, in a great measure, favourable to the conditions of its life. This idea, however, must not be pushed too far, since we find, for example, the young of *Tænia crassicollis* in many animals which are not preyed upon by cats; so also the human tape-worm is occasionally found in the asexual state in man himself—a fact which, on the principles just enunciated, would seem to justify cannibalism from the standpoint of natural history."

Examples of cestode worms have already been given (pp. 180-182). Among the Trematoda the common fluke, *Distomum hepaticum* (*Fasciola hepatica*), which produces liver-rot in sheep, and passes its intermediate "redia" and "cercaria" stages, as they are called, in a small mollusc (*Limnæa truncatulata*), has also been already referred to. A smaller distome, *Distomum lanceolatum* (whose intermediate host is also believed to be a small mollusc), *Distomum conjunctum* (East Indies), *Distomum Sinense* (China), *Distomum crassum* (China and India), *Distomum heterophyes* (Cairo), and *Distomum Ringeri* (Japan), have, like the common fluke, been in rare instances found in man. Of special pathological significance is *Bilharzia hæmatobia*, which differs from the other trematodes named in having the male and female reproductive organs in separate individuals, and which causes the endemic hæmaturia of Egypt, South Africa, and elsewhere.

Protozoa.—The Protozoa stand but little higher in the scale of life than the bacteria, moulds, yeasts, etc., to be presently referred to; indeed, the term micro-organism is sometimes applied in such a way as to include all these lowly microscopic forms. It is only of late years that attention has been directed to the Protozoa as possible excitants of disease. They are unicellular organisms, and various classes have been distinguished, mainly by the mode in which movement is effected and by the manner of reproduction. In one class, the RHIZOPODA (ῥίζα, a root; πούς, a foot), movement is brought about by the protrusion of pseudopodia, and reproduction takes place, as a rule, by simple division. This class includes the Radiolaria and Foraminifera, so well known as fossils, but most of the Rhizopoda have no hard parts. Many of them are parasitic in both animals and plants. *Amœba coli*, which has been found in the human intestine, and in water and soil, may be particularly referred to, as this organism, or possibly a distinct though closely allied form (*Amœba dysenteriæ*), has been supposed to play a part in causing dysentery.

Another class includes the FLAGELLATE PROTOZOA, such as *Cercomonas* (κέρκος, a tail), and *Trichomonas* (θρίξ, a hair), forms not infrequently detected in the human intestine and in the blood of some of the lower animals. Closely allied to these organisms are the Trypanosomata (τρύπανον, a borer; σῶμα, the body). *Trypanosoma Lewisi* was detected by Lewis, in 1879, in rat's blood; *Trypanosoma Brucei* (*See* p. 326) was described by Bruce in 1894 and 1897; *Trypanosoma Evansi* is the cause of the "surra disease" (*See* p. 327), met with in horses in India and the East Indies. The trypanosoma of "dourine" was described by Rouget in 1896, as occurring in the blood of mares and stallions. Another flagellate form, *Lamblia intestinalis*, has been found in the intestine of man and of some other animals.

A third class, the SPOROZOA, includes organisms which at one stage of their life-cycle form encapsuled "spores." All the known forms are parasitic. A well-known example is the *Coccidium* *cuniculi* (*Coccidium oviforme*), which produces coccidiosis or psorospermosis (ψώρος, scabby; σπέρμα, a seed) in rabbits and other animals. This, like the malaria organisms, has two modes of multiplication—a sexual multiplication by spore formation, and an asexual mode by fission. Fertilised oocysts may be found in the fæces of infected rabbits; within each of these four sporoblasts are, as a rule, developed, and from each sporoblast two crescentic sporozoites are formed. The sporozoites are found in epithelial cells, particularly those of the bile-ducts; they enlarge, and by multiple division give origin to merozoites, from which the sexual forms develop; fertilisation being effected, the cycle is completed, the oocyst being again produced. This alternation of generations presents a close parallel to the cycle observed in the Hæmosporidia, the group which includes the human malaria parasites and similar forms which occur in batrachians, reptiles, birds, dogs, monkeys, and bats. *Pyrosoma bigeminum*, the cause of Texas fever in cattle, which is transmitted by a tick (*Boophilus bovis*), is a closely allied organism. Less nearly related to the foregoing is the *Sarcocystis Miescheri*, which produces the fine white streaks, occasionally found between muscle fibres in mice and in swine, and made up of capsulated masses containing crescentic spores; it is important that these streaks, when they occur in pork, should be distinguished from the lesions of Trichinosis. It has been surmised that minute sporozoa play an all-important part in some other diseases; parasitic forms supposed to belong to this class have been described as occurring in syphilis, variola, molluscum contagiosum, and malignant growths, but the subject needs further investigation. The pébrine disease of silkworms is caused by an organism belonging to the sporozoa. In the class CILIATA there are species which have been detected in the human intestine. One of the best known of these is *Balantidium coli*.

The Germ Theory.—Coincidently with the later growth of knowledge concerning higher parasites, increasing importance was gradually attached to those microscopic forms to which Pasteur applied the term microbes. The germ-theory of disease began to assume special prominence between 1860 and 1870. The analogy between disease and fermentation processes had been hinted at long ere this. Kircher, in his "Contagium Animatum," published in 1671, had commented on the possibility of diseases being caused by animalculæ. Leeuwenhoek's researches stimulated inquiry into the nature of micro-organisms. Linnæus recognised the importance of the matter, and the doctrine that diseases might be caused by the multiplication of specific infective agents within the body was accepted by his followers, who also recognised the importance of the incubation period in this connection. The researches of Schwann and others definitely established the fact that the breaking up of organic matter in fermentation and putrefaction is not spontaneous, but is caused by micro-organisms introduced from without. In 1835, Bassi described the fungus of the muscardine disease of silkworms, and soon afterwards the parasitic diseases of grain, etc., were studied by Tulasne and De Bary.

Pasteur, in 1857, showed that lactic-acid fermentation is due to the growth of particular germs, and he later arrived at a like conclusion concerning the ammoniacal fermentation of urea. His work with regard to silkworm diseases paved the way for further developments. In 1863, Davaine maintained that the threads which he had already seen in anthrax blood, some years previously, were the cause of splenic fever; moreover, acquaintance with the life-history of this organism was greatly extended by Koch. Pasteur developed the method of protective inoculation in connection more particularly with fowl-cholera and anthrax, and devised a system of treatment for persons bitten by rabid animals. Lister advocated the antiseptic treatment of wounds. Koch studied septic processes in wounds, improved the method of separating organisms by plate cultivation, investigated cholera, and discovered, in 1882, the tubercle bacillus.

The question of *spontaneous generation* had again and again been raised and disposed of with regard to higher parasites: it came to the forefront in connection with the germ theory, after having been "chased successively," as Lister expressed it, "to lower and lower stations in the world of organised beings." The development of the evolution theory did much to clear the air with regard to the "*de novo*" origin of disease, and the experiments of Pasteur and others gradually rendered it possible to eliminate various sources of error. It had already been noted by Appert, in 1812, that infusions could be preserved in closely stoppered bottles after exposure to the temperature of boiling water, and Spallanzani carefully investigated this question of sterilisation by heat. In 1854 it had been found that filtration through cotton-wool deprived air of its organisms. Pasteur showed that by drawing out the neck of his flasks into tubes, to which a bent form was given, access of germs to infusions sterilised by heat could be arrested. Tyndall introduced sterilised infusions into a glass chamber, freed from suspended germs by settlement (the absence of particles being demonstrated by passage of a ray of light) and he found that no growth occurred in the infusions under such circumstances. In Pasteur's early work on yeasts comparatively pure cultures were obtained by the use of media which specially favoured development of particular organisms. Klebs, in 1873, introduced a fractional method of cultivation; improved dilution methods were soon advocated, and at length the plan of fixing growing colonies in gelatine was brought to perfection by Koch. Application of these newly-devised methods showed how many sources of fallacy had been ignored in earlier experiments.

There was still, however, left the consideration, that if living matter had ever been derived from matter not living, the like transformation might possibly still from time to time occur. Again it was urged that processes of evolution, which require ages for their development in higher forms of life, may be accomplished in comparatively short periods of time in the case of the lowliest germs. On the other hand, improved methods of research have shown how complex the organisation of a microbe is, and have made it possible to detect important differences, in appearance and behaviour on cultivation, and as regards formation of characteristic products in the test tube or in the animal body. That a pathogenic organism should be developed from non-living matter is as unthinkable, nowadays, as would have been a similar conception, fifty years ago, with regard to forms of life far higher in the scale.

The growth of micro-organisms in pure cultivation on artificial media has removed much misconception with regard to "mutability of species," and has also enabled precise study to be made, of "involution forms," of modifications in the ability of organisms to produce particular chemical changes, and of attenuation and loss of virulence. Little is known, however, of the behaviour of organisms when growing saprophytically and under natural, as opposed to artificially imposed, conditions. It may be that some germs are able to develop, outside the body, into organisms not at present recognised as having any connection with disease. Just as anthrax spores are capable of rendering hides and skins infective, after long exposure and transportation from one end of the world to the other, so other pathogenic forms may possess ability to assume resistant phases of existence, and thus to bring about disease in man, under circumstances in which the original source of mischief (the previous case of disease) may have become altogether untraceable. From this point of view many of the instances cited, to demonstrate the supposed *de novo* origin of disease, lose much in significance.

Before describing micro organisms and their products in further detail it will be well to refer to the distinction drawn between infections and intoxications. Certain alkaloids and some proteid and other substances act as poisons when introduced into the body, but do not reproduce themselves. Again, their ill-effects are manifested forthwith, and not after an interval of time. The distinction has already been referred to in connection with food poisoning. It should be noted, however, that the organism, causing a disease, may itself produce poisons capable of setting up intoxication, and, in some diseases—tetanus and diphtheria, for example—the multiplication of the organism may be, in the main, local, while its poison is distributed throughout the body, and is immediately responsible for the development of symptoms.

Micro-organisms and Infectious Disease.—Under the term infectious disease it is usual nowadays to include any malady caused by the growth and multiplication within the body of organisms introduced from without. The organisms causing infectious disease belong for the most part to the group known as the *bacteria*, fission-fungi, or schizomycetes (σχίζω, to cleave; μύκης, a fungus), the minute unicellular organisms which multiply by fission, which have not been shown to possess any nucleus, and which are described, according to the particular form they assume, as micrococci (diplococci, staphylococci, streptococci, etc.), bacilli, and spirilla.

In addition to the bacteria, however, mention must be made of other groups. There are, for instance, the *moulds*, hyphomycetes (ὑφαίνω, to weave), characterised by possessing a mycelium or network of filaments from which extend hyphæ carrying spores or fruit-bearing organs (conidia, sporangia). They are associated with certain varieties of skin disease: thus *Trichophyton tonsurâns* is the cause of ringworm, *Microsporon furfur* of pityriasis versicolor, and *Achorion Schönleinii* of favus. Species of aspergillus have been found occurring saprophytically in man, in the external auditory meatus, in the lungs, etc., and inoculation of aspergillus spores has been followed by their development in the viscera of animals. Saprolegnia is met with as a parasite in fish (salmon disease), and *Botrytis bassiana* is the cause of "muscardine" in silkworms.

Again, there are the *yeasts*, budding fungi, or blastomycetes (βλαστὸς, a sprout), consisting of round or oval cells which multiply as a rule by budding, and are generally devoid of mycelium. They include saccharomyces, torula, and mycoderma; also *Oïdium lactis*, the organism of thrush; and the group has been further suspected to contain important pathogenic forms. Sanfelice has isolated species of *Saccharomyces* which produce disease in some of the lower animals. Moreover, it has been maintained by Sanfelice and by Plimmer that the "cancer-bodies," which they have described as occurring within cells in cancer, really represent Blastomycetes.

The *streptothrices* (στρεπτὸς, twisted; θρὶξ, a hair) constitute a connecting link between bacteria and moulds; they present intertwined threads often branched and unsegmented, and sometimes terminal spore-like bodies. *Streptothrix bovis*, the organism of actinomycosis, and the *Streptothrix maduræ* of Madura foot belong to this group, and inasmuch as branching forms are occasionally met with in the bacilli of tubercle, leprosy, diphtheria, and glanders, it has been held that these organisms should be strictly regarded as streptothrices. According to Moeller (Tuberculosis Congress, 1901), all acid-fast bacilli belong to the streptothriciæ. Koch has insisted (*see* p. 207) on the differing pathogenic effects of tubercle bacilli of human and of bovine origin in the higher mammals (cattle, pigs, and sheep). The bacillus of avian tuberculosis shows marked divergence from that of human tuberculosis on culture, and when tested by inoculation. Bacilli of human origin have been modified by passage through frogs and other cold-blooded animals (*e.g.* the slow-worm). The Timothy bacillus, obtained from Timothy grass, and the Grass bacillus, organisms isolated by Moeller, are acid-fast and produce lesions indistinguishable from those of tuberculosis in guinea-pigs. The "Mist bacillus," which has been isolated from the dung of animals, and the Petri-Rabinowitsch butter bacillus are closely related forms. Aronson and Bulloch have shown that both tubercle bacilli and Timothy bacilli contain wax, to which their acid-fastness appears to be due; after extraction of the wax with boiling benzine or chloroform, they lose their power of retaining the stain while the wax itself is acid-fast. Leprosy bacilli closely resemble tubercle bacilli in appearance and staining reaction. The smegma-bacillus can be distinguished by its being decolorised by alcohol after treatment with acid.

A distinction is sometimes drawn between infection and contagion, and again between contagious and miasmatic diseases. For contagion, actual contact has been held to be essential, and here question may arise as to the need for the existence of some breach of surface. If this condition be found necessary, the disease is said to be an inoculable disease. The term contagious disease is, however, sometimes applied to any form of malady which can be transmitted from animal to animal, as distinguished from miasmatic disease which is acquired otherwise than by such transmission.

Incubation Period.—All infectious diseases being dependent on growth of an invading organism have an incubation period. The incubation periods of the principal infectious diseases are given in the table on p. 322, together with certain other particulars. The quarantine period is, as a rule, taken as including two or three days more than the maximum incubation period. In the last column the degree of protection an attack of the disease affords is indicated.

Disease.	Incubation period.	Day of disease on which rash, if any, first appears.	Duration of infectivity.	Quarantine period.	Tendency to relapses and second attacks.
Chicken-pox	10—19 days ...	First day or occasionally the second	Until all scabs have separated	21 days	Relapses and second attacks very rare
Cholera	1—5 days	——	Three weeks ...	7 days	——
Diphtheria	1—8 days	——	As long as the bacilli persist, and at least 3 weeks after disappearance of exudation	8 days	Relapses and second attacks not uncommon
Enteric fever	About 14 days (5-21)	4—7 days	——	——	Relapses common, second attacks rare
Erysipelas	1—5 days	Cutaneous inflammation usually within 24 hours	One week.........	5 days	Second attacks common
Influenza	1—4 days	——	——	——	Second attacks common
Measles	7—18 days ...	Fourth day (1—6)	Twenty-one days from date of rash	21 days	Relapses rare second attacks not common
Mumps	14—25 days ...	——	Three weeks ...	26 days	Relapses and second attacks uncommon
Rötheln	11—18 days ...	First day	Three weeks ...	21 days	Relapses very rare, if they ever occur. Second attacks very rare
Scarlet fever	1—5 days	Within 24 hours	Six weeks and as long as desquamation or discharge from mucous surfaces persists	7 days	Relapses not common. Second attacks occasionally met with
Small-pox	12 days (10-14)	Third day, occasionally later or earlier	Until all scabs have separated	15 days	Relapses unknown. Second attacks rare
Typhus fever	12 days (5-14)	Fifth day (4—8)	Four weeks from commencement of illness	15 days	Relapses very rare. Second attacks rare
Whooping-cough	5—14 days ...	——	Until the "whoop" quite disappears, and at least 8 weeks after commencement of illness	15 days	Relapses and second attacks rare

Conditions which influence Bacterial Growth.—The influences exerted by acidity and alkalinity of culture media, by temperature, by the presence or absence of free oxygen, by light, by atmospheric pressure, and by other variations in the conditions under which growth occurs, have been made the subject of careful study in recent years. Bacteria were distinguished by Pasteur as being aerobic and anaerobic, and they are often spoken of as belonging to one of the four following groups:—*Obligatory aerobes* (*e.g.* hay bacilli) can only grow in presence of oxygen. *Facultative anaerobes* flourish under like conditions, but can also grow anaerobically. *Facultative aerobes* can grow in the presence of oxygen, but flourish more particularly under anaerobic conditions. Most of the familiar organisms belong to one or other of these two last-named classes, and no hard and fast line can be drawn between them. The fourth class, to which the tetanus bacillus, the bacillus of rauschbrand, and the bacillus of malignant œdema belong, includes the *obligatory anaerobes* which can only grow in atmospheres devoid of oxygen.

Among known micro-organisms some (*e.g.* the leprosy bacillus and the spirillum of relapsing fever) cannot be artificially cultivated; others are very exclusive as regards media upon or in which, and conditions under which, they will develop. It is always necessary to bear in mind that absence of growth on a particular medium does not necessarily imply non-existence of organisms, indeed with increasing knowledge of the requirements of particular species it has from time to time, despite previous failures, been found possible to obtain growth under artificial conditions, by the adoption of particular devices, or by having recourse to new and hitherto untried culture media.

Products of Bacterial Growth.—Gas formation, the production of particular chemical substances (fatty acids, amido-compounds, indol, etc.), pigment formation, and the ability to cause phosphorescence, have been investigated in their relation to various species. Attention has, moreover, been devoted of late years, to elucidation of the nature of the substances, produced by bacteria, which cause special physiological and pathological effects. The phenomena of fermentation in particular have received a large share of consideration. It is usual to distinguish between fermentation set up by chemical products, and fermentation attributable to living cells. In the former case a chemical ferment or enzyme, in the latter what is called a true ferment, is said to be operative. It is customary to differentiate between the two by noting the action upon them of thymol, chloroform, and other substances which are inimical to cell life, but have no effect on the chemical ferments. Yet it has to be admitted that some enzymes, produced by cell activity, remain in the cells which generate them. Glycerine, while it inhibits the growth of many organisms, does not, as a rule, prejudicially affect the activity of enzymes. It has been found that it is possible by employing glycerine, to kill off extraneous organisms in vaccine lymph; hence the use of glycerinated lymph, as a means of producing the phenomena of vaccination uncomplicated by attendant development of foreign organisms.

Brieger especially directed attention to the formation, as the result of bacterial growth, of the bodies known as ptomaines (basic substances presenting resemblance to the vegetable alkaloids in chemical composition), some of which act as powerful poisons when inoculated. Sidney Martin and others later brought into prominence the toxic albumoses, and further researches showed that the poisonous substances yielded by cultures of particular bacteria might be, not albumoses, but allied albuminous bodies, and the general name, toxalbumins (or the wider term proteins) was applied to the group. The bacterial poisons are nowadays usually called toxines, and it is recognised that their chemical constitution is obscure and that they must be distinguished by their physiological effects.

Koch's Postulates.—Before it can be asserted that an organism is the cause of a particular disease the following requirements must, according to Koch, be complied with. The specific organisms must be found in the blood or tissues of the diseased animal, they must be isolated and cultivated in artificial media, a pure cultivation must be capable, in a susceptible animal species, of reproducing the disease, and the organism must be again demonstrated in the blood or tissues of the animal experimented upon. To these requirements has been added, as the outcome of Sidney Martin's researches, the condition, that the toxines obtained from artificial cultures shall be identical with those obtained from the diseased animal body.

These several requirements, including the last, are all satisfied in the case of anthrax, diphtheria, and tetanus; all save the last have been shown to be complied with by the organisms of tuberculosis, glanders, actinomycosis, gonorrhœa, plague, malignant œdema, pneumonia, pyæmia, erysipelas and endocarditis. In the cases of enteric fever, influenza, and certain forms of diarrhœa, animal experiments of a conclusive character have not hitherto been made. In cholera and in enteric fever, specific agglutinating properties are, it should be noted, demonstrable. In leprosy and relapsing fever artificial cultivations have not been obtained, but in relapsing fever monkeys have been successfully inoculated by employing human blood containing the spirillum. The bacteriology of scarlet fever is less conclusively established. In syphilis, rabies, typhus fever, mumps, whooping-cough, small-pox, measles, rötheln, rheumatic fever, yellow fever, dengue, beri-beri, and some other diseases of presumably microbic origin, the nature of the organism concerned still remains to be determined.

Spread of Infection.—Organisms are classed as parasitic and saprophytic, and (just as in dealing with aerobes and anaerobes) four groups, obligatory and facultative parasites, and obligatory and facultative saprophytes, may be distinguished. The organisms of rabies, syphilis, and gonorrhœa are *obligatory parasites.* In the case of these diseases the "stamping out" process by means of isolation, etc., might be expected to prove especially efficacious. Glanders, variola, and measles, too, are almost always directly contagious from person to person, and scarlet fever and diphtheria are usually communicated in this way, though they are also not infrequently spread indirectly, and notably by the agency of contaminated milk. Among *facultative saprophytes* the organisms which cause actinomycosis and erysipelas, and the pathogenic cocci which are associated with pyæmic conditions, may be particularly referred to. As examples of *facultative parasites*, anthrax, cholera, enteric fever, and tetanus bacilli may be cited. Anthrax and tetanus only spread in rare instances from person to person. It is said that malaria and relapsing fever are never thus transmitted. In the light of modern knowledge, limitation of spread of malaria is to be sought by eradication of the definitive host, the mosquito. It has been urged that plague in like manner must be controlled by the destruction of rats. *Obligatory saprophytes* are not directly concerned in the production of infectious disease, though they may elaborate poisons capable of giving rise to symptoms of a specific character when introduced into the living body.

The measures to be adopted in dealing with maladies usually transmitted to man by animals obviously differ from those which must be employed in instances in which the disease is generally communicated from man to man. Rabies in the dog has been effectively combated by muzzling orders, and by quarantining dogs newly arriving in particular localities. Glanders has been attacked by destroying affected horses, and with special success since the use of mallein, as a diagnostic agent, has facilitated recognition of the disease in its early stages. Among cow maladies tuberculosis stands pre-eminent as a source of mischief in man, and the need of excluding from milk supplies the milk of cows, affected with tubercular disease of the udder, has been increasingly realised of late years. Scarlet fever, diphtheria, and enteric fever are not infrequently spread by milk, and cholera was found to be thus diffused in one well-attested instance. Some attention is now being given to the necessity of obviating, by an adequate system of inspection, risk of spread of tuberculosis by the consumption of tuberculous meat. The possibility of other bacterial diseases (actinomycosis and anthrax for example) and of higher parasitic forms being transmitted to man by infected meat needs to be borne in mind. Other kinds of food may act as disease producers: the dissemination of enteric fever by shell-fish, and the numerous recorded instances of "meat poisoning," are cases in point.

Communication of disease to man, by infective material derived from a previous case of illness, often occurs in a roundabout way. Excremental matter containing the specific germs of enteric fever and cholera, and, perhaps, of other diseases, may by means of water be conveyed considerable distances. The urine in enteric fever may contain large numbers of bacilli. Particles of epidermis have been supposed capable of long retaining, in clothing, etc., the power of reproducing scarlet fever; and ability to produce disease has been ascribed to mucus in diphtheria, to the saliva in rabies, to purulent discharges in scarlet fever and other diseases, and to dried small-pox crusts, etc. The spread of disease by fomites is probably not of such frequent occurrence as it was at one time supposed to be. The infection of typhus is remarkable inasmuch as it is only conveyed, as a rule, through very small distances; the conditions favourable to the spread of this disease are particularly those of gross overcrowding. The breath presumably often acts as a source of infection in measles, whooping-cough, scarlet fever, diphtheria, typhus, and mumps, and possibly in pneumonia and small-pox. Dried sputa are assumed to be largely operative in promoting the spread of phthisis.

As has been already mentioned, the soil is supposed to be a medium which favours, under appropriate conditions, the growth of certain germs which cause disease. The existence of the anthrax, tetanus, and malignant œdema organisms in soil has been repeatedly demonstrated. Enteric fever, diphtheria, cholera, summer diarrhœa, and numerous other diseases have been from time to time studied in connection with soil states. The discovery of the *rôle* played by the mosquito, in filariasis and malaria, has led to direction of special attention to the possibility of other maladies being spread by the agency of blood-sucking insects. Quite recently experiments have been made which indicate that the mosquito can transmit the poison of yellow fever. In this connection, moreover, the tsetse fly disease may be referred to. It has long been believed that the tsetse fly (*Glossina morsitans*) was concerned in producing the "fly disease" which is apt to affect animals in some parts of Central Africa. Bruce showed in 1894 that the fly transmitted the disease by transferring a protozoon (trypanosoma) from infected to uninfected animals. The trypanosoma is allied to the organism which causes the disease known in India as "surra": again another allied form of organism is found in European rats. The "surra" disease does not, as a rule, affect bovines, whereas the tsetse fly disease does. Another interesting point is the fact that the fly disease vanishes with the disappearance of large game from a district.

Epidemic and Endemic Diseases.—Some diseases tend to permanently establish themselves in particular localities, notably, for example, cholera in special areas in India, small-pox in the Soudan, and plague, malaria, yellow fever, dysentery, etc., in other parts of the world. When a disease so establishes itself it is said to be *endemic* in the population concerned. Again, diseases which from time to time become widely prevalent, while at intervening periods there is more or less complete freedom from their ravages, are said to be *epidemic* in relation to the populations they affect during their times of activity. Originally the expression epidemic disease (ἐπί, upon; δῆμος, the people) was applied to any disease which attacked many persons at the same time, and, even in recent years, writers on epidemic diseases have made reference to such maladies as ergotism, scurvy, and the dancing mania of the Middle Ages. The modern use of the word is, as a rule, a more limited one; thus Davidson restricts the term epidemic "to that group of infective or micro-parasitic maladies which has the common property of spreading from time to time in a community," excluding intoxications, dietetic, and psychical diseases, as well as those arising from physical agencies such as heat and cold.

Soil conditions may play an important part in determining endemicity of disease, climatic conditions, too, are of importance; recent research has caused attention to be directed to search for intermediate hosts, in the case of maladies which especially occur in particular areas. Further, the habits and social circumstances of populations need to be borne in mind. A disease may be endemic in one or more localities, and from time to time show ability to become epidemic in other places. If the disease spreads over a large portion of the globe, as, for example, plague and cholera have done in the past, it is said to become pandemic (πᾶν, all; δῆμος, the people). The same disease may be, therefore, endemic as regards special areas and epidemic as regards other areas. As Davidson observes, "The converse of epidemic is not endemic but sporadic (σποράδικος, scattered)," and, he adds "an epidemic disease often occurs sporadically in inter-epidemic periods." The inability of the disease to produce more than a few scattered cases may depend upon attenuation of the virus, upon the absence of conditions necessary for the widespread diffusion of the disease, or upon insusceptibility on the part of the population generally. Diseases may be of fairly constant occurrence in particular communities, and yet from time to time exhibit cyclical variations of prevalence. Precise study of the phenomena of periodicity has only been undertaken in quite recent years, for the necessary statistical data have only become available within the last half-century.

Periodicity.—With the ancients, study of periodicity in disease was undertaken in relation to the symptoms of certain maladies; thus the doctrine of "critical days" in fevers arose out of considerations as to whether, on special days, particular symptoms appeared which enabled a forecast as to the probable course of the malady to be made. The modern conception of periodicity as affecting, not merely the course of a particular malady, but the phenomena of widespread prevalences of disease, was foreshadowed by Sydenham (*See* p. 2). The fluctuation in the prevalence of certain diseases at different seasons of the year was made the subject of exact study by Buchan and Mitchell, whose observations will be later referred to. Their researches, in addition to throwing light on seasonal prevalence, greatly stimulated inquiry with regard to the fluctuations which have been shown to occur when long periods of time are passed in review. Laycock and Edward Smith, early in the latter half of the last century, devoted much attention to the question of periodicity, and found indications, in numerous instances, that altered behaviour of disease was related to periodical recurrence of physical phenomena. Laycock held that it would be possible to establish a system of vital proleptics, or, as Netten Radcliffe, in commenting on his work, termed it, a science of pathological forecasting.

Netten Radcliffe attached special importance to "the influence of an accumulation of susceptible persons in the intervals between epidemic prevalence." He showed that, making certain assumptions with a view to simplifying the problem, a rough approximation to the number of years covered by an epidemic cycle could be obtained by dividing "the number of people attacked, or otherwise rendered insusceptible, during an epidemic," by "the annual excess of births over deaths (all causes), with other increments of susceptible population." He pointed out that variations in the numbers attacked, fluctuations in the number of susceptible people from whatever cause arising, and other influences, required to be kept in mind, and he said, "it is easy in these considerations to find reasons for differences in epidemic cycles among different communities, for differences in the intensity of successive epidemics, and for apparent alterations of susceptibility among communities, and these reasons will deserve to be considered before going in search of other reasons."

Ransome was struck by the remarkable behaviour of small-pox in Sweden in the latter half of the eighteenth century, during which period epidemics occurred with striking regularity, at intervals of about five years, up to the time when, in correspondence with the introduction of vaccination, the prevalence of the disease underwent remarkable diminution. Ransome obtained from Dr. Berg, of Stockholm, the figures relating to whooping-cough, scarlet fever, and measles in Sweden. In the case of measles, eight well-marked major prevalences occurred between 1775 and 1830, the interval between each prevalence being about six years. In the case of whooping-cough the cycles of prevalence were less distinctly marked, but some ten major prevalences were, roughly speaking, traceable, the interval being thus somewhat shorter than that noted in measles. In scarlet fever only four well-marked prevalences occurred, the intervals being about fifteen to twenty years, and thus considerably longer than in measles, whooping-cough, and small-pox.

Ransome pointed out that, in the case of scarlet fever more particularly, there were shorter cycles, in addition to the longer undulations; he compared the latter to vast waves of disease on which "the lesser epidemics show like little ripples upon the surface of an ocean swell." He sought to find an explanation of the shorter cycles on several hypotheses. On one, the "age theory," the phenomena were held to be accounted for by the fact that "certain years of life are prone to the disease, and that, when these have been cleared away, the disease could not prevail extensively until there were again persons of fit age to receive the poison." On another, explanation was sought in variations "in the powers of offence and virulence" manifested by the disease. A third hypothesis, which Ransome thought afforded the best explanation of all, was to the effect that "a certain density of the population at susceptible ages is necessary before a disease can spread with the vigour of an epidemic." According to this hypothesis the disease "can only become epidemic when the proximity between susceptible persons becomes sufficiently close for the infection to pass freely from one to the other." Ransome says, when an epidemic "has, by either a fatal or non-fatal attack, cleared away nearly all the susceptible persons in a population, mostly infants and children up to a certain age, then it must necessarily wait a certain number of years before the requisite nearness of susceptible individuals has been secured. There must, in the interval, be a gradual re-stocking of the nation with material fit for the epidemic to feed upon, and it can only spread when the requisite proximity is attained, when the meshes of the network of communication are sufficiently close to enable it to include all susceptible persons in one grand haul." Ransome thus accounted for the minor cycles; with regard to the larger undulations, which he called the "nutation periods" of diseases, he was unable to offer any explanation.

Whitelegge, in 1892, in a paper entitled "Measles Epidemics, Major and Minor," referred to minor epidemics as "occurring every year or two, and in a sense, mechanically," and suggested that the "major epidemics, the waves of long periods, were due to progressive alterations in the intensity of the measles virus." This question of "Change of type in epidemic diseases" was considered in detail by Whitelegge in his Milroy lectures. Putting aside "superadded waves" (annual seasonal waves, milk epidemics and water epidemics), he attributed the broader cycles to change in the quality of the disease itself. He held that the virus was able to manifest at certain periods greater severity of attack, greater power of overcoming comparative insusceptibility and greater power of epidemic diffusion. In some diseases, those of "stable type," variations of intensity of virus are little marked; in others those of "unstable type" (or "mobile diseases") the quality of the virus appears to undergo rapid and even abrupt changes in intensity.

Scarlet fever is, from this point of view, a disease of an intermediate character, but, as evidence of gradual change in the quality of this disease, Whitelegge pointed out that the hospital case-mortality from scarlet fever, from 1832 onwards, showed a rise and fall, in close correspondence with the general scarlet fever mortality, especially during the period 1859 to 1880. In small-pox there was found to be doubt as to whether a rise in case-mortality could be definitely traced, at the times of occurrence of major prevalences of the disease. In measles there was some suggestion that long waves of prevalence were accompanied by variations in type; but the minor explosions, occurring at short intervals, were attributed to the fact that accumulation of susceptible persons favours spread of disease, at times when the climatic and other external conditions offer sufficiently small resistance. It may be noted that the variations in prevalence of scarlet fever between 1859 and 1880, which were accompanied by alterations in case-mortality, were also accompanied by variations in age-incidence of the malady and similar variations in age-incidence are clearly marked in the case of small-pox. Such fluctuations in age-incidence may, however, be regarded as being produced, in part at any rate, by the variations in prevalence, and thus as being the effect rather than the cause of those variations, it is therefore difficult to say to what extent, if any, they represent altered susceptibility of the population to disease of such a kind as may have had influence in favouring prevalence or otherwise.

The periodicity of a disease, which has become established in a particular community, undoubtedly influences to a marked extent the age-distribution of the deaths due to it. Indeed, McVail says "the periodicity of small-pox is the governing factor in its age-distribution." He points out, referring to small-pox in the eighteenth century, that in Kilmarnock and Geneva epidemics came every four or five years, and the disease was, to nine-tenths of its extent, found to affect children under five years old, "the average age at death in Kilmarnock being not much over the average age of the children born since the previous epidemic. But in Boston, U.S.A., where epidemics came every twelve years, the average age at death would be greater; and so also in country towns and villages, and in the Hebrides, Iceland, etc. In London small-pox attacks among adults appear to have been not at all uncommon, and the explanation is doubtless to be found in the largeness of the number of immigrants from country districts, where opportunities of attack were less frequent."

Protection and Immunity.—The notion that a condition of protection against disease could be obtained, by submitting the body to the operation of the malady in a mild form, lay at the root of the ancient beliefs in the efficacy of small-pox inoculation. The Brahmins are said to have first put the question to the test of practice, employing what would be termed, in modern phraseology, an attenuated virus, obtained by storing material from cases of the disease, and conducting their operations with careful regard to diet, regimen, etc., during the progress of the treatment. Variolation is, moreover, said to have been long ago practised, in China, by applying small-pox crusts to the nostrils, and other methods have been adopted in various parts of the world. Attention was pointedly called to the question in modern times, when, early in the eighteenth century, under the auspices of Lady Mary Wortley Montagu, small-pox inoculation was introduced into this country, and the practice soon became widely extended.

Jenner's discovery, at the end of the century, by substituting vaccination for the more formidable variolation, led to the general adoption, in those civilised countries in which small-pox prevailed, of the new method, the dangers attendant upon which were seen to be insignificant in comparison with those associated with inoculation of small-pox virus. As statistical records have accumulated on a larger and larger scale, and the behaviour of small-pox in relation to vaccination has admitted of being more and more critically examined, the significance of the new departure inaugurated in 1798 has been increasingly realised. Moreover, experiments made in recent years have shown that Jenner's "variolæ vaccinæ" is, in point of fact, variola of the cow, and thus, while confirming Jenner's thesis, have been the means of greatly stimulating inquiry upon the lines which he indicated more than a century ago.

Prior to the collection of statistics on a comprehensive scale, second attacks of small-pox were regarded, if not as altogether unknown, at least as quite exceptional; such occurrences were, no doubt, very rare in the experience of any individual observer. In the Sheffield outbreak of 1887-1888, however, in which the matter was tested, by Barry, in a large population severely attacked it was found that twenty-three persons, out of a total of 18,292, reported to have suffered from small-pox prior to 1887, again developed the disease, an attack rate of 0·13 per cent. The rate upon the Sheffield population considered as a whole was about thirteen times as great (1·7 per cent.), while that upon the unvaccinated portion of the population was more than fifty times as great (7·5 per cent.).

The frequency of occurrence of second attacks of other diseases has not been studied with precision, the necessary data not having been hitherto available on a large scale; with the growth of the system of notifying disease, increase of knowledge in this connection may be anticipated. That some forms of disease protect the sufferer against future attack is made clear, apart from evidence of the kind which has already been referred to in the case of small-pox, by certain other considerations. The normal behaviour of such diseases as measles and whooping-cough, in attacking young children and sparing adults, may be mentioned. It has further been found that when, as in the Fiji epidemic of 1875, measles attacks a community containing persons who have not suffered from the disease in childhood, its incidence upon adults is marked. Moreover, precise statistical record of the ability of this disease to attack children and others, at higher ages, is forthcoming in the case of sparsely populated places, in which measles outbreaks are of infrequent occurrence. Thus, while in certain sparsely populated parts of England the deaths under five years of age constitute only 78 per cent. of the total deaths from measles, in large towns such deaths contribute 93 or 94 per cent. of the total deaths.

Small-pox, like measles nowadays, was once a disease of childhood. Thus in Kilmarnock from 1728 to 1764, outbreaks of small-pox occurred every three or four years, and 88 per cent. of the total deaths, taking the entire period, occurred in children who had been born since the height of the epidemic preceding that in which their small-pox was contracted. McVail, in 1882, in a paper, extracts from which appear in the Fourteenth Annual Report of the Medical Officer of the Local Government Board, commented upon these facts. He pointed out that the Kilmarnock population in question (some 5,000 persons) might be regarded as being composed of three groups; there were, in fact, from the point of view of small-pox, three Kilmarnocks. "One, a Kilmarnock of 3,700 persons, had no fear of its attacks. These had already met with and battled with the disease fiend. On many were to be seen the marks of the conflict. Some were blind, some had lost their hearing, many were permanently injured in constitution, and very many were scarred and disfigured for life; and for every one that conquered another had fallen never to rise again. There was, indeed, a second Kilmarnock under the green sod of the kirkyard. The Kilmarnock which had reason to dread the epidemic's approach was a Kilmarnock the least able to meet it. It consisted of a band of little children, numbering less than 500 in all."

The experience of Kilmarnock is borne out by records kept in other places, and the question is seen to be one of exceptional interest when the altered behaviour of small-pox in comparatively recent years is studied in connection with it. McVail has referred to this subject in commenting upon the annexed table of statistics relating to small-pox in Geneva (1580–1760), Kilmarnock, 1728–1764, and London, 1848–1851. The table appeared in the Report of the Medical Officer of the Local Government Board for 1884.

CONTRIBUTIONS OF VARIOUS AGES TO 1,000 SMALL-POX DEATHS AT ALL AGES.

Ages at death.	Geneva, 1580—1760.	Kilmarnock, 1728—1764.	London, 1848—1851.	London, 1884. Unvaccinated community.	Vaccinated community.	Total Inhabitants.
0—10	961	988	815	612	86	343
10—20	26½	5	59	146	173	170
20—30	10	7	83	108	319	213
30—40	2½ (30—40 and 40 and upwards together)	—	32	72	221	142
40 and upwards		—	11	62	201	132
Total ...	1,000	1,000	1,000	1,000	1,000	1,000

McVail remarks—"These figures show: (1) That when vaccination was unknown, from 96 to 99 per cent. of all small-pox deaths in Geneva and Kilmarnock occurred under 10 years of age—that, indeed, small-pox was in such places a disease of childhood. (2) That in London in 1848–1851, when vaccination was partially in vogue, without being enforced by law, 80 per cent. of the victims were under this age. (3) That in London, in 1884, under general vaccination, only 34 per cent. of the total small-pox deaths were under 10 years. (4) That among the vaccinated community of London less than 9 per cent.; while among the unvaccinated community 61 per cent. were under 10 years. Thus we find that with the spread of vaccination, children, as a whole, and especially vaccinated children, bear less and less of the total small-pox mortality, while among the unvaccinated the distribution approaches more nearly to that of pre-vaccination times."

Altogether, apart from statistical evidence as to the infrequency of second attacks of special diseases, there is a further consideration which must not be lost sight of. When a patient is attacked by disease and recovers, the mere fact of his recovery suggests that some altered condition of body has been induced, in the course of the malady, which renders him, at any rate for the time being, able to resist the disease. This consideration was brought into prominence with the development of the germ theory of disease, and Pasteur, applying to the phenomena of infectious disease the facts learnt concerning the behaviour of micro-organisms in culture fluids, propounded an "hypothesis of exhaustion" as an explanation of the reason why protection was afforded. According to this theory, the organisms causing disease, or the attenuated organisms employed for bringing about a condition of protection against the disease, use up certain constituents of the body necessary for their own growth and development. This hypothesis fails to explain many of the phenomena of immunity, but its promulgation at any rate shows how materially the point of view with regard to protection and immunity had been changed by growth of knowledge concerning the relation of micro-organisms to disease.

The exhaustion theory has been thrown a good deal into the background by the discovery that the multiplication of living organisms in the body is not necessary for the production of protection. The conditions can, as recent research has shown, be brought about also, in certain instances, by inoculation with materials altogether free from living organisms. Another hypothesis, the theory of "retention," was therefore propounded as an alternative to Pasteur's hypothesis. This hypothesis assumed that organisms growing in the body produce substances inimical to their further development, and so promote recovery from disease, and (as long as the inimical substances are retained in the body) a condition of protection against future attacks of the disease. The theory seems to be confirmed by the phenomena observed in connection with inoculation of toxines and with "chemical vaccination" (as it has been termed) generally. But there are difficulties in connection with this hypothesis also—it is hard to understand how toxines can be retained for long periods in the body, and, in point of fact, observation shows they are speedily eliminated. Again, the tissue juices of protected animals are, as a rule, capable of acting as media in which the organism, concerned in causing the disease, can be cultivated. The retention hypothesis, too, has thus of late years become discredited.

One result of recent knowledge has been to bring into prominence certain distinctions between the condition of immunity to disease which is "natural" or "innate" on the one hand, and that which is "acquired" or "artificially induced" on the other. Instances of natural immunity are the insusceptibility of the human species to cattle plague, fowl cholera, swine erysipelas, and other diseases which affect animals, the insusceptibility of animals to measles, whooping-cough, gonorrhœa, etc., and the relative insusceptibility of the dog, frog, rat, and the Algerian sheep to anthrax. As examples of acquired, artificially induced, or, as it is sometimes termed, specific immunity, may be mentioned the protection against subsequent attack manifested after recovery from particular diseases, and the condition of protection produced by certain kinds of specific treatment.

Natural Immunity.—The causes of natural immunity have been sought, of late years, in the ability of fixed and wandering cells to engulf and destroy bacteria and intruding matter foreign to the body (phagocyte theory), and again in the bactericidal properties of the body fluids. Metchnikoff, in 1884, first drew attention to the power exhibited by the leucocytes of daphnia (a water flea) of enveloping and destroying the spores of a fungus, which causes a diseased condition in this animal. He afterwards described the phenomena of phagocytosis as occurring in frogs infected with anthrax, and particularly laid emphasis upon the degenerative processes which affect the anthrax bacilli within the leucocytes of the frog. He was led to the conclusion that this phenomenon was especially manifested in the case of resistant animals, and that the likelihood of an animal being able to resist a particular form of disease could be predicted by noting the extent to which phagocytosis occurred. Much controversy arose with regard to the generalisations of Metchnikoff, and not a few phenomena difficult of explanation on his hypothesis were observed. An important point was, however, noted, in connection with these investigations, as to the behaviour of invading organisms in relation to cells. It was found that introduction of disease germs in particular situations was followed by migration of leucocytes and by inflammatory reaction. The migration was presumed to be due to the influence of attraction exerted by certain chemical substances, and was termed "positive chemiotaxis"; in other instances chemical substances were found to exert a repellant influence, "negative chemiotaxis." The phagocyte theory has fallen a good deal into disfavour since the discovery of the action of bacterial toxines, and it is probable that in many instances the phenomena of phagocytosis are to be regarded as an after effect and not as the cause of the production of immunity.

The rival theory to the phagocytic, or "cellular theory" of Metchnikoff, assumes that the body fluids are mainly operative in destroying invading bacteria. Freshly drawn blood, pericardial fluid, and cell-free serum have been found to possess marked bactericidal properties. This power is lost on heating to 55° C. Buchner showed that the destructive power of these fluids was due to contained protective substances, "alexins," as he termed them (from a Greek word signifying to protect). The fact that withdrawal of the mineral salts from serum deprives it of its protective properties, while, furthermore, the salts alone cannot be regarded as operative, inasmuch as in that case the destructive powers of the serum should not be abolished by heating to 55° C., suggested that the alexins were proteid-like substances in loose combination with salts. It has been shown that the protective bodies can be precipitated with the proteids from serum, and, after drying, again dissolved and shown to retain their activity.

Neither the phagocytic or "cellular" nor the alexin or "humoral" theory seems capable of explaining all the facts as to natural immunity. It has been suggested that there is a via media, and that the phagocytes produce the alexins. By injection of a sterilised emulsion of wheat gluten into the pleural cavity of rabbits and dogs an exudation containing leucocytes in abundance and possessing pronounced bactericidal properties is obtained. It has been argued that these powers cannot be attributed to the leucocytes, as they are still manifested after freezing and thawing, and that they must therefore be due to substances (alexins) which have been yielded to the exudation by the leucocytes.

The phenomena observed as regards behaviour of leucocytes, towards foreign material introduced into the body, have suggested that in order to increase the natural power of resistance to bacteria, "hyperleucocytosis" should be induced. Koch's original tuberculin has been supposed to act by bringing about accumulation of leucocytes in the diseased tissues, and thus favouring destruction of the tubercle bacilli present in them. The production of chronic venous congestion has hence been advocated in the treatment of tuberculous disease of joints and bones with the idea of promoting local increase of resistance.

Apart from power of dealing with invading micro-organisms there may be a natural resistance to certain poisons. The ichneumon and many snakes are unaffected by snake venom, and scorpions are said to be immune against their own poison. Poisons which are fatal when injected may be comparatively harmless when swallowed. Hence the success, in some instances, of the practice of sucking poisoned wounds. In the case of snake venom, it has been stated that the saliva itself possesses a definite anti-toxic action.

Specific or Acquired Immunity may result from an attack of specific disease or from the production of one of the two states which Ehrlich distinguishes as active and passive immunity. The former condition is brought about by protective inoculation, the specific immunising substances being generated in the body itself; the latter is induced by introduction of protective substances, the development of which has been accomplished in the serum of some other animal.

As instances of immunity produced by an actual attack of disease, the protection afforded by small-pox, scarlet fever, measles, and whooping-cough, and perhaps in less degree by typhoid fever and plague, among human diseases may be mentioned—cattle plague, pleuro-pneumonia, etc., among animal diseases, may also be cited. Some infectious diseases appear to afford little or no protection against subsequent invasion, or the protection is only very transitory, while in the case of pneumonia and erysipelas one attack of the disease seems to render the sufferer even more liable than before to future attacks. The possible influence of mild, unrecognised forms of disease has to be kept in mind, and the fact that certain diseases such as malaria, yellow fever, and typhoid fever, not infrequently attack new comers in a particular locality, and fail to affect to a like extent persons long resident in the place, may perhaps be thus explained. The production of immunity by the "active" method, *i.e.*, by inducing the formation of specific protective substances in the body itself, involves, as a rule, the setting up of some febrile reaction, and further a period of delay must inevitably intervene before the formation in the body of the protective substance is accomplished. On the other hand, the immunity, when successfully induced, is usually of a more or less lasting character, whereas in that produced by the "passive" method, although there may be absence of reaction, and the body is at once supplied with the protective substance, this last-named material may be rapidly excreted, and the immunity prove thus of a merely transitory nature.

The active method of producing immunity has been practised—

(*a*) *By inoculation with living virulent virus*, *e.g.*, in small-pox inoculation in man, and in pleuro-pneumonia inoculation in cattle.

(*b*) *By inoculation with living but attenuated virus.* This method was first employed by Pasteur in the case of fowl cholera, by use of cultures which had been attenuated by exposure to the air. The attenuation has since been effected in the case of anthrax and rauschbrand by application of heat. Anthrax inoculation by Pasteur's method has been somewhat extensively employed on the Continent, but the protection afforded has been found not to be of lasting character. In swine erysipelas attenuation has been produced by passage of the virus through comparatively insusceptible animals, and this method, it may be noted, has been shown by recent research to be that which is operative in vaccination against small-pox, human variola and cow-pox being really one and the same disease. In Pasteur's prophylactic treatment of rabies attenuation is effected by drying the spinal cords of rabbits, and the material thus obtained is used as vaccine. This form of treatment has been attended with marked success, but, as the process of producing immunity takes time, its commencement must not be too long delayed. Lastly, it has been suggested that attenuation may be brought about by the addition of antiseptics.

(*c*) *By inoculation of cultures, the organisms in which have been destroyed.* This method has been particularly tried in connection with cholera, enteric fever, and plague. As regards the first-named disease, R. Pfeiffer showed that guinea-pigs could be immunised by injection of cultures containing living or dead cholera organisms. He found that living organisms, on being introduced into the peritoneal cavity of such immunised animals, were rendered incapable of exhibiting motility; moreover, after a few minutes, the vibrios became swollen and were broken up, and finally dissolved. The like reaction ("Pfeiffer's phenomenon") was exhibited when the serum of a person convalescent from cholera was mixed with vibrios and injected into the peritoneal cavity of a normal guinea-pig. The reaction is a specific one, only true cholera vibrios being affected in this way, and the "bacteriolysis" induced has therefore been attributed to a "specific bactericidal" substance which, it is presumed, has been generated in the body of the immune guinea-pig, and is present in the serum of the immunised patient. It was later found that perfectly fresh immune serum was by itself capable of producing Pfeiffer's phenomenon, outside the body of the guinea-pig; such serum was liable to become inactive, but could be "activated" by addition of a small quantity of normal serum. Hence, it was argued, two factors were at work; there must be present a specific "immune body," and, in addition, an eminently unstable ferment-like "complement" or "addiment," which induces the bacteriolysis, and which is only present in minute quantities in the serum, but is capable of being elaborated by living cells.

The subject has been further investigated in connection with the "laking" of blood. Evidence has been forthcoming that active serum, capable of producing laking of particular kinds of blood, can be obtained by injection of the blood of one animal into another animal. Thus Bordet injected defibrinated rabbits' blood into guinea-pigs, and found that the serum of the latter then possessed hæmolytic properties, *i.e.*, it was capable of laking rabbit's blood corpuscles. This serum was rendered inactive by heating to 55° C., but could be "activated" by addition of normal guinea-pig's serum.

Gruber and Durham, starting from the observation that cholera vibrios on being brought in contact with cholera-immune serum in a test-tube lost their motility, and adhered and collected into clumps, studied further this "agglutination," which they attributed to the presence of specific protective substances. They found that care was needed in drawing conclusions with regard to this test; a cholera-immune serum was able to agglutinate certain allied organisms, but the reaction, in the case of the specific organism, was still marked, even when the serum was greatly diluted. Similar phenomena were observed when the enteric fever bacillus and some other organisms were made the subject of experiment. The agglutinines were found to be used up in the reaction, being absorbed by the bacteria; it has been further shown that they can be again redissolved from the organisms and made to exhibit anew their agglutinating property.

Typhoid immune serum sometimes agglutinates *Bacillus coli* and the bacillus of Gärtner, but only when the serum is in sufficient strength, the phenomenon being, on the other hand, produced, in the case of the true enteric fever bacillus, even when the serum is much diluted. Widal advanced matters a step further when he showed that enteric fever bacilli were agglutinated by serum obtained from cases of enteric fever even before the end of the first week. This discovery of the fact that the characteristic reaction occurred after the lapse of a few days only from the date of attack, afforded a most valuable means of detecting the existence of enteric fever, and in doubtful cases of illness this "Widal reaction" has been extensively employed for clearing up the diagnosis.

For the production of immunisation against enteric fever, Wright has employed cultures of Eberth's bacillus, after first sterilising them by application of heat. Injection of an appropriate dose of sterilised culture produces transient febrile disturbance, with headache and malaise, the site of inoculation becomes tender, and the nearest lymphatic glands are rendered painful on pressure. The blood a few days later may agglutinate the specific bacilli, but sufficient data are not yet forthcoming to enable a precise estimate to be made of the degree of protection afforded against enteric fever, as ordinarily conveyed by water, milk, food, etc.

In the case of plague certain animals have been rendered immune by the active process, and serum obtained in this way (Yersin's, Lustig's, etc., serum) has been employed for inoculation in the human subject. The results hitherto reported have not been particularly encouraging. Haffkine introduced in 1897 a modified method by treatment with killed plague cultures. Specially prepared broth cultures of plague bacilli, from two to six weeks old, were heated to 65° C. for an hour; a small amount of carbolic acid was then added, and the vaccine was decanted and bottled, with suitable precautions. It was intended that the first injection of "prophylactic" should be followed by a second injection after eight or ten days. Haffkine obtained favourable results in Bombay, and in a series of cases at the Byculla gaol his method of treatment was carefully tested. Among inoculated prisoners (some 152) only two cases of plague occurred, while among the uninoculated (some 172), living under the same circumstances, twelve were attacked and six died. Haffkine's prophylactic has during recent years been somewhat extensively used. In the report of the Indian Plague Commission (vol. v. 1901) an elaborate critical study of the results obtained is given. The Commissioners conclude that "inoculation sensibly diminishes the incidence of plague attacks on the inoculated population, but the protection which is afforded against attacks is not absolute." Again, they find that "inoculation diminishes the death-rate among the inoculated population." They recommend that inoculations, under safeguards and conditions to which they refer, should be encouraged wherever possible.

(*d*) *By inoculation with material derived from bacterial cells.*

Such material has been obtained by one of two methods. In the preparation of the original tuberculin of Koch and in that of mallein, cultures in glycerine broth were concentrated by evaporation, and the substances, mainly proteids, thus extracted were subsequently purified by precipitation with alcohol. Koch's tuberculin undoubtedly sets up remarkable local changes in parts of the body affected with tubercular mischief. The condition of hyperæmia and reaction induced was thought of as being likely to bring about cure of the disease; the failure of the remedy, to realise anticipations formed with regard to it, has been attributed to the fact that, in cases of tubercular mischief, it is not only the tubercle bacillus that has to be contended against, inasmuch as streptococci and other organisms are also present in the diseased tissues; this is the reason, it is said, why tuberculin has been found not to produce good results. Tuberculin, has, however, been largely employed with great success as a diagnostic agent in cattle. Healthy animals only react to large doses; if the dosage therefore be carefully regulated, it is possible to detect the presence of disease by the fact that there is greater susceptibility to inoculation in the affected animals. If the injection of half a cubic centimetre of tuberculin in a cow, kept under appropriate conditions, is followed by a greater rise of temperature than 1° C., the animal is almost certainly tuberculous. At first the test was found unreliable, but increase in knowledge, as to the conditions which should be observed in employing it, has led to the attainment of very precise results. Mallein, made from cultures of glanders bacilli, by a similar process to that adopted in the preparation of tuberculin from tubercle bacilli, has been employed as a diagnostic agent in cases of suspected glanders. Its use has not been attended with quite that degree of success which has been attained with tuberculin.

The second of the two methods above referred to is that employed by Koch for the manufacture of his tuberculin (T. R.) introduced in 1897. In this method the bacilli are dried, powdered, and extracted with distilled water; the residue ("rest," whence the name T. R. "tuberculin rest"), is again subjected to similar treatment to that already mentioned. Koch obtained with this new tuberculin favourable results with regard to immunisation and cure of animals, but the remedy has not been found satisfactory in the case of tuberculosis in man.

(*e*) *By injection of toxine.*

The fact that immunity can be brought about by injection of cultures, from which the organisms have been removed by filtration, was first demonstrated in 1886 by Salmon and Smith, in the case of a disease known as hog cholera, and similar results were later obtained in other forms of disease. The method, however, attained special prominence in connection with development of knowledge concerning the specific toxines of diphtheria and tetanus, and particularly after the remarkable discovery was made by Behring in 1890, that the serum of an animal immunised by repeated injection of toxine is possessed of definite antitoxic properties. This discovery opened up a new field of inquiry, leading, as it did, to the production of immunity by the passive method and to study of the whole question of serum therapeutics.

The specific toxine, which the researches of Roux, Brieger, and Fränkel have shown can be obtained by precipitation from cell-free cultures, and which is capable of producing, in susceptible animals, the special symptoms of diphtheria or tetanus, and of rendering them, after repeated doses, increasingly immune against its own operation, was found to give the reactions of albuminous substances. Doubt has been raised, however, as to the precise nature of the toxine. On the one hand, recent researches have led to the conclusion that, as it appears to diffuse through a colloid membrane, it is allied to albumose, while antitoxine, which does not diffuse, is said to be a globulin-like body. On the other hand, Brieger has expressed the view that diphtheria toxine is not an albuminous body at all. Question has been raised again as to whether the toxine alone is concerned in the production of immunity. Ehrlich has found that cultures devoid of toxic properties can nevertheless produce immunity, and he concludes, therefore, that modified toxines, which he calls toxones and toxoids, are also operative.

The passive method of producing immunity.—Antitoxic serum was first obtained, in the case of diphtheria, by Behring in 1890. Behring and Kitasato shortly afterwards showed that analogous phenomena were demonstrable as regards tetanus. Ehrlich and others obtained similar results by inoculation of vegetable toxines, ricin, abrin, and robin. Experiments made with a view to the employment of antitoxic serum in plague have already been referred to. The attempts to obtain such sera in cholera and enteric fever have not yielded very encouraging results, nor have the efforts to manufacture antitoxic sera in the case of pneumonia, and in streptococcus and staphylococcus infections, been decisively successful. Calmette and others have endeavoured to practise antitoxic treatment in snake-poisoning. Calmette found that to a certain extent antitoxic action could be produced; a serum protecting against one kind of venom was, however, also protective against other kinds, and thus the antitoxine is not specific in the same sense as in the cases of diphtheria and tetanus. No success has hitherto attended the attempt to apply antitoxic treatment in tuberculosis. In swine erysipelas a kind of combination of the active and passive methods has been found of value. In cattle plague the use of bile, and that of serum and infected blood, have been tried. The nature of the immunity produced in the former case is uncertain; in the latter a true antitoxic serum appears to have been obtained. In tetanus no good result is yielded unless the antitoxine is used quite early, and the practical value of this form of treatment has not therefore, in this disease, been found to be great.

In diphtheria, however, antitoxic treatment has produced unmistakably beneficial results. Extensive trial of the method in Germany, in this country, and elsewhere, has been attended not only with marked diminution of mortality from the disease—this fact might find explanation in variation of type of the malady, or possibly in other directions,—but it has been ascertained that, comparing instances in which the treatment has been commenced on the first, second, third, etc., days of illness, the statistical results tell greatly in favour of antitoxine. Cases in which the treatment has been adopted at an early stage show comparatively insignificant mortality rates, and the longer the interval which has elapsed, before antitoxine has been brought upon the scene, the less has been found to be the chance of recovery.

The serum used is an antitoxic, not an antimicrobic serum. It inhibits the action of toxine, and thus gives opportunity for the natural powers of resistance of the body to come into play and to bring about destruction of the invading microbes. It may be noted that in both diphtheria and tetanus the development of the bacilli is mainly local, and that it is the toxines produced which gain access to the general circulation, and cause the main symptoms of illness. The fact that toxic diseases, as distinguished from what are sometimes called septicæmic diseases (in which the organisms invade the blood), are in question, may explain why it is that, in the case of diphtheria and tetanus, antitoxic treatment has been particularly successful.

Diphtheria antitoxine is obtained, according to Behring's method, by inoculating horses with toxine of progressively increasing strength.

At first carbolised cultures, to which iodine terchloride has been added, are used; ultimately toxine, the virulence of which is unattenuated, is employed. Horses bear the treatment well, and serum is readily obtainable from them. The immunisation value of the serum obtained requires to be carefully estimated. According to one method, that of Behring, a normal toxine, ·01 c.c. of which will kill a guinea-pig of 250 to 300 grammes weight within five days, is prepared, and the serum is standardised against this. If ·1 c.c. of serum neutralises 1 c.c. of normal toxine, then each c.c. of serum is said to contain one immunisation unit. According to another, the French method, the weight of the guinea-pig used in the experiment is carefully taken into account, and the quantity of serum required to protect the animal against inoculation with ten times the lethal dose of toxine is determined. The proportion borne, by this amount, to the total body-weight of the guinea-pig, is used to express the value of the serum. Thus a serum with the immunising value 10,000 is of such strength that a weight of serum $\frac{1}{10,000}$th of the weight of a particular guinea-pig will protect that animal against ten times the lethal dose of toxine. Ehrlich introduced a third method, in which antitoxine, obtained by evaporating serum, is used as the standard. By this device the difficulty incidental to the tendency, of antitoxine and toxine in soluble form, to vary in strength was obviated; for it was found that the dry antitoxine afforded a reliable means of standardising any particular serum which might be in question. Adopting Ehrlich's method of indicating the strength of serum, 200 units represent an immunising dose, while from 600 to 1,500 or more units may be used for a curative dose, according to the severity of the case, and the stage of the disease at which the treatment is commenced.

Origin and Action of Antitoxine.—There has been much speculation as to the mode of production of antitoxine, and as to the cause of its antagonism to toxine. With regard to the latter, the action, it was said, could not be explained on the supposition that antitoxine is a mere chemical antidote to toxine, for the reason that discrepancies are apt to be observed in the quantitative results obtained, and a mixture of the two substances, which is neutral when tested on one kind of animal, may produce fatal disease in another species. It was therefore suggested by Roux that the antitoxine acted upon the living cells of the body, rendering them immune to toxine, and producing a physiological as opposed to a chemical neutralisation.

Ehrlich, however, from his experiments with ricin, concluded that as the reaction between toxine and antitoxine was accentuated and diminished, by the factors which bring about similar modifications in chemical reactions, (warmth accelerating, cold retarding, and the reaction being more rapid in concentrated than in dilute solutions), it was essentially of the same nature. He explained the observed fact that varying amounts of toxine bouillon are neutralised by one immunity unit of antitoxine, on the hypothesis that the toxine contains two constituents, or combined groups, the one very stable, the other unstable. The affinity of the toxine for antitoxine is dependent on the former or "haptophore" group (from a Greek word meaning to fasten on or to fix); the unstable group is styled "toxophore." On this hypothesis the toxic action on animals, and the combining capacity with antitoxine, are two different functions of toxine, and the former may be weakened while the latter remains constant. Thus, when Ehrlich investigated the neutralisation point of toxine and antitoxine, for one and the same sample of poison, he obtained the following results:—"Immediately on its preparation, fresh from the incubator, it was found that one immunity unit neutralised α c.c. of toxic bouillon, and this quantity represented β simple lethal doses. When the same toxic bouillon was examined, after a considerable interval, the remarkable fact was discovered that exactly α c.c. of the toxic bouillon were again neutralised by one immunity unity; but that these α c.c. now represented only $\beta—x$ simple lethal doses." If the toxophore group is altogether destroyed and the other group is retained, a modification of toxine, which Ehrlich calls "toxoid" or "toxone" results, and this toxoid or toxone is capable of neutralising antitoxine, although, *per se*, it possesses no toxic property.

The question now arose whether the haptophore group, which accounted for the capacity of the toxine molecule to enter into combination with other bodies, was itself in any way concerned in the causation of symptoms of illness. Having in view the fact "that chemical substances are only able to exercise an action on the tissue elements with which they are able to establish an intimate chemical relationship," Ehrlich realised the importance of discovering upon which of these elements the toxines operate, but inasmuch as knowledge of distribution in the body of common chemical substances, administered as drugs, is very imperfect, he thought it might have been assumed *à priori* to be "very unlikely that efforts directed to locating the toxines, which are potent in the slightest traces, and which are bodies we have no means of rendering perceptible to our senses, would be anything else than absolutely without result." . . . . .

The experiments of Dönitz, however, threw light on this matter. This observer estimated the amount of antitoxine which must be injected intravenously, immediately after inoculation with diphtheria or tetanus toxine, in order to neutralise the effect. Dönitz found that if an interval was allowed to elapse the neutralising dose was inoperative; "the minimal lethal dose of toxine had passed through the walls of the vessels, and had been taken up by the tissues." On increasing the amount of antitoxine, the toxine held in the tissues could be withdrawn from them; the longer the interval allowed to elapse, however, the greater the amount of antitoxine required, and, after a definite period had been exceeded, even the largest doses of antitoxine were impotent. The property of being able to withdraw toxine, once deposited in the central nervous system, was manifested by the specific antitoxine, and by it alone; hence the conclusion appeared irresistible, "that the union between the toxine and the tissues, which could only be overcome by means of a specifically related antagonising agent, must itself depend on a chemical combination." In other words, the central nervous system, or certain ganglion cells in it, must possess atom groups resembling those of antitoxine in having a maximum affinity for tetanus poison. Dönitz found that the tetanophile atom groups in the guinea-pig were confined to the central nervous system; but that in rabbits they were also present in other organs. In correspondence with this fact, Roux found the same dose of tetanus was lethal in guinea-pigs, whether it was given by intracerebral or subcutaneous injection; but in rabbits the lethal dose was twenty times greater subcutaneously than it was in intracerebral injection. In subcutaneous injection in the rabbit, therefore, the absorption of toxine by toxophile groups, present in organs other than the brain, was so considerable, that of twenty parts only one part found its way into union with the nervous system. Thus the "possession of a toxophile group by a cell is the necessary preliminary and cause of the poisonous action of the toxine." If the cells possess no such group the toxophore group cannot become fixed to the cell, which therefore suffers no injury—*i.e.*, the organism is naturally immune.

By considerations of the kind which have now been detailed, Ehrlich, in 1897, was led to announce what is known as the "Seitenkette," or "Side-chain" theory, in explanation of the phenomena of antitoxine formation. He concluded that antitoxine was the substance, entering into the composition of certain kinds of protoplasm, which caused the cells containing it to be susceptible to the action of toxine. This substance, he argued, does not enter into the composition of the functioning centre of the cell, but is an attached "side-chain" of atoms—the term being adopted from the nomenclature of organic chemistry. The side-chains he held to be normally nutritive in function, attaching to themselves foodstuffs important in the cell economy; but they might incidentally be "toxophile." The idea that they are specially designed to seize upon toxines could not, of course, be entertained; it would be superfluous, as Ehrlich remarks, to suppose that "all our native animals possess in their tissues atomic groups deliberately adapted to unite with abrin, ricin, and crotin, substances coming from the far distant tropics"; but by chance, as it were, these toxophile groups may possess the capacity of anchoring themselves to this or that toxine. Ehrlich notes a distinction between toxines related to proteids—which it is not surprising, therefore, should possess a haptophore group corresponding to that of a food-stuff, and in the case of which antitoxine formation has been in some instances, as a matter of fact, demonstrated—and alkaloids and other poisons in connection with which similar phenomena have not been observed. The fixation, whether it be of normal food-stuff or of toxine, is, however, of a specific character; Ehrlich suggests the analogy of the male and female screw, or of lock and key, as throwing light on the manner of adaptation to one another, of the groups of atoms in the side-chains and in the haptophorous constituents of toxine.

Thus, the side-chain theory assumes that the molecule of toxine is possessed of two groups of atoms; by means of the one, the haptophorous group, the toxine becomes "anchored" to the side-chains of the protoplasm of susceptible cells, and then the latter, the toxophorous group of atoms, is able to set up in the protoplasm characteristic disturbances. The side-chains being destroyed, are reproduced by the protoplasm, and they may be, and commonly are, reproduced in excess ("over-compensation"), and are then transferred to and accumulate in the general circulation. If this be the case a condition of immunity results, for the side-chains "anchor" any haptophorous groups of the toxine which may be introduced into the blood, and the groups so anchored are deprived of any opportunity of obtaining access to susceptible cell-protoplasm (Croonian Lecture "On Immunity with Special Reference to Cell Life," *Proc. of Royal Society*, vol. lxvi. No. 432). Wassermann has shown that tetanus poison can be anchored to the brain substance of guinea-pigs, by demonstrating that on mixing the toxine with broken-down, fresh, guinea-pig's brain-substance, the surrounding fluid is toxine-free, while the brain charged with toxine has also lost all poisonous property.

The "Seitenkette" theory serves to explain many of the phenomena of antitoxine production. It has been urged that it does not so satisfactorily explain the action of sera which possess antimicrobic as opposed to antitoxic properties. Here, as Ehrlich says, the phenomena are much more complex, for in addition to antitoxine many reaction products, the numerous "antibodies" produced by the life and growth in the body of bacteria, are generated. He refers, for example, to the "bacteriolysines," which break up bacteria, to "coagulines," which cause precipitation of albuminous bodies in the culture fluid, to the "agglutinines," and to the bodies which have been termed "antiferments." The organism, as has been already noted, is capable of forming anti-substances, not only after injection with toxine, and with bacterial cultures, but also, as in hæmolysis, when foreign red corpuscles are inoculated. Again, similar phenomena have been observed after inoculation with other kinds of cells foreign to the body, ciliated epithelium, spermatozoa, etc. The production of these "cytotoxines," as the result of the introduction of foreign cells, has been studied by Metchnikoff and others, who have shown that, on treatment of animals with such cells, their serum acquires the ability to destroy the particular cells employed.

It has been thought that these phenomena are best explained on the supposition that the anti-substances are really modified forms of the foreign poisons, deprived of all poisonous property. Ehrlich, however, has contended that his side-chain theory affords explanation of the production of anti-substances (*Antikörper*) in the blood; such bodies may, he points out, exist in normal blood, just as diphtheria antitoxine may exceptionally be present in the blood of normal horses or in that of man. These anti-substances represent, he argues, nutritive side-chains which have been developed in excess and pushed off into the circulation.

In explanation of Pfeiffer's phenomenon, as already noted, it had been suggested that in addition to the specific stable "immune body" there must also be operative a highly unstable "complement." Similarly in hæmolysis the existence of two such factors is assumed by Ehrlich, but he now distinguishes between two kinds of affinity manifested by the "immune body." By centrifugalising blood at 0° C. the immune body was found to be attached to the corpuscles, while the complement remained in the serum, and, on admixture of the two components, in the presence of blood corpuscles, hæmolysis was shown to occur at higher temperatures, but not at 0° C. Hence Ehrlich concludes that the specific immune body is possessed of two haptophore groups—one having affinity for a corresponding group in the red blood corpuscles, the union taking place at low temperatures; the other uniting with the complement, this union only occurring at higher temperatures.

If a proteid molecule be fixed by a cell, "there is provided one of the conditions essential for cell nourishment"; if it is to be utilised, however, ferment-like material must be taken up, which will split the complex molecule into smaller fragments. Arguing from the analogy presented by the tentacles of the sun-dew, Drosera, which secrete a proteid-digesting fluid, it may be presumed that there are "side-chains of a special nature so constituted that they are endowed not only with an atomic group, by virtue of the affinities of which they are enabled to pick up material, but also with a second atomic group, which, being ferment-loving in its nature, brings about the digestion of the material taken up." Side-chains thus constituted, if pushed off in the process of immunisation, would correspond with those which have been assumed to exist in the immune body of the hæmolysine.

"In this manner," says Ehrlich, "is simply and naturally explained the astonishingly specialised arrangement that, through the introduction of a definite bacterium into the body, something is produced which is endowed with the power of destroying, by solution, the bacterium which was administered, and no other. This contrivance of the organism is to be regarded as nothing more than a repetition of a process of normal cell-life, and the outcome of primitive wisdom on the part of the protoplasm."

In bacteriolysis the immune bodies may, it has been suggested, be identified with the substances which produce agglutination; it is at any rate clear that "agglutinines," like the immune bodies, resist a temperature of 58° C., and that they, again like the immune bodies, have a special affinity for the sheaths of bacteria.

An important observation has been made by Ehrlich, to the effect that immunity, as regards ricin and abrin poisoning, is transferred in the process of suckling; and a similar result has been obtained in the case of tetanus. Antitoxine has, moreover, been actually shown to be present in milk. Ehrlich suggested that herein explanation may be forthcoming of the fact that infants enjoy a special immunity from measles, scarlatina, etc., diseases which particularly attack children after the first year or two of life.

CHAPTER IX.

INFECTIOUS DISEASES.

Actinomycosis.—The history of this disease may be said to date from 1876, when its occurrence in cattle was first drawn attention to by Bollinger. In 1877, Israel described the disease in man; in 1878 the parasite concerned was named by Harz the actinomyces or "ray fungus." The malady is by no means a new one, as is made clear from accounts of earlier date of "wooden tongue." Cattle are said to be often affected in Austria, Germany, Italy, Russia, and North America; in some abattoirs on the Continent the disease was present in one form or another in as large a proportion as 2 per cent. of the cattle slaughtered. In England in certain herds an appreciable percentage of the animals proved on examination to be affected. Swine and horses are occasionally attacked. In man the disease is far less common. Some 450 cases in the human subject were placed on record between 1879 and 1892, most of them during the later years of that period.

The malady is inoculable, but does not, as a rule, spread from one animal to another. The mammary gland is occasionally involved, and it has been thought that milk might serve as the medium of infection, but there is no evidence that this is the case. It has been suggested that contaminated grasses constitute a possible source of mischief, and it has been stated that if grain be inoculated, the plant which develops is infected with actinomyces, and the sharp awms of barley, etc., if contaminated, on being eaten by an animal, would be specially likely to convey infection, by scratching or penetrating the mucous membrane of the alimentary tract. This theory is supported by the fact that material recognisable as being of vegetable origin has been found within actinomycotic growths. Again, the majority of the recorded cases have occurred in farmers, labourers, grooms, millers, and others, who by the nature of their work have been brought in contact with grain.

Actinomycosis runs a chronic course, and its nature is apt to be overlooked; the case may be regarded as one of tubercular disease of the jaw (other bones may be the seat of mischief, but the lower jaw is involved in the majority of instances), or of chronic abcess or "tumour" (in the liver or other viscera), or of peritonitis, empyema, or phthisis. In cattle the tongue is specially affected. On careful examination of material from an actinomycotic growth, minute yellow granules can, as a rule, be detected, and if one of these be squeezed out, stained, and examined under the microscope, the arrangement of the fungus as a mycelial network, from which radiate filaments possessing characteristic club-shaped peripheral extremities, can be demonstrated. The grains can be transplanted and cultures made. (Glycerine-agar is specially adapted for the purpose.) In artificial media the "clubs" are not, as a rule, found. The botanical position of actinomyces has been much discussed. The fungus is generally regarded as belonging to the streptothrix group, and it presents a close similarity to, if it be not identical with, the fungus of Madura foot.

Anthrax.—Outbreaks of this disease affect cattle, sheep, swine, horses, camels, and goats, and occasionally occur in man. The malady was found to prevail in this country in 1891 among deer. Little was accurately known concerning anthrax until the end of the eighteenth century, when it was found that it occasionally occurred in men who had been engaged in the manipulation of hair, wool, etc. In 1849 the anthrax organism was first observed by Pollender, and Davaine, some years later, showed that the bacillus was the actual cause of the disease. In 1876 and subsequent years, Koch greatly extended knowledge concerning the life-history of the organism. In 1863 deaths begin to appear in the Registrar-General's returns under the heading "malignant pustule." Since 1881 all anthrax deaths in those returns are classed as instances of "splenic fever," and their number has varied from three or four up to some eighteen or twenty annually.

In cattle the disease is generally referred to as "splenic fever," marked enlargement of the spleen being a conspicuous feature of the malady. On the Continent outbreaks in cattle have been frequently observed — in France, Germany, Russia, and Italy,—and accounts of anthrax prevalence among lower animals have been forthcoming from Persia, India, Siberia, China, and parts of Africa and North and South America. Animals appear to acquire the disease, as a rule, by infection from the alimentary tract, possibly also by inhalation. The infective property seems to be imparted to fields and pastures by contamination with the blood, secretions, and excretions of infected animals, and it is said that the danger, incidental to grazing upon such pastures, is particularly great when the surface soil has become thoroughly warmed, and when certain conditions as regards moisture obtain. Pasteur thought it likely that spores were brought to the surface by earth-worms, but it has been shown that spores are not formed when the carcases of infected animals are buried without being opened. The Board of Agriculture has compiled, since 1887, returns showing the number of anthrax outbreaks affecting cattle, sheep, swine, and (since 1893) horses in the counties of Great Britain. In 1887, 236 outbreaks (636 animals attacked) occurred, and the numbers have fairly steadily augmented until, in 1898, 556 outbreaks (856 animals attacked) were reported. The increase is doubtless due, in the main, rather to greater accuracy of diagnosis than to more extended prevalence of the malady.

Reference has already been made (*See* p. 70) to outbreaks occurring among workers engaged in the manipulation of animal products; the extent to which hides, skins, hair, and wool, which have become smeared with blood or discharges, are capable of retaining the property of being able to transmit infection, is not a little remarkable. On tabulating the recorded cases of anthrax, occurring in London and its neighbourhood between 1873 and 1896, it transpired that 148 cases of the disease had been recognised during those years; of these 108 occurred among persons engaged in the hide and skin trade, 5 among persons engaged in slaughtering animals, 18 in connection with the manipulation of horsehair or the manufacture of brushes, 1 case occurred in an individual employed in a bacteriological laboratory, and 16 cases under circumstances in which the source of infection was not traceable.

In 1895, cases of anthrax contracted in any factory or workshop were made compulsorily notifiable to H.M. Chief Inspector of Factories. In 1896, 17 cases; in 1897, 23 cases; in 1898, 28 cases; in 1899, 55 cases; in 1900, 37 cases; and in 1901, 39 cases were so notified. The increase in the later years probably represents greater accuracy in notification rather than growing prevalence of disease. It is noteworthy that in several of the cases reported in London of late years persons who have manipulated goat-skins have suffered, and there is a remarkable tendency for such attacks (and the same thing has been observed in cases associated with horsehair, and with hides) to occur in groups, and in connection with the manipulation of particular consignments of goods. Careful study of the origin of infecting material is obviously, therefore, necessary, and special precautions should be taken in all instances in which material from a source which is under suspicion has to be manipulated. If the products dealt with present any unusual appearance, suggestive of the fact that "dead hides" or specially contaminated horsehair, etc., possibly containing anthrax spores, are in question, the need for such precautions is particularly obvious.

Experiments have been carried out of late years in Germany, with a view to determining whether it is practicable to apply steam disinfection in connection with horsehair, and a translation of a report by Dr. Kübler, of the German Health Office, upon this subject appears in the Annual Report for 1900 of H.M. Chief Inspector of Factories. It is noteworthy that certain horsehair manufacturers in London, in 1899, resolved "to buy no Russian, Siberian, or Chinese undyed mane hair until satisfactory guarantees had been given by the sellers that the hair had been thoroughly disinfected." A circular letter was addressed to occupiers of horsehair works in 1900, indicating means whereby risk of anthrax to operatives might be diminished (*See* p. 113 of the Annual Report already referred to). With regard to hides and skins, Mr. Spear first pointed out that it might be possible, in the process of "curing," to cause any attached spores to germinate into the easily-destructible rods. In this connection the rarity of instances in which suspicion has fallen upon "wet hides," as opposed to "dry hides," is noteworthy.

Special Rules were issued in 1899 by the Home Office authorities for Hide and Skin Factories and Workshops, and Special Rules for Wool-combing Factories were finally agreed upon in 1900. (*See* pp. 56—58 of the Annual Report, 1899, of H.M. Chief Inspector of Factories.) These Rules prohibit the opening of certain kinds of hair unless steeping in water is practised, and an efficient opening board is used. Van mohair must be steeped in water before being opened, and special treatment is prescribed in the case of badly damaged material. The provision of means for extracting dust, and preventing it from being inhaled by workers, and the exercise of cleanliness, and of precaution with respect to partaking of food, and as regards any scratch or abrasion on exposed parts of the body, are points especially dealt with in the Rules.

The Anthrax Order of 1899, issued by the Board of Agriculture, directs that the carcases of diseased or suspected animals shall be buried, unopened, in lime, at a depth of not less than six feet below the surface, or else destroyed by exposure to a high temperature or to chemical agents, in a place approved for the purpose by the Board. Precautions to be adopted in relation to infected dung, litter, etc., and with regard to preventing contamination by excretions, blood, etc., are also specified in this Order. Preventive inoculation has been extensively practised in France and Germany, but the protection afforded by the methods hitherto employed has not proved of a lasting character.

Beri-beri (the "Kakke" of Japan).—This disease has long been prevalent in China and South-East Asia. Its existence in numerous localities in the tropics has been recognised of late years, and it is occasionally met with even in temperate regions. In Japan the malady is now common, and it has either newly appeared, or has for the first time been reported of late years, in Australia, Fiji, the Sandwich Islands, and elsewhere, including even certain institutions in Ireland and the United States. In Brazil and in the Malayan archipelago it is especially frequently met with. In the tropics, the disease may occur at all times of the year; in temperate regions, only, as a rule, during the summer. An attack may supervene within four or five weeks of arrival in a place in which beri-beri is endemic. The symptoms are, in the main, those of multiple neuritis, with accompanying œdema of more or less marked character; in some instances (the "wet" form) there is general dropsy, together with more or less pronounced evidence of dilatation of the heart. Three types of the disease—the "dry," the "wet," and the "mixed"—have been described; the "wet" form is said to be the most dangerous. The mortality has varied greatly in different outbreaks, from 5 to 50 per cent.

The cause of the disease was at one time thought to be deficiency of particular articles of diet, "nitrogen starvation"; again, beri-beri has been regarded as a cachectic condition, due to malaria or to some kind of parasite; of late years, both bacteria and protozoa have been presumed to be the agents which produce the disease; it has further been suggested that the symptoms are caused by a toxine, elaborated outside the body by a saprophytic organism, which is able to flourish under the conditions obtaining in the areas in which the disease is endemic. This last-named hypothesis would explain the rapid recovery noted when affected persons are removed from an infected vessel, institution, or locality. It has been suggested that some of the cases of multiple neuritis, which are attributed in temperate climates to alcohol or arsenic, may really be examples of the disease; on the other hand, there appears in the tropics to be a tendency to assume that all forms of neuritis are due to beri-beri. The malady does not appear to spread directly from patient to patient. Low-lying areas are specially apt to be affected. Institutions (asylums, jails, etc.) and ships sometimes become infective centres, and may retain the power of conveying infection for long periods; in such instances it may be found necessary to accommodate the inmates, or crew, elsewhere, while the infected building or ship is thoroughly disinfected.

Chicken-pox.—This malady has only been distinguished from small-pox for about 150 years. Attacks generally occur in children, and the disease is rarely fatal. A few deaths are recorded each year; but it is probable that some of these, at any rate, represent errors of diagnosis, and that small-pox has really been in question. The incubation period lasts about fourteen days; the eruption usually appears at the outset, or is at most preceded by only a few hours of indisposition. The vesicles are not, as a rule, umbilicated; they differ from those of small-pox in that they contain only a single cavity, and hence it is said a prick with a needle evacuates all the contained fluid; there is also less hardness at the base of the vesicles in varicella than is observable in the case of variola. The vesicles mature more quickly than small-pox vesicles, as within a week a crust, as a rule, forms; and, most noteworthy point of all, they usually occur in crops, and it is generally possible, on examination of the chicken-pox eruption, to make out the fact that while some of the spots are in an early stage of development, others have already matured. The eruption may occur on any part of the body, and has not the characteristic distribution of the small-pox rash. It has not been found possible to transmit chicken-pox by inoculation.

Cancer.—Of late years this disease has received a good deal of attention. Knowledge of its prevalence in past times, and of its geographical distribution at the present day, is far from precise; the interpretation of such statistical records as are available has been rendered especially difficult by looseness of terminology, and by the fact that malignant disease not infrequently affects internal organs, and hence, in the absence of post-mortem examination, has, no doubt, been in numerous instances altogether overlooked. Having regard to these considerations, it is not surprising that the recorded cancer mortality has notably increased in recent times; indeed, comparison of registered mortality thirty or forty years ago (1861–70), with the registered mortality nowadays, shows that the deaths per million living in this country have practically doubled. The increase is much more marked in males than in females. While less than half as many deaths, per million living, were recorded in males as compared with females in 1861–70, the rate in males now is about two-thirds of that in females.

This fact accords with the hypothesis that the increase in cancer mortality is more apparent than real. The supposition is borne out by the observations of Newsholme and King with regard to the data collected in the Scottish Widows Office and to certain Frankfort statistics. The former set of figures shows increased mortality from cancer; but on comparison with the curves for the English, Scotch and Irish populations generally, the Scottish Widows Office curve has "the easiest gradient." "The policy-holders in the Scottish Widows Office are presumably well-to-do, and able to secure, on the whole, better medical attendance than the mass of the people, and their death returns consequently show to a less extent the effect of increased accuracy of diagnosis and certification." Again, in Frankfort the records enable the cancer deaths to be classified as "accessible, inaccessible, and cancer of undefined position," and it transpires that "between 1860 and 1889 there has been no increase in the mortality from cancer affecting positions in which it is easily accessible and detected." It has been suggested that, inasmuch as more people nowadays survive and reach those age-periods at which cancer mortality is especially marked, it is to be anticipated that the deaths from cancer would show increase. This is doubtless true; but study of cancer death-rates, per million living at different age-periods, shows that the factor referred to does not account for the whole of the increase observed.

Cancer mortality is comparatively small until the age-period 35—45 is reached; it then steadily increases with advancing years. The increase observed of late years, as compared with the decade 1861–70, is specially marked, in males, at all age-periods after and including the period 35—45; in females, the increase is less marked up to 55, but is very marked at the later age-periods.

The distribution of cancer in English counties is dealt with by the Registrar-General in the Supplement to his Fifty-fifth Annual Report (p. liii. *et seq.*). In determining the rates observed, the question of age and sex distribution exerts considerable influence. The Registrar-General has, therefore, calculated (*loc. cit.*) the cancer mortality for each county in terms of a "standard million" of population over 35 years of age; as an instance of the alteration thus brought about, it may be noted that whereas the difference between the crude rates for London and Cornwall is some 2 per cent., the difference in their corrected rates is 38 per cent. Taking the rates as corrected by the Registrar-General, those of London and Huntingdonshire are the highest, those of Wiltshire and Cornwall are the lowest; the highest rate, that of London, is 2,250, the lowest, that of Cornwall, 1,630 per standard million above 35 years of age.

The view that cancer is an hereditary disease was at one time generally accepted. The Registrar-General, in his Fifty-second Annual Report, p. xiv., pointed out, however, how considerable was the probability of multiple occurrences of cancer among the near relatives of a given individual, having regard to the fact that it appeared, from the figures of 1887–89, that one out of twenty-one men, and one out of twelve women, who reach the age of 35, die eventually of cancerous disease. The Registrar-General's conclusions on this matter have been generally accepted; but, curiously enough, a new doctrine, which from a statistical standpoint appears to be equally groundless, has latterly obtained some credence.

Behla first drew attention to the frequency of occurrence of multiple cases of cancer in one and the same house. If the scope of the inquiry be sufficiently extended, "cancer houses," as Behla terms them, are not, as a rule, hard to find. Symons, however, showed that the statistics of Bath proved these multiple invasions of houses by cancer to be actually less frequent than might have been anticipated as a matter of pure chance. Niven, in the annual report for Manchester, 1897, discusses the mathematical treatment of this question of multiple invasions of houses. He shows that if $x = \frac{\text{Average number of houses affected}}{\text{Average number of occupied houses}}$, and m be the number of years over which the inquiry extends; then the chance of any house being invaded twice $= \frac{x^2 m\ (m-1)}{1 \cdot 2}$, and the chance of triple invasion $= \frac{x^3 m\ (m-1)\ (m-2)}{1 \cdot 2 \cdot 3}$. Hence the number of double invasions must be $\frac{x^2 m\ (m-1)}{1 \cdot 2} \times$ the total number of occupied houses; and the number of triple invasions must be $\frac{x^3 m\ (m-1)\ (m-2)}{1 \cdot 2 \cdot 3} \times$ the total number of occupied houses.

Applying these formulæ to Behla's figures, the number of multiple invasions proves (as Symons had already found to be the case at Bath) to be rather smaller than might have been predicted, assuming the question to be merely one of casual coincidence. Remarkable cancer sequences have been recorded—cases in which successive occupants of particular rooms, persons who visited from time to time particular localities, and so on, have succumbed to cancer. The instances cited serve, as a rule, merely to show how little attention is commonly given to the question of the probability, *à priori*, of a particular sequence of events occurring. With further study of cancer sequences and cancer localities, it is possible that knowledge concerning such matters may be advanced; due regard must, however, be paid to the fact that, inasmuch as the disease is an exceedingly common one, the chance of occurrence of these so-called "notable sequences" is considerable.

Cancer has been extensively studied from the point of view of its inoculability in lower animals, and with the object of isolating a specific organism. Latterly it has been claimed that some forms of blastomycetes, or again that protozoa, are concerned in the production of cancer. (*See* pp. 317 and 320.)

Cerebro-spinal Fever. Epidemic Cerebro-spinal Meningitis.—This disease was first described by Vieusseaux, of Geneva, in 1804-5, and during the early part of the nineteenth century it attracted attention in the United States. It was not until 1837 that it assumed special prominence; in that year, and the years immediately succeeding, the malady was observed, particularly among troops, in various parts of France, and between 1846 and 1850 epidemic waves of the disease were again noted in that country. In Italy, Algiers, and in the United States outbreaks occurred between 1837 and 1850. Between 1854 and 1874 the disease was observed in parts of Europe, and in the United States and Canada; moreover, less marked prevalences of the malady occurred in various localities between 1876 and 1884. Again, in the concluding years of the nineteenth century, small outbreaks were noted in France, Germany, and the United States.

In the United Kingdom epidemics of the disease have never attained considerable proportions. They have been noted as occurring from time to time in Ireland—in 1846; again, in Dublin, in 1866-67, when a number of persons, mainly soldiers, were attacked; and yet again in 1885–86 and in 1890. Detailed account of presumed occurrences of the disease in England is given by Bruce Low in a paper in the *Epidemiological Society's Transactions* for 1898–99. In 1890 cases suspected to have been cerebro-spinal fever were observed in some of the Eastern counties of England, and especially at Oakley, in Suffolk. The Oakley cases were attended by comparatively small mortality, and in several instances multiple cases occurred in the same household, a phenomenon not observed, as a rule, in cerebro-spinal fever, though Osler has seen "house epidemics" in America. Bruce Low reported on this Oakley outbreak, and again, later, on a series of "anomalous illnesses" in Northamptonshire, and he inclined to the view that these were instances of cerebro-spinal fever, though it was difficult to exclude the possibility of their being cases of influenza (*See* Annual Reports of the Medical Officer of the Local Government Board for 1890, 1891, and 1894).

The fatality is, as a rule, high, 60 per cent. or more. In outbreaks of the disease the numbers attacked are not sufficiently large to produce any appreciable effect upon the mortality rate. Children and young adults are most commonly attacked, about half the cases occurring in persons under ten years of age. Cold weather appears to favour the prevalence of the malady, which, moreover, does not seem to occur at all in the tropics, though there was an outbreak in Fiji in 1885 during an "unusually cool" season. Institutions, barracks, workhouses, and prisons have, in some instances, been exclusively attacked; again, overcrowding, dirt, and want of ventilation have been held to favour the occurrence of the disease. It has been suggested that what is known as posterior basic meningitis in children is actually epidemic cerebro-spinal fever occurring sporadically. In 1887, Weichselbaum described an organism, the "diplococcus intracellularis," or "meningococcus," which he held to be the cause of cerebro-spinal fever; it can be cultivated on Löffler's blood serum, and has feeble pathogenic properties when inoculated in animals. The same organism has been isolated by Still from material derived from cases of posterior basic meningitis occurring sporadically in London.

The disease has been defined as "a malignant fever attended by painful contraction of the muscles of the neck and retraction of the head. In some epidemics it is frequently accompanied by a profuse purpuric eruption, and occasionally by secondary effusions into certain joints. Lesions of the brain and spinal cord are found on dissection." Bruce Low refers to the great difficulty of diagnosis. The above description covers, as he says, only the severer forms of the disease: milder cases are apt to be mistaken for influenza, and if the illness last some time it may be diagnosed as typhoid fever or tubercular meningitis, while if it be speedily fatal it is apt to be regarded as typhus fever, idiopathic tetanus, or malignant measles. Bruce Low suggests that some of the epidemics of jail fever, spotted fever, petechial fever, or hospital fever, of earlier days, may have been forms of the disease now in question.

Osler attaches special importance to the two following aids to diagnosis of the existence of meningitis, brought into notice in recent years. The one, "Kernig's sign," is elicited when the thigh is flexed preliminarily on the trunk, either by causing the patient to assume the sitting posture, or by placing the thigh at a right angle with the trunk as the patient lies in bed; on the attempt being then made to extend the leg, this is resisted by strong contraction of the flexors of the leg upon the thigh. The other method, that of "lumbar puncture," was first advocated by Quincke; an exploring syringe is introduced within the theca, below the termination of the cord, and a bacteriological examination can be made of the fluid drawn off. In acute cases of cerebro-spinal meningitis, Osler has obtained a turbid fluid in which the characteristic organisms are present in large numbers. Bruce Low states that the organism known as the pneumococcus lanceolatus of Fränkel, which occurs in croupous pneumonia, has been erroneously associated with cerebro-spinal fever; the pneumococcus, he says, if present, is to be regarded in the light of a secondary infection, but "in true epidemic cerebro-spinal meningitis the organism that is invariably present is the diplococcus intracellularis of Weichselbaum." Washbourn refers to an outbreak of pneumococcal meningitis among Kaffirs, in 1893, in which, he says, "the virus obviously gained access to the body by the nasal cavity."

Cholera.—This disease has doubtless long prevailed in India, but of its extension to Europe practically nothing is known before the early part of the last century, and it is doubtful whether earlier references to cholera, by Sydenham and others, relate to the Asiatic form of the disease.

The first great pandemic of which there is any record seems to have commenced about 1817 in Bengal, and by 1823 it had extended by way of the Caspian Sea to Astrakhan, but it did not reach Western Europe. The second pandemic commenced in 1826 in Bengal, it extended to Russia, passed across Europe and reached America; England was attacked in 1831, the disease being imported by ships arriving in the Medway from Riga, and later being introduced at Sunderland by vessels from Hamburg; it appeared in Canada in 1832, and spread through the United States. The third pandemic commenced in 1846, reached the Caspian in the following year, and prevailed extensively in Russia in 1848. London was attacked in the autumn of that year, being apparently infected from Hamburg. Edinburgh seems to have been shortly afterwards infected from Cronstadt, and other ports became implicated as a result of the arrival of ships from Hamburg. In the spring of 1849 the disease was extensively prevalent in England and in America. In 1850 it was widely diffused in America, to a less extent in Europe, and in the latter there was further diminution in its prevalence during the next two years. In 1853 cholera was widely distributed over Europe; in 1854 Great Britain was again infected from German ports. Small outbreaks, moreover, occurred in this country in 1855, 1857, and 1859, and Europe was not altogether free from cholera until 1860. The fourth pandemic commenced in 1863, and now for the first time Europe was invaded *viâ* the Red Sea, the disease being brought to Suez by Mecca pilgrims, and spreading from Egypt to Mediterranean ports, and thence northwards. Cases occurred at Southampton, in August, 1865, and persons who were attacked at Theydon Bois were apparently infected from this source. In 1866 the disease was imported at several English seaports, and America seems to have been infected by emigrants from Liverpool. The disease lingered in Europe until 1874, though the cholera of the years following 1870 may have been due to renewed importation from the East.

It will be noted, as regards the share borne by this country in these four pandemics, that England escaped the first altogether; it was involved in 1831 during the second; it was attacked twice, in 1848–49 and in 1854, in the third; and again in 1865-66 in the fourth pandemic. Since the date last-named cholera has not prevailed on a large scale in this country.

During the years 1884–87, Europe, however, suffered somewhat severely. In 1884, Toulon, Marseilles, and Paris were attacked, and 5,000 deaths occurred in France during the year. In 1885 Spain experienced an even more serious visitation; and later, Italy and Austria-Hungary were invaded. England remained, however, free from attack. In 1890 cholera again threatened an advance upon Europe; there was great mortality among Mecca pilgrims in 1891, and in 1892 the disease travelled into Russia *viâ* the Caspian. In August the Hamburg outbreak commenced, the town being presumably infected by Russian emigrants. During the same year Paris and other parts of France were implicated. The mortality in 1892 in Russia exceeded 130,000 deaths. In Hamburg upwards of 8,000 deaths occurred, and in Paris over 1,400. Cholera was imported into England from Hamburg and other European ports, but it did not spread. In 1893 the disease was still prevalent in various parts of Europe, particularly in Russia; a second outbreak occurred in Hamburg, and Altona was involved. Grimsby and Cleethorpes were now invaded, and a few scattered cases, for the most part traceable to Grimsby and Cleethorpes, occurred in various parts of this country; but the disease showed no ability to assume epidemic form, and in the succeeding years it gradually disappeared altogether from Europe, lingering longest in Russia.

The fatality of cholera is very high, usually from 30 to 50 per cent. In Europe the malady has generally attained its maximum prevalence from June to August, but it has caused considerable mortality in Russia even in the depth of winter. The negro race is said to be specially liable both to attack, and to a fatal issue if the disease occurs. As regards age, children and old people contribute largely to the total number of deaths. The period of incubation varies from a few hours to three or four days. The degree of protection afforded by attack appears to be but slight.

The organism discovered by Koch in Egypt, in 1883, is always present in cholera evacuations, and its existence is thus practically looked upon as the final diagnostic test of the presence of the disease. The attempts made to infect lower animals have not been decisively successful. Again, the spirillum has been found to be present at times of cholera prevalence in persons who exhibit no symptoms of cholera, and cholera cultures have been swallowed without ill effect. Question has been raised as to whether the spirilla found in cholera invariably belong to one and the same species; they are certainly apt to present considerable differences in cultural characters. The Finkler-Prior bacillus, which occurs in certain forms of diarrhœa not due to cholera, presents a rough resemblance to Koch's spirillum, but is readily distinguishable from it. Deneke has obtained an organism, morphologically closely resembling Koch's organism, from old cheese; Lewis has isolated a somewhat similar spirillum from saliva; and the *Vibrio Metchnikovi*, isolated by Gamaleia from material obtained in a disease occurring in fowls in Russia, very nearly approximates in its characteristics to the *Spirillum Choleræ Asiaticæ*.

The "cholera red" reaction yielded by cholera cultures in Dunham's peptone salt solution, on addition of pure hydrochloric or sulphuric acid, is a valuable aid to diagnosis. The colour is similar to that produced on addition of nitrous acid to solutions containing indol, and the reaction is hence often referred to as the "indol reaction," it being assumed that the true cholera organism is able to produce indol from the peptone, and also nitrites, which are decomposed on the addition of acid. Other organisms can form indol or can form nitrites, but cannot effect both changes coincidently; the *Vibrio Metchnikovi*, like the cholera organism, is, however, able to do this. The question of the relation of Koch's spirillum to cholera has been already considered in the chapter on Soil, and reference has also been made to the subject of water-borne cholera and to the extent to which the disease should be regarded as a water-borne or a soil-borne disease.

As regards prevention, the often quoted dictum of Simon, that "excrement-sodden earth, excrement-reeking air, excrement tainted-water, these are for us the causes of cholera," should be borne in mind. The dangers which have especially to be guarded against are stated, in a Memorandum issued in 1892 by the Local Government Board, to be, firstly, the danger of water supplies "where there is outflow, leakage, or filtration from sewers, house-drains, privies, cesspools, foul ditches or the like, into springs, streams, wells, or reservoirs from which the supply of water is drawn, or into the soil in which the wells are situate," and secondly, "the danger of breathing air which is foul with effluvia from the same sort of impurity." The importance of disinfection of excremental matter, urine, etc., need not here be insisted upon. Preventive measures in connection with ships arriving in this country are elsewhere fully considered (*See* p. 529). A method of protective inoculation designed by Haffkine has been extensively practised in India.

Dengue.—This disease is known to have prevailed from time to time for more than a century in various parts of the tropics, and at long intervals it has assumed the characters of a pandemic, spreading widely along lines of human intercourse, attacking entire communities within a brief space of time, and then disappearing again as suddenly as it came. It rarely extends into temperate regions, though it has during hot seasons prevailed as far north as Philadelphia, and it has been seen in southern Europe. The last great prevalence of dengue was in the years 1870–73.

Fever, headache, pain referred to the back of the eyeballs, and rheumatic pains in the loins and limbs, as a rule usher in the disease, which is thus particularly likely to be confused with "influenza," and the mistake appears to have often been made. In dengue an initial erythematous eruption is early developed with the first onset of fever; after a few days the temperature comes down, and then, about the fifth or sixth day of the disease, a secondary fever is developed, and this is as a rule accompanied by a "terminal" rash, consisting of slightly raised circular patches, which may later run into one another, and present an appearance not unlike that of measles; or again, the entire area of the skin may be, as Manson says, "covered with one unbroken sheet of red," this being not infrequently the case at favourite sites of the eruption, such as the hands, wrists, elbows, and knees. During convalescence severe pain may be experienced in the neighbourhood of one or more joints, the limb may be held quite stiffly for some days or weeks, and wasting of muscles may supervene; apparently the stiffness of gait and difficulty of movement occasioned by the disease led to its receiving the name of dandy fever (the term dengue, moreover, signifies a dandy).

The incubation period is probably from one to four or five days; relapses sometimes occur; the disease is rarely fatal, though it may leave behind it a persistent condition of impaired health. Nothing is known as to the micro-organism which presumably causes dengue, or as to measures effectual in preventing spread of the disease.

Diarrhœa. Epidemic Enteritis. Zymotic Enteritis. Epidemic Diarrhœa.—The opinion has now for some years been gaining ground that under the heading "diarrhœa," the mortality returns have included many deaths due to a specific malady, which particularly needs to be further studied with a view to obtaining knowledge upon which to base preventive measures. The deaths recorded as due to "diarrhœa and dysentery" in England and Wales were comparatively few in number in the earliest years of registration, but from 1847 to 1880, the rate per million living ranged between about 500 and 1,000; since 1880 the higher limit has not been again reached, but though the recorded mortality has thus shown of late years some tendency to decline, from ten to twenty thousand deaths are still annually registered under the headings named. The term diarrhœa has, in the past, no doubt, included a

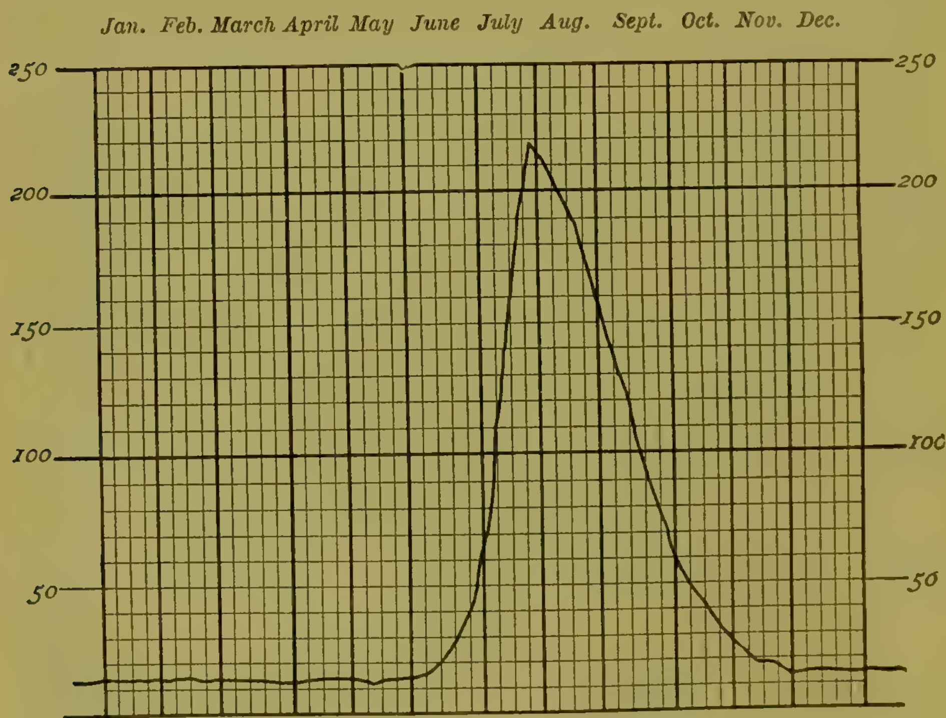

FIG. 84.

Average number of deaths from diarrhœa, registered in London in each week, 1841-1890.

large number of the deaths from the specific malady in question, but other designations have also been employed, such as gastro-enteritis, muco-enteritis, etc. With a view to securing some sort of uniformity the College of Physicians in 1900 recommended the use of the term "epidemic diarrhœa," or of one or other of two synonyms, "epidemic enteritis" or "zymotic enteritis."

The disease is conspicuously influenced by season. Fig. 84 shows the average number of deaths recorded in each week in London, during the years 1841–90. Again, diarrhœa notably prevails among young children. Ballard says attacks occur chiefly in children under 5 years of age. After 5 years the incidence greatly lessens; beyond 25 it gradually increases again. "Among children under 5 years of age, the incidence is comparatively small upon those under 3 months, after which age it apparently increases, beginning to diminish somewhat between the ages 1 to 2 years." Most of the deaths occur during the first year, the 3 to 6 months age group having the highest mortality.

The seasonal prevalence of the malady led to its being generally attributed, years ago, to the eating of fruit; but the mortality mainly occurs at ages at which but little fruit is eaten. Another obvious line of inquiry was the association of the disease with high temperature. If the mortality in London from diarrhœa be compared, year by year, with the variations in the mean temperature recorded during the summer quarter, the two curves will be found to present remarkable correspondences. Certain discrepancies will be noted, however, and Ballard and others after him have held that it is not atmospheric temperature that is of importance, but soil temperature (*See* p. 161). Newsholme, who has recently reviewed the whole question, concludes that diarrhœa is more closely related to absence of rainfall than to the mean temperature of the air.

The results of Ballard's inquiry concerning the causation of diarrhœa are given in a volume published as a Supplement to the Report of the Medical Officer of the Local Government Board for 1887. He summarises his conclusions under the following heads:—

(*a*) *General Conditions.*—Atmospheric temperature and earth-temperature are referred to, and also rainfall and air movement. The influence exerted by rainfall is not, Ballard concludes, direct (a "washing of the atmosphere," so to speak), but indirect, operating by preventing the rise and hastening the fall of the temperature of the earth. As regards air movement—in the diarrhœal season, calm promotes, and high winds tend to lessen, diarrhœa.

(*b*) *Conditions of Locality.*—Under this head elevation above sea-level, soil, density of buildings upon area, restrictions of and impediments to the free circulation of air, domestic darkness and general dirtiness, and accumulations of refuse, etc., sewer and cesspool emanations, and water pollution are considered.

(c) *Conditions relating to Population.*—In this connection social position, food, maternal neglect, and occupation of females away from home are referred to. With regard to the question of infant feeding, Ballard found that there was an impression that breast-fed infants were more exempt from diarrhœa than bottle-fed infants. Hope made some observations in Liverpool which tend to confirm this conclusion. It was found that "even among the low-class Irish" in Liverpool, infants fed solely from the breast were remarkably free from fatal diarrhœa. The question of the relation of milk to the disease has been elsewhere referred to (*See* p. 196); other foods may also transmit the infection, but it must not be assumed that in all the diarrhœa outbreaks traced to food, the organism of epidemic enteritis is at fault. In institutions (work-houses, asylums, etc.), and in connection with meals supplied to large gatherings of persons, extensive outbreaks of diarrhœa, have, from time to time, been recorded, and these have been ascribed to various articles of food (water, milk, butter, cheese, tinned meats, etc., *See* pp. 208 and 210). It is possible that study of such outbreaks may throw light upon the causation of epidemic enteritis, as these institution outbreaks occur not infrequently during the special season of that disease.

With regard to prevention, Ballard made certain "provisional practical suggestions." In order to obviate "fouling of the soil with matters out of which the material of diarrhœa can be produced," he urged that attention should be directed to the removal of filth, liquid and solid. To domestic cleanliness great importance was attached, and the need of securing dryness and purity of soil adjoining dwellings, by provision of impermeable covering to the ground surface immediately about them, so that water may with certainty be carried off into the sewers, was also referred to. Further, questions of lowering the level of subsoil water, of preventing the rise of ground air, and of securing free ventilation about and within dwellings, were alluded to. The need of protecting milk from infection "from the time of leaving the cow's udder to the time of its being used as food," was specially pointed out, the desirability of boiling all milk on its receipt into houses was commented upon, and the importance of ensuring the sanitary condition of all places where food is prepared and sold was particularly insisted upon. Finally, the regulation of sewers and drains and measures of general sanitation were considered.

Diphtheria.—In the middle of the second century of the Christian era, Aretæus described a throat affection which there can be no doubt was what is now termed diphtheria. "Angina," he said, is "a very acute affection, for it is a compression of the respiration—the organs affected are the tonsils, epiglottis, pharynx, uvula, and top of the trachea." One species, he noted, derived its name, cynanche (from the Greek words κύων, dog, and ἄγχω, to strangle), "either from its being a common affection of those animals, or from its being a customary practice for dogs to protrude the tongue even in health." He then proceeded to give a description of the Egyptian or Syrian ulcer, which Bretonneau declared to be unsurpassed, as an account of the mode of termination of diphtheritic cases.

The Arabian physicians described "angina," but it is not until the sixteenth century that clear accounts of what is now known as diphtheria are forthcoming. The disease appears, then, to have prevailed in Holland, and there are descriptions of what was called the "morbus strangulatorius," from southern Europe. Fothergill's account of the "putrid sore throat" was written in 1748, and Huxham's dissertation, on the "malignant ulcerous sore throat," was published three years later. In North America, and in various parts of Europe, angina maligna was prevalent during the eighteenth century. Ghisi described it at Cremona in 1747, and mentions the false membrane, and Bard, in New York, pointed out the error of describing the appearances in the fauces, by the epithets "gangrenous" and the like. Both observers appear to have recognised the liability to paralytic sequelæ.

Towards the close of the century, however, as Hirsch remarked, "angina retired into the background." In 1765 Home's work on croup appeared. "Francis Home," says Bretonneau, "suspended the progress of observation initiated by Ghisi," he "persuaded himself that he had just met with an affection which had hitherto escaped the attention of his predecessors, he thought that he ought to give it the popular name under which he found it designated in a Scotch province." The new denomination, undoubtedly, tended to obscure, as Bretonneau says, the relationship of "a disease observed from the most remote antiquity."

In 1821 Bretonneau published his first memoir describing "diphthérite," or, as he afterwards termed it, "diphthérie" (from the Greek word διφθέρα, a skin). He wrote four further memoirs on the subject, referring, *inter alia*, to a school epidemic which occurred at Tours, and to outbreaks in the barracks of that city. It was some years, however, before the nomenclature introduced by

Bretonneau was popularised in this country. The great epidemic of the late "fifties" and the early "sixties" brought diphtheria into special prominence. Netten Radcliffe states that from 1854 onwards croup, thrush, quinsy, and noma showed increased prevalence; in fact, he adds, "it is not too much to say that all the affections allied to diphtheria prevailed epidemically contemporaneously with diphtheria."

Confusion of nomenclature has continued up to recent times; the extent to which deaths previously ascribed to other forms of throat malady have been ascribed to diphtheria, has been studied by Sykes ("Public Health," vol. vi.). As has been seen, scarlet fever and diphtheria were not distinguished by the Registrar-

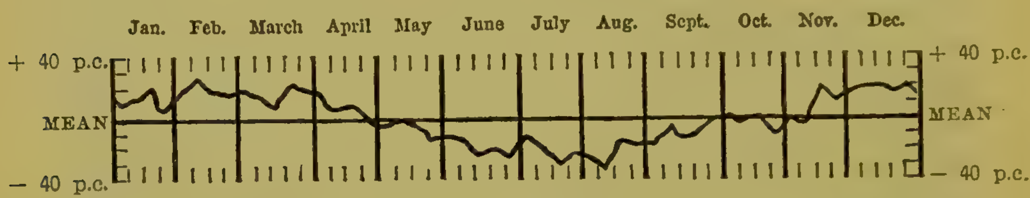

FIG. 85.

Average number of Deaths in London from Croup, in each week, 1845–1874.
(*After Buchan and Mitchell.*)

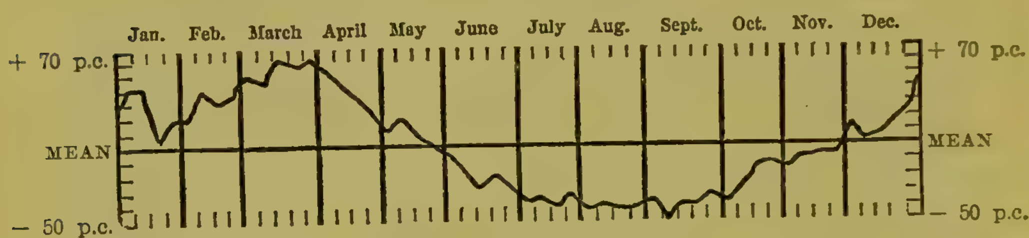

FIG. 86.

Average number of Deaths in London from Laryngitis, in each week, 1845–1874.
(*After Buchan and Mitchell.*)

General till 1855, and even when fatal cases of those diseases were separately recorded, after that year, there can be no doubt that large numbers of what were really diphtheria deaths were returned under the heading croup. A table given in the Sixtieth Annual Report of the Registrar-General (page xxiii.) shows striking diminution in the number of deaths ascribed to croup, from 286 per million living in 1859, to only 35 per million living in 1897.* It must not be assumed, however, that all the deaths

* The Registrar-General points out in the supplement to the Fifty-fifth Annual Report, p. xxvi., that it is his practice "to class under the head of diphtheria all deaths which are referred to 'membranous croup,' deaths returned, as from croup simply, being referred to the heading 'croup' among diseases of the respiratory system."

recorded as croup, during those years, were really diphtheria deaths, for, as Whitelegge has pointed out, the seasonal mortality curve of croup, approximates more closely to the laryngitis curve, than to that of diphtheria. Moreover, "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." The extent to which transference between scarlet fever and diphtheria may have occurred since 1859 has been referred to by Shirley Murphy, in connection with the altered age-incidence, observed since 1871, in the last-named disease.

The death-rate from diphtheria, recorded in England and Wales

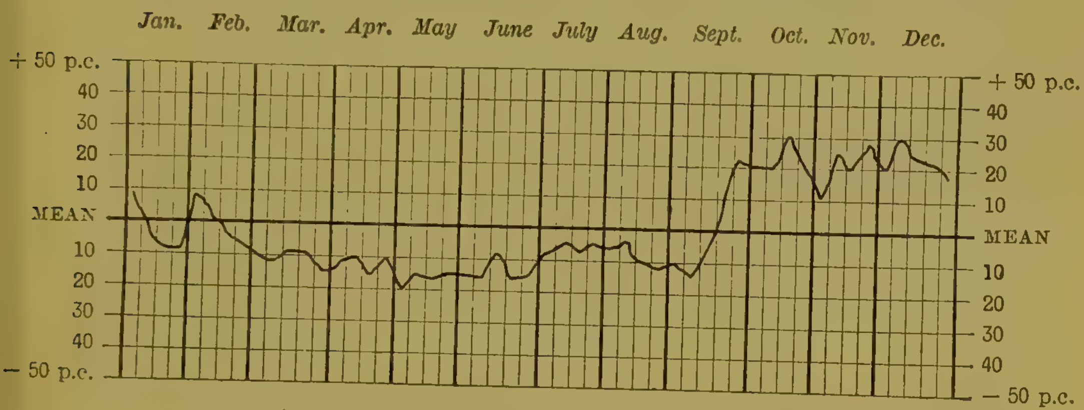

Fig. 87.—Diphtheria in London (forty years, 1861-1900).
The mean line represents an average weekly number of 20 deaths.
(*After Shirley Murphy.*)

in 1859, was 517 per million living; this rate has never since been attained; the mortality declined steadily during the "sixties"; but in the "seventies," "eighties," and "nineties" there has been a fairly steady increase in the recorded rates, with some tendency to manifestations of increased prevalence, extending over a few years. In 1893, a year of high prevalence, a mortality of 318 per million living was recorded.

Influence of Climate and Season.—The disease is less common in the tropics than in temperate and cold climates. The seasonal curve, Fig. 87, shows that the malady tends especially to prevail in the last quarter of the year in London, and the relation to cold and damp weather has been noted, though not invariably, elsewhere. Newsholme's observations, with regard to rainfall, already referred to, may be borne in mind in this connection. Perhaps humidity and allied atmospheric conditions operate rather by promoting individual susceptibility, than by directly increasing the virulence of the diphtheria germ. Diphtheria presents seasonal variations of age-incidence and fatality, and similar phenomena are observed in the case of scarlet fever. The matter has been discussed by Shirley Murphy, in the *Transactions of the Epidemiological Society* for 1897–98.

Longstaff showed, from consideration of the recorded mortality of the "sixties," "seventies," and "eighties," that diphtheria was especially a disease of sparsely populated localities. He prepared the following table :—

Districts according to density of population.	1855–60.	1861–70.	1871–80.
Dense districts, or those with less than 1 acre per person	123	163	114
Medium districts, or those with from 1 to 2 acres per person	182	164	125
Sparse districts, or those with over 2 acres per person ...	248	223	132

This behaviour of diphtheria led Longstaff to conclude that "the cause or causes of diphtheria 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 mode of life." The line of investigation which seemed to him most promising, lay in comparative pathology, inasmuch as "the peasantry live on terms of great intimacy with domestic animals, more especially with cows, sheep, pigs, and poultry, including pigeons." In the final decade of the last century, however, diphtheria conspicuously invaded the towns, and notably the metropolis. It has been thought to explain this altered behaviour, as resulting from increased facilities of communication, or from the aggregation of susceptible children in schools, and there can be no question that this last named factor accounts, at any rate, in some part for the phenomenon.

Influence of Sex and Age.—There is notable excess of female mortality from about the third year of life to the thirty-fifth, and this has been explained by the greater exposure of women to infection, incidental to their attendance upon the sick; but, as Downes has observed, it is remarkable that the excess should be already apparent at such very early ages. The mortality, taking the two sexes together, attains a maximum at the age-period 3—4. It is markedly less under one year, however, than at the other ages in the 0—5 age group. After ten years of age the mortality falls notably, and it becomes comparatively insignificant after the fifteenth year. The altered age-incidence, which was manifested during the last three decades of the nineteenth century, has already been commented upon in connection with school influence (*See* p. 292).

Cause and Dissemination.—The bacillus, first described by Klebs, and afterwards studied by Löffler, and known as the Klebs-Löffler bacillus, has of late years come to be regarded as the cause of diphtheria, and its presence in the throat is appealed to as the final test of the existence of the malady in particular individuals. In large towns, in which diphtheria is constantly present, and among communities of children, in school outbreaks, the bacillus has been found in the throat in quite an appreciable percentage of apparently healthy persons. Again, the organism may persist for several weeks after the appearance of the fauces becomes normal. It was ascertained in New York that in four per cent. of the cases examined, the bacillus was recoverable for fifteen days, and in two per cent. for periods of from three to five weeks, after all traces of exudation had disappeared.

At one time diphtheria was commonly supposed to be spread by sewer and drain emanations; but it is now generally accepted that effluvia, of the kind referred to, operate merely by bringing about a relaxed condition of the mucous membrane of the throat, and thus predisposing persons subjected to them to an attack of the disease. For production of actual diphtheria the specific germ is a *sine quâ non*, and the possibility of its transmission by sewer or drain air has not been demonstrated. The influence of soil and rainfall, and the spread of the disease by the agency of milk, have already been fully considered. In the last-named connection, the question of the existence of a specific cow malady has been referred to. Other animals, moreover, may apparently be affected by the disease; thus, it has been described as occurring from time to time in the cat. Throat affections which have been suspected to be identical in origin with human diphtheria have been observed in pigeons, fowls, and other birds, and instances have even been recorded in which such affections have prevailed in association with human diphtheria. The question has not, however, been as yet satisfactorily disposed of. The operation of "school influence," in promoting the spread of diphtheria, has been considered

(*See* p. 289), and the possibility of mischief of a like kind being caused by other aggregations of persons, as, for example, of soldiers in barracks, must not be lost sight of.

The curious way in which cases of diphtheria and scarlet fever occur in association with one another is noteworthy. In instances in which infective throat malady affects several members of a family, some of the cases may present examples of what appears to be the one form of disease, and some of the other. Again, in milk outbreaks, a like source of confusion has been noted. The precise nature and origin of the cases of so-called "post-scarlatinal diphtheria," has been the subject of numerous inquiries of late years.* Many of these cases are considered to represent instances of the engrafting of a second disease during recovery from the first, but the question does not seem to have been as yet completely cleared up.

The period of incubation, in diphtheria, is usually only two or three days, but it may extend to six or seven. The length of time during which cases may continue to be infective is not precisely known. The New York observations, already referred to, show that bacilli may still be present in the throat after a number of weeks. Gresswell has been led to conclude that in some individuals diphtheria may become, so to speak, chronic, with liability from time to time to active recrudescence, as the result of exposure to cold, damp, etc. It was supposed until recently that one attack of diphtheria conferred no immunity against subsequent attack, but the more precise study of the malady, which has been made of late years and especially since the bacteriological test has been applied, does not appear to bear out this view.

The case-mortality of diphtheria has undergone marked reduction since the introduction of the use of antitoxine. The question of the antitoxic serum treatment has already been referred to, and it was very fully considered in the Medical supplement to the Report for the year 1896 of the Statistical Committee of the Metropolitan Asylums Board. It must suffice here to state that the mortality observed in all cases treated in hospital in 1894 (a pre-antitoxine year), as compared with 1896 (an antitoxine year), was 29·6 per cent. as against 20·8. The mortality under five fell from 47·4 to 30·2 per cent. It was found, in dealing with the cases treated with antitoxine, that a marked difference was noticeable in the percentage

* In particular, papers by Sweeting and Goodall in the *Transactions of the Epidemiological Society* for 1892-3 and 1895-6, respectively, may be referred to.

mortality, according to the day of the disease on which the cases first came under treatment.

PERCENTAGE MORTALITY IN RELATION TO DAY OF DISEASE ON WHICH CASES CAME UNDER TREATMENT.

Day of Disease.	1894.	1896.	Difference.
First	22·5	4·7	17·8
Second	27·0	12·8	14·2
Third...	29·4	17·7	11·7
Fourth	31·6	22·5	9·1
Fifth and over	30·8	24·6	6·2
All cases	29·6	20·8	8·8

It is thus seen "that the percentage mortality of cases admitted on the same day of the disease is less in every instance in the year 1896." Moreover, the difference is most marked in the patients admitted on the first, second, and third days of illness. Furthermore, the beneficial effect of antitoxic serum treatment was found to be specially pronounced in laryngeal and tracheotomy cases. In practice it is the rule to inject large doses (1,000 immunisation units) as early as possible, and in severe cases somewhat larger doses (2,000 or more units) may be given. It is said that post-diphtheritic paralysis has been of more frequent occurrence since the introduction of serum treatment; but even if this be a fact, it must be borne in mind that a larger number of patients reach the stage at which paralysis is apt to develop, now a days, than was formerly the case. Albuminuria, too, is said to have become more common, but this appears doubtful. Certain minor effects—urticaria, joint pains, and swellings, etc., have been noted as being produced; they appear to be attributable not to the antitoxine itself, but to the vehicle, the serum, in which it is administered. The subject of "return cases" will be referred to in connection with scarlet fever.

In diphtheria, proper isolation and thorough disinfection are specially valuable as means of preventing spread of infection; care is particularly necessary in dealing with discharges and expectorated material, and disinfection of clothing, bedding, etc., should be thoroughly carried out. Children from infected households, even though they present no signs of illness themselves, should be kept away from other children, and in localities where diphtheria is prevalent, much benefit may result from the daily examination of the throats of school children, with a view to isolation of any suspected case at an early stage. The necessity for boiling all milk given to children need not again be insisted upon. In some instances, when diphtheria has been prevalent in a particular locality, antitoxic serum has been employed with a view to *preventing* an attack of the disease.

Dysentery.—The term dysentery possibly includes more than one form of specific malady; thus, as Manson points out, dysentery contracted in the East Indies is "prone to eventuate in abscess of the liver," whereas this sequela is rare in the dysentery of temperate climates and certain tropical countries, *e.g.*, the West Indies. Dysentery at the present day is pre-eminently a disease of the tropics. In the time of Sydenham, Morton, and Willis, it seems to have been common enough in this country. Indeed, Baly, writing in 1847, said: "Two hundred years ago dysentery was one of the most prevalent and fatal diseases of London." Baly's account of the malady, as he observed it at the Millbank Penitentiary, again brought into notice what appears to have been practically a forgotten disease. It is now recognised that dysentery is by no means confined to tropical countries, though in temperate climates, as a rule, it only excites attention in connection with institutions, particularly lunatic asylums.

Mott and Durham in their report on "Colitis, or Asylum Dysentery," on a review of this question, say: "Until we know the exact nature of the essential cause in different countries, we shall not be in a position to dogmatise, but it seems probable that such distinctive and similar lesions of the colon must be determined either by identical, or by very closely allied agents. It is hardly credible that the same disease should be caused by amœbæ in one place, by a micrococcus in another, and by a variety of colon-like bacilli in others." These observers altogether reject the doctrine that the dysentery of lunatics is due to degeneration of the intestinal nerves, for, they say, the disease is not limited to any one class of mental disorder; moreover, it affects occasionally persons in attendance upon the insane.

The cause of dysentery remains obscure. *Amœba coli* (or *Amœba dysenteriæ*) has been found in the stools in many cases, but does not occur in others. It has been assumed, therefore, that there is an "amœbic dysentery"; and this variety of the disease, in particular, has been held to be associated with abscess of the liver. Moreover, the *Amœba coli* has been found in liver pus. On the other hand, amœbæ have been presumed to be present, merely, as it were, by chance, inasmuch as in some places in which dysentery occurs, amœbæ abound. The theory has also been advanced that *Bacillus coli* is capable, under certain circumstances, of becoming a pathogenic organism and causing dysentery. Again, Durham has isolated a micrococcus from the organs in cases of asylum dysentery.

Dysentery is markedly influenced by season. In Europe it has prevailed, as a rule, in summer and early autumn. Soil has been held to also exert influence, and a moist and polluted sub-soil has been supposed to specially favour its development. Clouston attributed an outbreak at the Cumberland asylum to sewage emanations. As regards means of entrance of the organism, whatever its nature, into the human body, water has repeatedly fallen under suspicion, but this mode of origin does not appear to have been conclusively demonstrated in any one instance. Flies have been regarded as possible agents of infection, and the question as to whether some blood-sucking insect may be concerned in the matter has been raised. Predisposing causes (lowered vitality, errors of diet, etc.) seem to play a very important part in favouring the occurrence of dysentery.

In the absence of further knowledge the main points to be looked to, in connection with the prevention of dysentery, are water supply, the dietary, and the avoidance in institutions of insanitary conditions and overcrowding. Strict regard to cleanliness is necessary in the case of those brought in contact with the subjects of dysentery, and the stools and linen, etc., used by patients, should be carefully disinfected. In camps the proper disposal of excreta must be carefully looked to.

Enteric Fever.—This disease has probably prevailed from very early times. The accounts given of "fever" in the seventeenth century make it almost certain that in some instances the illness described is what is now known as enteric fever, and it becomes increasingly clear, in the eighteenth and in the early part of the nineteenth century, that such an inference should be drawn. In the period last named the intestinal lesions were described by Bretonneau, Louis, and others, but there was still confusion as between enteric fever and typhus. Ultimately, towards the close of the first half of the nineteenth century, the distinction between the two maladies was established owing to the researches of a number of observers, and especially of Dr. Stewart and Sir William Jenner.

The deaths from enteric fever have, however, only been separately recorded by the Registrar-General since 1869. In the earlier years of registration the death-rate, as a rule, was not far short of 400 per million living, but, as time went on, fairly steady diminution was noticeable, and since 1884 the death-rate has not reached 200 per million. In this connection the inquiry made by Buchanan into the effect upon mortality from various causes, including enteric fever, produced by the carrying out of sanitary works, and in particular of works of drainage and water supply, may be referred to. (*See* p. 163.)

Enteric fever is a widely distributed disease, but the tropics appear to be comparatively free from it. Its prevalence is markedly influenced by season; the annexed figure indicates the behaviour of the disease in London on the average of a number of years.

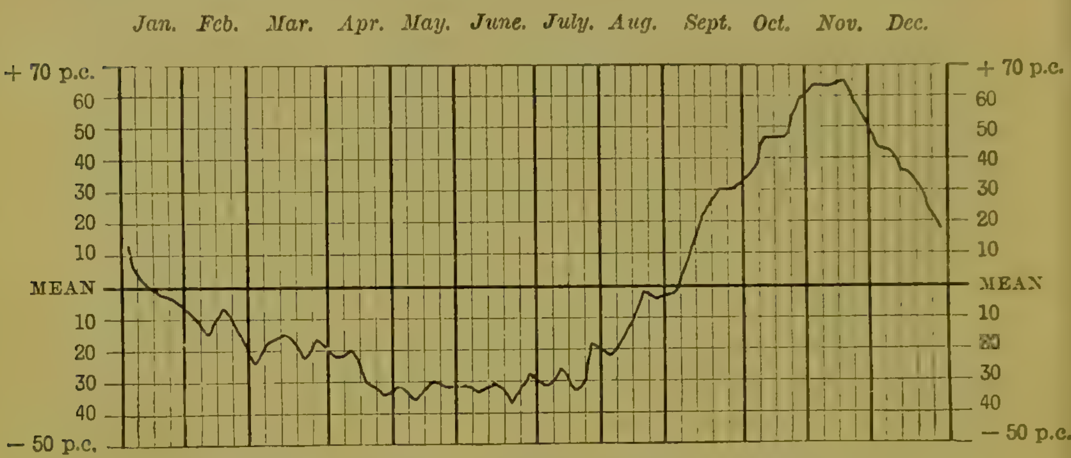

FIG. 88.—ENTERIC FEVER IN LONDON (thirty years, 1871–1900).
The mean line represents an average weekly number of fourteen deaths.
(*After Shirley Murphy.*)

The case-mortality, as shown by hospital statistics, is about 15 per cent. Race, *per se*, seems to exercise little or no influence on liability to enteric fever. As regards sex, males, between 5 and 20 years of age, are somewhat more frequently attacked than females, but at these ages the *mortality* among females is rather higher than among males. The disease mainly affects the ages 10—25, and particularly the age-period 15—20. In outbreaks of enteric fever due to milk and other articles of food, deviation from the age-incidence generally observed, in enteric fever attacks as a whole, may be noted.

The period of incubation is generally about a fortnight, but it may range from four or five days to about four weeks. It is doubtful whether one attack affords any marked degree of protection against subsequent attacks. It may be noted, moreover, that relapses are of common occurrence.

The bacillus first discovered by Eberth, and afterwards studied by Gaffky, is almost always found in the mesenteric glands and in the spleen. Its demonstration in the stools, in sewage, and in specifically contaminated water is beset with difficulty. The enteric fever bacillus, and *Bacillus coli* and its allies, grow in media containing carbolic acid, and can be thus separated from other organisms; but *Bacillus coli* and related organisms greatly preponderate, as a rule, among the colonies which develop, and the isolation of Eberth's bacillus from such forms, which on preliminary study are well-nigh indistinguishable from it, may be an impossible task.

In the urine, however, of some 25 per cent. of the sufferers from enteric fever, the organism can be demonstrated, and in that fluid it may be present in pure culture. Horton-Smith pointedly drew attention to this fact in 1897. He found as many as 500 million bacilli in one cubic centimetre of urine. Moreover, this "typhoid bacilluria" may persist for a very long time; indeed, a case was recorded by Gwynn, in which, five years after an attack of enteric fever, the organism was obtained in the urine in pure culture. Urotropin has been found to be a valuable remedy in typhoid bacilluria. Horton-Smith advocates its use throughout the disease and for some weeks after convalescence is established, and this course is especially desirable with a view to preventing spread of infection. The administration of the drug requires to be carefully watched, as albuminuria and hæmaturia have been caused by its use in a few instances.

The discovery of the fact that the blood serum, soon after the commencement of an attack of enteric fever, acquires the property of giving a specific reaction with cultures of the bacillus (Widal's reaction) has greatly facilitated the diagnosis of the disease. Not only, moreover, can the blood of a suspected case of enteric fever be tested with cultures of Eberth's bacillus, but the serum of enteric fever patients, or of an immunised animal, can be used to test the identity of an unknown organism which it is thought may prove to be the bacillus of enteric fever. It must be borne in mind that this serum test is not quite decisive, for Durham showed that Gärtner's bacillus (*Bacillus enteritidis*) reacts to the serum of enteric fever patients, and Lorrain Smith isolated from Belfast water, which was presumed to have spread enteric fever, and also from the spleens of patients who had consumed this water, organisms which "clumped" with enteric fever serum, but which did not possess all the characteristics of Eberth's bacilli. Houston records having isolated "coli-like microbes from water which were certainly not *Bacillus typhosus*, and could not be classed as *Bacillus enteritidis*, yet which 'clumped' in marked fashion with one or other or both sera."

Houston concludes that "all coli-like microbes which can in any way be distinguished from *Bacillus typhosus* should be considered varieties of *Bacillus coli*." He, further, states that, "since the introduction of the serum test," *Bacillus typhosus* "has not been isolated from water in this country," but he adds that abroad "they have been more fortunate." The points to which attention must be directed in distinguishing *Bacillus typhosus* from *Bacillus coli* are enumerated by Houston.* They may be thus briefly summarised:—The tendency of *Bacillus typhosus* to appear as long thin rods, which are actively motile and possess numerous (about ten) long and wavy easily-stained flagella; its colourless transparent growth on potato, and failure to form gas in gelatine "shake cultures"; differences as compared with *Bacillus coli* when grown on what are termed the Proskauer and Capaldi media; failure to form indol in broth cultures; exhibition of a slightly acid reaction, and absence of clotting in litmus milk cultures; failure to affect the red colour of neutral-red tinted media; a positive serum test; response to Pfeiffer's test (*i.e.*, the serum of a typhoid-immunised animal protects against a lethal dose); finally on gelatine and other media *Bacillus typhosus* manifests less rapid and luxuriant growth than *Bacillus coli*.

Some varieties of *Bacillus coli* agree with *Bacillus typhosus* in presenting one or more of the peculiarities specified, but *Bacillus typhosus* possesses them all. As Houston says, by using these tests microbes, "which in the past would almost certainly have been confused with the bacillus of enteric fever," can be readily differentiated from it, but he reiterates Horton Smith's caution to the effect that an unknown bacillus must not be regarded as *Bacillus typhosus* "simply because it responds to the agglutination phenomenon, without seeing whether it answers to the other tests for the typhoid bacillus."

The question of the spread of enteric fever by sewer and drain emanations and by water, milk, shell-fish, etc., has already been considered, and the relation of the disease to soil has also been referred to. The fact that the bowel discharges and the urine contain the organism suffices to explain the occasional infection of nurses and others who are brought in contact with enteric fever cases. In some hospitals, nurses have not infrequently been attacked; in others the infection of nurses has rarely been observed. The question of age may have played a part in determining these differences. It is notable, moreover, that medical

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* *Brit. Med. Journal*, Aug. 17th, 1901.

men, as compared with nurses, rarely suffer; this may be in part explained by their being brought into less intimate relation with soiled linen, etc., and in part by the greater care exercised by medical men in cleansing their hands after they have examined a patient.

As regards prevention, purity of water supplies is undoubtedly of the first importance. The fact that infection is not infrequently conveyed by milk is a reason, among others, for boiling all milk before use. Inasmuch as dissemination of enteric fever is sometimes caused by consumption of shell fish, etc., there is special need for the exercise of care with regard to their use as articles of diet. The possibility of spread of the disease by sewer air must be borne in mind, and due precaution should be taken with regard to the disposal of excreta in connection with camps, etc. In this country it has been often noted that enteric fever incidence is greater upon houses with dry systems of removal than upon water-closeted houses. The difference may be partly, at any rate, due to varying social conditions, as the disease tends to prevail among the poor, other things being equal, to a greater extent than among the well-to-do. It may be noted that in hot countries the possibility of infection being spread by dust and of its being transmitted by flies has been mooted. Disinfection of the stools and urine of patients should be scrupulously carried out, and those in attendance should be most particular with regard to washing in disinfectant solution and carefully cleansing the nails, etc., before touching food.

Anti-typhoid inoculation has been extensively practised since 1896. The serum of persons, who have been inoculated, is found to give Widal's reaction, and it was hoped that a sure means of protecting against attack by enteric fever had been discovered. Favourable results were in the first instance reported from India, but in South Africa the measure of success obtained appears to have been less complete.

Erysipelas.—This disease has been known since early times, and it occurs all over the world, but only comparatively infrequently in the tropics. In England the average death-rate per million living has not greatly varied during registration times, though it has shown some tendency to diminish in recent years. The close correspondence between cyclical manifestations of high mortality from erysipelas and from puerperal fever, the relation observed between those cycles and periods of high mortality from certain other diseases, and their inverse relationship to periods of excessive rainfall, have already been referred to (*See* p. 168). Hirsch points out, as regards puerperal fever and erysipelas—that the two diseases often prevail coincidently in lying-in institutions; that women in labour who have been attended by persons suffering from erysipelas have taken puerperal fever; conversely, that doctors, nurses, etc., and newborn infants, associated with puerperal fever, have developed erysipelas; and further, that puerperal fever sometimes appears, as it were, "to develop from an erysipelas which mostly arises in the lacerated vaginal mucous membrane."

Erysipelas is more fatal in the colder months, and its seasonal curve corresponds fairly closely with that of puerperal fever. Nearly 30 per cent. of all the recorded deaths from erysipelas occur during the first year of life, and the mortality is particularly excessive in infants, from 0 to 3 months old.

The organism which causes erysipelas was isolated by Fehleisen, who named it the *Streptococcus erysipelatosus*; it can be cultivated, and by inoculation of the material obtained from cultures, erysipelas can be produced in rabbits. The disease is probably always induced by inoculation, though the point of entrance of the organism cannot be detected in all instances. Cases in which the site of introduction of infection was not apparent were denominated at one time "idiopathic," to distinguish them from the ordinary "traumatic" erysipelas.

The incubation period is generally three or four days. An attack of the disease appears rather to predispose to, than to protect against, subsequent attacks; perhaps the more correct interpretation of the facts observed would be to say that some persons appear especially prone to be attacked by the malady. Outbreaks of erysipelas—for example, that at the Radcliffe Infirmary, investigated by Netten Radcliffe—have been associated with drainage emanations. There can be no doubt that the occurrence of erysipelas in hospital wards has been materially controlled by the improvement of sanitary conditions and the strict enforcement of cleanliness. Cases of the disease should be isolated, and careful disinfection should be carried out.

Glanders, Farcy (Latin, *Malleus* or *Equinia*).—This disease has been known in horses since ancient times; the fact that it is contagious appears to have been first recognised in the seventeenth century. In 1882 the *Bacillus mallei* was shown by Löffler and Schütz to be the cause of the disease. Glanders is widely distributed throughout Europe, and occurs in parts of North and South America; cases have, of late years, been reported from South Africa and from the East Indies. It occurs in the horse, mule, and donkey, and is in rare instances communicated to other animals and to man, usually by direct infection from nasal discharges, either by inhalation or by inoculation through a scratch on the skin. Nocard regards the intestinal tract as the chief site of entry of infective material in horses.

In the horse the incubation period is from three to eight days. Nasal discharge appears a day or two after the onset of the malady, and in acute glanders the disease reaches its height rapidly, the nasal mucous membrane becoming extensively ulcerated, the submaxillary glands enlarged, and the lymphatics of the face "corded" (farcy); the lungs generally become affected by metastasis, and dyspnœa and death from suffocation speedily supervene. In farcy the characteristic appearances are due to inflamed lymphatic vessels, which can be felt as cords and nodules ("farcy buds") beneath the skin. In chronic glanders the onset is insidious: cough, enlarged glands, and other symptoms may precede the development of nasal discharge, and corded lymphatics may be noted in connection with affected parts. The disease may last for months or years.

In man the usual incubation period is three to eight days, but it may extend to three weeks. Headache, "rheumatic pains," œdematous swellings, an inflamed condition at the site, if there be one, of inoculation, and gastro-intestinal symptoms may be noted. Nodules which subsequently break down and ulcerate may appear under the skin, and the nasal mucous membrane may also be affected, though this is less frequent than in the case of the horse. The lungs are usually involved, and œdema of the glottis may supervene. The chronic form of the disease is rarely met with in the human subject. The average number of deaths registered as due to glanders in man in this country is about four a year.

The diagnosis of glanders in horses has been greatly facilitated by introduction of the "mallein" test; reaction, with rise of temperature (1·5° to 2·5° C.), persisting for twenty-four hours or more, is in the case of glandered horses produced by doses which have no appreciable effect on healthy animals. A reaction is sometimes observed, however, in animals which are the subject of disease, but which are not glandered. In case of doubt the mallein test is checked by application of what is known as the Straus test, which consists in inoculating a male guinea-pig intraperitoneally with suspected pus, gland juice, or nasal discharge; characteristic orchitis is, as a rule, set up in the guinea-pig if glanders be in question.

If glanders is present in a stable, all diseased animals should be destroyed, and those apparently healthy should be isolated and tested with mallein. The carcases of slaughtered animals must not be cut up, but should be destroyed by fire, or treated in a digestor, or, if this is impracticable, they should be buried at least six feet beneath the surface of the ground, and covered with quicklime. The stables, harness, troughs, buckets, etc., should all be thoroughly disinfected. The need for scrupulous care on the part of persons brought in contact with infected, or suspected, horses cannot be too strongly insisted upon.

An Order of the Board of Agriculture of 1892 provides for compensation on slaughter, and gives powers for securing examination of horses and for enabling local authorities to dispose of infected carcases. A Departmental Committee reported on glanders in 1899 and recommended—that notification of the disease should be obligatory upon veterinary surgeons, and upon owners of knackers' yards in the event of glandered animals being taken to their premises for slaughter; that the slaughter of animals showing clinical symptoms of glanders should be made compulsory; and that compensation for horses slaughtered, solely on account of reaction to the mallein test, should be on a higher scale than in the case of horses presenting clinical symptoms of the disease.

Hydrophobia is the disease occasionally produced in human beings who have been bitten by a dog or other animal affected with "rabies." Wolves, jackals, and foxes may be the subjects of rabies; cats are very rarely attacked; certain of the herbivora may be infected experimentally or as the result of a dog-bite. An outbreak occurred among deer in 1889. In dogs the incubation period of rabies is from three to six weeks, and the disease is marked either by a condition of maniacal excitement, or more rarely paralytic symptoms are especially pronounced ("dumb madness"). In the maniacal form, paralysis, notably of the lower jaw and of the hind quarters, supervenes after a few days, and the disease terminates fatally at the end of about a week.

In man the incubation period is generally about six weeks; it may be as short as eleven days, and on the other hand may, it is said, extend to four years. There is sometimes pain at the site of the scar caused by the bite, and accompanying enlargement of the neighbouring lymphatic glands. The characteristic dread of the thought of drinking water is usually early developed, delirium and mania commonly supervene, and most distressing spasm of the throat muscles may be induced when the attempt is made to swallow. Paralytic symptoms soon appear, and the case usually proves fatal in three or four days.

Hydrophobia occurs in almost all parts of the world. In England some counties have suffered more than others; London has yielded a considerable percentage of the total number of cases. From 1838 onwards the deaths ascribed to hydrophobia in the metropolis have averaged about three or four annually. In some years no death has been recorded; in 1885 there were twenty-seven. Cases occur rather more commonly in July, August, and September than at other times of the year.

Pasteur's treatment by preventive inoculation, with material derived from the spinal cords of rabbits, has been extensively practised. The spinal cord of a rabbit which has been rendered rabid, contains the virus in an intensified form, but by exposing the cord to dry air its virulence becomes weakened, and after some days it may be employed, as Pasteur showed by experiments performed in dogs, for the purposes of preventive inoculation. As a rule, injections of material derived from a cord dried for fourteen days are first made, then material from cords which have been dried a less and less number of days is employed, the treatment lasting altogether about a fortnight. "Intensive treatment" is adopted in exceptionally severe cases.

The case-mortality of patients treated at the Pasteur Institute, in Paris, is about ·5 per cent. (excluding deaths occurring during treatment, or within fifteen days of the last inoculation). The natural case-mortality among persons bitten by rabid animals is very difficult of ascertainment, but it is said that 15 per cent. develop hydrophobia, and the disease is almost necessarily fatal. It appears legitimate to assume, therefore, that a far higher percentage of deaths, than that recorded at the Pasteur Institute, would occur in the absence of treatment. Rabies can be completely stamped out by rigorous enforcement of muzzling. This has been proved in Sweden and in Berlin; in England also excellent results have been obtained, but there has been a tendency to abandon the regulations as soon as a marked impression on the prevalence of the disease has been produced. In 1899 and 1900 no deaths from hydrophobia were reported in the whole of England.

Influenza.—Hirsch says this disease "may be followed into the remotest periods from which we have any epidemiological record at all," and he gives a list of epidemics which have been observed in various parts of the globe, from the twelfth century onwards. In England the malady was prevalent during the last century, and outbreaks occurred in 1803, in 1833, and in 1837–38. During the early years of the period of registration considerable numbers of deaths from influenza were recorded; thus there were over 1,000 in 1840 and in 1841. In 1847–48 the disease was much more widely prevalent; indeed, in the latter year the mortality was nearly 8,000. From this time onwards until 1860, more than 1,000 deaths were registered in each year, while in 1851 the number was 2,000, and in 1855 the number 3,500 was exceeded. Thus, following upon the 1847–48 outbreak, came a series of years of marked though lessened influenza mortality.

After 1860 the influenza deaths did not again exceed 1,000 in any one year until the commencement of the recent prevalence, which dates from 1890. During the "sixties" and "seventies" the mortality was notably diminished, occasional slightly marked exacerbations were, however, observed. During the "eighties" the number of deaths recorded was comparatively trivial, and probably a considerable number of these were not really due to influenza at all. In the first year of the great epidemic of the "nineties" 4,523 deaths were registered; in 1891 the number amounted to 16,686; in 1892 there was again high mortality; there was evidence of abatement in 1893 and 1894; but in 1895 the deaths were in marked excess; the two following years again showed diminution. The closing years of the century were years of high mortality, the deaths recorded in 1900 being not far short of the number registered in 1895.

Influenza has an almost world-wide distribution, and appears to be practically uninfluenced by race, soil, climate, or season. Parsons has pointed out that in passing over the northern hemisphere the epidemic waves of influenza have travelled, as a rule, from east to west; they have, moreover, spread along the chief lines of human intercourse, and have not travelled faster than human beings could travel. In each country the disease "has appeared first in the capital, or the ports of entry, or the frontier towns in communication with countries previously invaded." The persons brought much in contact with others have been the first to suffer, and the disease has specially prevailed in institutions and in large establishments, where considerable numbers of persons are collected together. Hence Parsons concludes that the disease is "propagated mainly, perhaps entirely, by human intercourse." As he remarks, however, it is not to be denied that the contagion, once imported into a locality, may propagate itself outside the human body. The causes which determine the re-awakening of the disease into activity after it has spent its first force in any particular place are not understood.

The case-mortality of influenza is difficult to gauge. Parsons found in 1890 that 1·6 per 1,000 of the patients treated for influenza at eight large London hospitals died. The mortality returns show that during years when deaths returned as due to influenza are in excess, those ascribed to pneumonia and bronchitis, and to some other diseases, also show increase, and there can be no doubt that many of these deaths are really due to influenza. The Registrar-General estimates that during the four years, 1890—1893, influenza was really accountable for some 125,000 deaths in this country. During 1890 a large percentage of the recorded influenza deaths occurred at the ages 40 to 60, and it has been pointed out that in 1847–48 the disease showed a greater tendency to prove fatal in young children, and in persons over 60, than was the case in the later outbreak (*See* p. 436). Some people suffer from influenza again and again, but in the majority of persons an attack seems to confer immunity of a more or less lasting character; even those who undergo repeated attacks appear to acquire a temporary protection after passing through one of them, and later attacks, generally speaking, show gradually diminishing intensity. The period of incubation is probably from one to three days.

Pfeiffer in 1892 discovered a bacillus which is almost constantly present in the sputum, and is not found in any other disease. It can be cultivated on artificial media. It has been held that a disease known as "pink eye," which affects horses, is really influenza, and domestic animals have been observed to be attacked concurrently with the appearance of the disease in a household; but nothing is certainly known concerning influenza in the lower animals.

The ordinary preventive measures cannot be applied to influenza; during epidemics large numbers of persons are attacked, and of these a considerable percentage are adults, many of whom are unwilling even to submit to confinement to the house. Whole households may be suddenly stricken down, and to carry out complete isolation is altogether impracticable. Some advantage may accrue from isolation of early cases, and confinement to bed is indicated, as a rule, in the interest of the patient, even if it serve no good purpose in checking spread of the disease. Avoidance of crowded assembly rooms, public places of meeting, etc., during epidemics of influenza is advisable. Sputa, etc., should be disinfected.

Leprosy.—This disease is known to have existed in Egypt, India, and China at a very remote period, but it would appear to have been introduced into Greece after the time of Hippocrates, and it was not well known in Europe generally until the end of the seventh century, A.D. It had spread widely before the end of the eleventh century; hence the notion that it was introduced by returned Crusaders. Leper-houses were extensively brought into use in the twelfth, thirteenth, and fourteenth centuries, and cases of the disease were isolated on a large scale. The diminution in prevalence of leprosy in Europe, in the centuries succeeding, has been attributed to this practice ; Koch speaks, for example, of the "rigorous isolation in the numerous leper-houses," and says, "the consequence was that leprosy, which had spread to an alarming extent, was completely stamped out in Central Europe."

The disease did not finally disappear from Great Britain until the end of the eighteenth century. It is still met with in Norway (where, however, the number of lepers is said to have decreased from 2,833 in 1856 to 321 in 1895), and it occasionally occurs in other countries of Europe, particularly in the south-eastern portion of the Continent. Throughout almost the whole of tropical Asia the disease is prevalent, in India there are upwards of 100,000 lepers, and there are probably more in China ; it is widely distributed on the African Continent, and occurs in Madagascar, Mauritius, and Réunion ; the east side of South America is said to be more severely affected than the west side ; North America is comparatively free from the disease. In the Sandwich Islands and New Caledonia leprosy seems to have been unknown until recent years ; once introduced it has spread widely.

As regards the distribution of the varieties of leprosy, "lepra tuberosa" or tubercular leprosy, "lepra maculo-anæsthetica" or nerve leprosy, and the "mixed" form, it has been suggested that climate has influence, nodular leprosy being more common in cold, damp climates, and the nerve form in warm or dry climates. Another theory attributes differing manifestations of the disease to variations in the number of bacilli present. The incubation period of leprosy is said to range from a few weeks to years. The disease is rare in young children, and in most instances commences between 10 and 30 years of age. Sex and occupation seem to have no special predisposing influence. The malady was generally held in former times to be hereditary, but there is no evidence that such is the case, indeed, in the light of modern knowledge, this supposition is exceedingly improbable.

Hansen's discovery of the *Bacillus lepræ* has materially changed the point of view as regards leprosy. The bacillus is universally present in the disease, and absent in persons free from leprosy ; it resembles somewhat in its appearance, and in being "acid-fast," the tubercle bacillus, but differs from the latter in certain points of detail as regards staining (it takes, and also parts with, carbol-fuchsin more readily), and as regards its arrangement and appearance in the tissues ; moreover, it has not been successfully cultivated, and the results of inoculation of animals are markedly different. The fact that the leprosy bacillus cannot be cultivated in artificial media or inoculated in animals, makes it impossible to apply the final tests prescribed by Koch.

It has been claimed that leprosy has been inoculated in man, but the evidence in the one case in which symptoms have developed subsequent to inoculation, is not at all conclusive, as the man had lived among lepers, indeed, members of his own family were affected. The results of inoculation have in other cases been entirely negative. If the bacillus be regarded as the cause of the disease it is difficult to understand how leprosy can be hereditary, in the ordinary sense of the word, though apart altogether from the bacillus there is little to be said for, and much against, the heredity hypothesis.

Various kinds of food, and particularly fish, have been held to cause leprosy, but no conclusive evidence is forthcoming under this head. The general opinion, nowadays, is that leprosy is communicated from person to person by contagion, and certain concrete instances supporting this conclusion have been recorded; for example, a case of the disease occurred in Dublin, and the patient had never been out of the United Kingdom, but had been in intimate relation with a brother, who, after acquiring leprosy abroad, had returned to Dublin. The fact that attendants in leper asylums are rarely attacked, and the failure of numerous attempts to inoculate the disease, have been cited as reasons for disbelieving in personal infectiveness; but neither of these arguments can be deemed conclusive, and in the existing state of knowledge isolation must be regarded as the mainstay of prevention. In Norway segregation is not rigorously carried out, but the putting in practice of the modified system at present in force, has been followed by diminution in the prevalence of the disease. In India and China the difficulties, financial and other, of isolation on a comprehensive scale have not hitherto been surmounted.

Malta Fever. Mediterranean Fever. Febris Undulans.—This disease is not confined to the Mediterranean but has been found to occur in India, China, and the West Indies. Until recent years it has not been recognised as a distinct malady, but has been confounded with enteric fever, malaria, etc. The early symptoms are, as a rule, similar to those of the onset of enteric fever; transitory joint swellings may later be developed, and the behaviour of the temperature is stated to be peculiarly characteristic. Hughes describes a "malignant," an "undulating," and an "intermittent" type of the malady. The period of incubation varies from six days to a fortnight. As regards age, children, but not very young children, are found to be specially susceptible. The time of greatest prevalence in Malta is during the summer months. The fatality does not exceed two per cent., but great debility, anæmia, and neuralgia are apt to supervene after an attack.

Bruce, in 1887, isolated an organism, the *Micrococcus melitensis*, from the spleen (an organ which, in fatal cases, is usually found to be soft and swollen). Injection of pure cultures of this organism produced a similar disease in monkeys and the characteristic symptoms in men. The organism is very sparsely distributed in human blood. Wright showed, in 1897, that the phenomena of agglutination are markedly displayed, on treatment of cultures of the organism with the serum of persons affected with the disease. This important discovery has immensely facilitated diagnosis of the disease; the reaction is manifested at the end of the first week, and persists long after recovery.

Malaria.—This disease was known to the Greeks and Romans; Hippocrates discussed its relation to season. In the sixteenth, seventeenth, and eighteenth centuries it received some measure of attention, and it again figures in the works of medical writers; it is noteworthy that Sydenham and others in this country seem to have frequently encountered it. In the middle of the last century Virchow studied the pigment observed on post-mortem examination of malaria cases, and at about this time the suspicion appears to have been already entertained, by various observers, that the disease was due to invasion of the body by some lowly organism; it is interesting to note that the suggestion that the mosquito was concerned in producing malaria was definitely put forward as early as 1848. Klebs and Tommasi-Crudeli, in 1879, contended that a bacillus was the cause of the malady.

In 1880, Laveran drew attention to the presence of "crescents" in the blood of malaria patients, and he subsequently described the "amœboid form" of the organism and also some of the changes which the crescents undergo; he thus laid a foundation upon which the subsequent study of the "plasmodium malariæ," as he called the parasite, has been based. Golgi materially added to this knowledge, distinguishing between the different forms of parasite in quartan and tertian agues, and showing the relation, of stages of their growth in the blood, to the periodicity of the symptoms observed. In 1892 Koch and Pfeiffer suggested that in the case of the malarial parasite, as in that of the coccidia, there might be a double cycle of development, one cycle occurring in man, the other possibly in some suctorial insect.

The Mosquito Theory.—In 1894 Manson, who had years previously worked out the relation of the mosquito to filariasis, suggested that this insect also played an important part in disseminating malaria. The need of explaining the conveyance of the parasite from man to man was obvious in malaria, as it had been in filariasis; the geographical distribution of *Filaria nocturna*, as Manson pointed out, corresponded with that of malaria, suggesting that the mosquito might equally serve for transmitting the parasite of malaria as well as that of filariasis; the association of the mosquito with swamps, and with high atmospheric temperatures, and its nocturnal habits, all tended to confirm the hypothesis; moreover, the crescents of malarial blood, when removed from the body, had been found to undergo development and to become possessed of flagella, and this acquirement of locomotive and penetrating faculty led Manson to conclude that here was the initial phase of the mosquito cycle of development.

Surgeon-Major Ross took up the study of the mosquito theory; working at first with the ordinary mosquito (Culex), he was merely able to show that the development of the "flagellated body" took place somewhat more readily, in the stomach of the insect, than under the ordinary circumstances in which the behaviour of the crescents, in a drop of blood taken from man, could be watched. On experimenting, however, with the genus Anopheles, in 1897, he was able to demonstrate the existence of pigmented cells in the stomach-wall of the mosquito, after it had been supplied with crescent-containing blood, and thus to detect a further stage in the mosquito cycle of development. Attention, moreover, became directed to the fact that forms of parasites, allied to the human malaria parasite, could be demonstrated in the blood of sparrows and other birds. Ross studied one of these organisms (Proteosoma), and showed that when he fed the mosquito (Culex, in this instance) with sparrow's blood containing the parasite, and then kept the insect alive for rather more than a week, it was possible to demonstrate the presence of the sporozoites of Proteosoma, in the mosquito's veneno-salivary gland. If infected mosquitoes were made to bite healthy sparrows it was found, after five to eight days, that evidence that the sparrows had been infected was forthcoming on examination of their blood.

The Malaria Parasite.—The various phases of the mosquito cycle of development, of these and other parasites, have since been extensively studied. The parasites in question have been styled Hæmamœbidæ. One group of the family includes Proteosoma (which affects sparrows), Halteridium (observed in pigeons, jays, and crows), and *Hæmamœba malariæ* and *Hæmamœba vivax*, as the parasites of quartan and tertian fever have been called. A second group includes the parasite of remittent fever (æstivo-autumnal fever of Italy), to which the name *Hæmomenas præcox* has been given. It is probable that, with growth of knowledge, this provisional classification may be considerably modified. In Italy three distinct forms of malignant parasite have been described. Moreover, Koch discovered an organism allied to the parasites of human malaria in apes, and similar forms appear to occur in bats. In Italy it was proved by Grassi and Bignami that the malarial parasite can be transmitted from man to man by the mosquito. Manson infected two Englishmen in London by means of mosquitoes fed in Rome on blood from a case of benign tertian malaria. The incubation period in these two cases was fourteen and fifteen days respectively. When infection is produced by injection of malarial blood the incubation period is said to be, about thirteen days in quartan, about ten days in benign tertian, and about three days in æstivo-autumnal fever.

The asexual cycle of development of the malaria organism occurs, so far as is known, only in the human body; a remarkable feature is the relation of the phases of this development to the stage of the attack. If the blood be examined immediately after a rigor, small amœboid organisms (amœbulæ) may be found in the blood corpuscles; these increase in size, develop pigment, and at length, shortly before the next paroxysm becomes due, occupy almost the entire volume of the blood corpuscles. At this stage, on examination of stained specimens, the nucleus, hitherto single, is found to have become broken up, and sporulation is found to be well advanced, the "rosette body" or "sporocyte" stage, as it is termed, being now reached. The breaking up of the "rosette body" with freeing of the contained spores, corresponds in point of time with the onset of the ague paroxysm. The sporocyte of quartan ague is described as being of "daisy shape" and contains six to fourteen round spores; that of benign tertian ague is of "sunflower shape" and contains fifteen to twenty-six oval spores; that of malignant malaria is of irregular shape and contains seven to fifteen round and very small spores.

The reason why the parasites all mature and reach the sporulating stage at about the same time is not understood. The cycle of development is, under certain circumstances, moreover, shortened or lengthened; in the former case the fever is said to "anticipate," in the latter to "postpone." In malignant malaria it is noteworthy that, while in the earlier part of the cycle the parasites may abound in the peripheral circulation, just before the paroxysm they tend to disappear, but may then be found undergoing sporu lation in the spleen. The accumulation of parasites in internal organs is presumed to stand in close relation to development of pernicious symptoms. In order to explain the recurrence of attacks of ague, after a period of freedom from symptoms, and under circumstances in which fresh infection from without is out of the question, it is necessary to assume that the parasite can enter into a resting state, or assume a latent phase, but with regard to this nothing is precisely known.

In addition to the ordinary asexual cycle in the human body, it has been ascertained that a sexual cycle of development may be there initiated. Certain of the parasites, while within the red blood corpuscles, appear to develop into spheres, some of which possess flagella, while others do not. These two varieties are called gametocytes, and represent male and female elements. The crescent bodies, which only occur in malignant malarial infection, develop two sorts of spheres, flagellated and non-flagellated, corresponding to the gametocytes of the benign quartans and tertians. The study of these sexual forms has been much facilitated by adopting the staining process known as the Romanowsky method. Further stages in the history of the sexual cycle have been observed, in Halteridium, which result in the production of worm-like bodies, "travelling vermicules." These, it is said, subsequently develop, after piercing the stomach wall of the mosquito, into what are termed "zygotes." Analogous phenomena are presumed to occur also in human malaria. In infected mosquitoes the further development of the zygotes, through a series of transformations (zygotomeres, blastophores, and, ultimately, mature zygotes which contain numerous sickle-shaped "sporozoites") has been traced. The whole process occupies some six to ten days; the sporozoites finally escape into the body cavity of the mosquito and are conveyed to the veneno-salivary glands; their existence, in large numbers, has been demonstrated more particularly in the middle lobe of the gland. When the mosquito bites, these sporozoites are injected into the tissues of the bitten animal.

Anopheles is the only genus of the Culicidæ, so far as is known, in which the sexual cycle of development of the human malaria parasite can be completed. The distinctive characteristics and habits of Anopheles have been made the subject of some study, but there is still a great deal to learn in this connection. The Culicidæ, mosquitoes or gnats, include three genera—Anopheles, Culex, and Aedes. The first-named is distinguished by the fact that the palpi in both sexes are equal in length to the proboscis. The ova are minute black specks, and float on the surface of the pools, ditches, etc., in which they are laid. In Culex the ova are generally arranged in boat-shaped masses; but they are more irregularly disposed, though sometimes with indication of a star-shaped arrangement, in Anopheles. The larvæ hatch out after some twenty-four hours, those of Culex swim about actively; those of Anopheles are less active, and are, moreover, smaller and darker. Again, in Culex the larvæ hang head downwards, and at right angles to the surface, the breathing organ being situated in the tail; while in Anopheles the larvæ float flat on the surface, owing to the absence of a caudal breathing tube. The pupa stage supervenes after about a week, and some two or three days later the perfect insect escapes.

The female insect alone bites, and, generally speaking, only during the day time. The duration of its life extends for several weeks; in places where there is a cold season it is presumably able to hibernate. Ross laid emphasis upon the resting attitude of Anopheles as distinguishing it from Culex; in the former the body being placed almost at right angles, while in the latter it is parallel to the surface on which the insect has alighted. The distinction does not hold good as regards all species, and a more reliable criterion is said to be, that whereas Culex has a hunchback appearance when at rest, Anopheles keeps its "proboscis, head, thorax, and abdomen in one straight line."

It is, of course, possible that some other vertebrate can take the place of man in relation to the malarial cycle. Dionisi has described parasites closely resembling those of human malaria in bats from the Campagna. It has been suggested again that the "black spores" described, by Ross, as occurring in mosquitoes fed on Proteosoma-containing blood, may represent "resting spores," destined to play a part in maintaining the existence of the organism. The parasite *Pyrosoma bigeminum* of "Texas cattle fever" is transmitted by the parent tick "boophilus bovis" to its offspring, and Manson suggests the possibility of some such cycle of events occurring in the mosquito. Koch points out, however, that *Pyrosoma bigeminum* is not very closely allied to the human malaria parasites; it forms no pigment, and deviates to a notable extent from them in its mode of development.

Geographical Distribution.—Hirsch states that malaria covers "a broad zone on both sides of the equator," attaining "a maximum of frequency in tropical and sub-tropical regions," but continuing "to be endemic for some distance into the temperate zone, with diminishing severity and frequency towards the higher latitudes." The disease prevails in tropical Africa and especially on the west coast; in Asia (India, Ceylon, China and the Malay

Peninsula, and parts of the East Indies); in certain of the southern states of the Union in North America; in many localities in Central America; and in parts of South America. The islands of the West Indies are comparatively free from it; so is Australia, save as regards northern Queensland. In Europe malaria mainly occurs in the countries bordering on the Mediterranean. In this country the disease is almost unknown, though mild attacks of the malady are still, it is said, occasionally met with in parts of the fen country, and in the Essex marshes.

The benign tertian form is by far the most common outside the tropics; for the most part in Europe malaria is benign, though in the Campagna there is a malignant variety, known in Italy as "æstivo-autumnal fever." Double infection may occur, in which case two paroxysms may develop within twenty-four hours; or, as is more usual, a double tertian or quotidian fever is produced, two sets of parasites sporulating on alternate days. The benign quartan form, though less frequently met with than the tertian, is not uncommon in temperate regions; the infection may be single, double, or it is said, even treble; if the last-named, a quotidian fever is produced; if the infection be double, there are two days of fever and one of freedom from fever; if the infection be single, the ordinary quartan type obtains. It is noteworthy that while the malarial paroxysm may commence at any period of the twenty-four hours, more than half the attacks occur between midnight and midday. This fact has an important bearing upon diagnosis.

The malignant (remittent, as distinguished from intermittent) forms of malaria are met with in the tropics, though during the warmer seasons of the year they may occur elsewhere, as, for example, in Italy. Mixed infections, tertian and quartan, or tertian and malignant, or quartan and malignant, are often encountered. In malignant, or tropical malaria, not only are the periods of intermission, as a rule, absent, but there is risk of development of grave or "pernicious" symptoms, as they are called, and malarial cachexia is apt to supervene. Relapses of malaria often occur some time after a person has left a malarious locality, the "latent phase" of the parasite is then said to become "active." The tendency to relapse apparently persists longer in the case of benign, than in that of malignant fevers. Malarial cachexia is only observed, as a rule, after malignant forms of fever, and generally as the result of prolonged exposure, but it may supervene after one severe attack.

Preventive Measures.—Malaria is not usually developed in towns, as drainage, paving, etc., interfere with the breeding of the mosquito; moreover, Anopheles is more rural in its habits than other members of the Culicidæ. Again, mosquitoes are low flying, so that sleeping in the upper storey of a house may serve as a safeguard against attack. Mosquitoes do not, as a rule, fly far from their breeding places, which are usually, it is said, small puddles, so small that they contain no fish and yet large enough to remain a sufficient time without being dried up. This fact explains the freedom from malaria, often enjoyed by persons on board ships, anchored at some little distance from the shore of intensely malarious localities. Koch showed that in New Guinea the blood of nearly all young native children contained malarial parasites, while that of adults did not. The comparative immunity of natives, therefore, appears to be an acquired immunity. The abundant distribution of parasites, in the blood of native children, makes the neighbourhood of native camps an undesirable place of settlement for newcomers to a district, as they run increased risk, if bitten by mosquitoes, of being inoculated with the malaria parasite.

Manson writes that until some method of producing artificial immunity is devised, prophylaxis must be directed to the suppression of mosquitoes, to the prevention of infection of mosquitoes, or to the prevention of infection by mosquitoes. Koch proposes to exterminate malaria by destroying at one and the same time all parasites in the blood of infected persons in a given community, by exhibition of quinine. Early treatment with this drug reduces the number of gametocytes in the peripheral circulation if it does not absolutely prevent their appearance. If such treatment were universally adopted, and all parasites were thus destroyed or driven from the peripheral circulation, mosquitoes could no more become infected, and malaria must, he argues, cease. On the other hand, it has been suggested that the way to abolish malaria, in a particular locality, is to exterminate the larvæ of the mosquito. Pools, etc., suitable for the breeding of Anopheles, should, it is urged, be filled up; if this cannot be done, larvicidal material should be applied to the water. Such substances as paraffin and tar have been recommended; the notion being that, by forming a thin layer on the surface of the water, the access of air to the larvæ and pupæ would be prevented. As evaporation occurs, this "painting" of the water needs to be renewed at short intervals. Exact study of the distribution of Anopheles in the district would seem to be necessary before this plan of extermination can be carried out with much hope of success.

Pending the carrying out of measures of one kind or the other, reliance must, in the main, of necessity be placed by the individual upon attempting to protect himself against being bitten by mosquitoes. Experiments carried out in the Roman Campagna show that by remaining in a mosquito-proof house from sunset to sunrise, it is possible to continue to live in a malarious district and yet remain free from attack. In cases in which a mosquito-proof house is not available a good deal may be done, it is said, by using an efficient mosquito net, and by avoiding, not only the haunts of the mosquito, but also infected individuals, and particularly the neighbourhood of native villages.

Elevation of site of the dwelling is desirable, but in some places "hill fevers" occur, even at a considerable height above sea level. The higher the site, however, the better as a general rule; houses themselves may be raised above the ground on arches or piles, and the upper storeys, only, should be used for sleeping purposes. Water has been suspected to have been the means of transmitting infection, but nothing is certainly known with regard to the matter. In the absence of precise knowledge it is desirable that all water of doubtful origin should be boiled. Much was written in former days concerning the relation of soil to malaria; a good many of the observations are explicable on the mosquito theory, but there remains the fact, of which this theory has not as yet afforded complete explanation, that outbreaks have often occurred in connection with operations involving disturbance of the soil. Further inquiry may throw light on this question.

There is a form of fever known variously as "Blackwater fever," bilious remittent fever, hæmoglobinuric fever, etc., to which attention has been particularly directed of late years. It prevails throughout tropical Africa, in the southern states of the North American Union, and in parts of Central America; it has only recently been observed in India. In Europe it has been described in Greece, Sicily, Sardinia, and Central Italy. The mortality is high, 20 per cent. and upwards, and relapses are common. The characteristic symptom is hæmoglobinuria, which is preceded, however, as a rule, by fever, bilious vomiting, and jaundice. This group of symptoms has been regarded as a manifestation of malaria; another theory is to the effect that the phenomena result from long-continued exhibition of quinine; in 1893, Manson expressed the view that a distinct specific malady was in question. In support of the "quinine theory," it has been urged that new comers to a place where blackwater fever prevails are not attacked for some time, and indeed, not until after they have suffered from, and undergone treatment for, malaria. In support of the specific theory it has been pointed out that the disease is closely analogous to the "red water fever" of cattle, the Texas fever already referred to, in producing which a specific parasite has been shown to be concerned. The question awaits final settlement.

Measles.—This disease appears to have been known to the Arabian physicians. Hirsch concludes that it was "in all probability widely diffused over Asiatic and European soil during the middle ages," and, as he notes, it has retained that position in the centuries following. It has, no doubt, been often confounded with other eruptive maladies, notably small-pox and scarlet fever. "At the present day," says Hirsch, "the area of its distribution may be taken to extend over the whole habitable globe." It has prevailed in epidemic form, though at long intervals, in outlying parts of Europe. (In the Faröe Islands in 1781, 1846, 1862, and 1875; in Ireland, 1664, 1694, 1846, and 1868; and also in Lapland.) Accounts relating to it have been received from all parts of Asia and Africa, concerning which knowledge as to the distribution of disease is forthcoming, and as colonisation has progressed in the Western Hemisphere and in Australasia, so measles has spread. In England and Wales the average annual death-rate, taken over periods of five years, from measles, since 1838, has varied from 373 (1871–1875) to 539 (1838–1842) per million living.

Periodicity.—Whitelegge traces "major waves" of prevalence of measles (as distinguished from "minor waves," extending over long periods of years. *See* page 330). He found that in this country, a maximum occurred somewhere about 1815; the succeeding minimum was probably reached in the early "thirties"; another maximum occurred in the early "forties," another in the "sixties," and yet another in the "eighties." He therefore suggests that there may be cyclic variation "in the quality of measles itself." Ransome found that in Sweden measles assumed widespread epidemic form every six or seven years, an interval which, as Whitelegge says, "is intermediate between the two classes of waves which we meet with in England." But in Sweden the population was sparsely distributed, and in scattered populations the phenomena might be expected to differ from those observed in thickly inhabited localities.

Hirsch gives the periodicity of epidemic recurrence for a number of places. In England "minor waves" occur, as a rule, at intervals of from eighteen months to two, three, or four years. It is a common experience to find, in the case of a particular town, that years of high mortality alternate with years of low mortality, and even when this sequence of events is not clearly exhibited on study of annual figures, it sometimes becomes apparent, as Whitelegge has pointed out, when the deaths are taken out in quarterly instead of annual periods. These "minor waves" are doubtless due in the main to accumulations of susceptible children, and "among the conditions tending to shorten the interval between successive epidemics are density of population, facility for close contact between infected and uninfected children at school and elsewhere, and certain meteorological states." On the other hand, the interval would be lengthened by "sparsity of population, scanty intercommunication especially among children, precautions as to isolation, and unfavourable states of weather."

Fatality.—The case-mortality at Burton-on-Trent was found to vary from 1·5 to 3·5 per cent. in the years 1894–1900. In Lancaster, 1889–1896, Theodore Thomson reported 138 deaths to 4,387 cases, a fatality of 3·1 per cent. In this country the fatality rarely exceeds 10 per cent. (Whitelegge, *Transactions of Epidemiological Society*, 1892–93). Whitelegge has pointed out that at Sunderland, at Hanley, and at Barnsley there occurred a succession of outbreaks, reaching their maximum destructiveness in 1885, in 1889, and in 1891 respectively in these three towns; the evidence, moreover, he says, indicates that "severity of type" accompanied the increase in recorded mortality. Examination of the statistics of a large number of towns yielded "abundant examples of tolerable regularity in periodic explosions, but very few unmistakable evidences of cyclic changes of the kind now in question."

The elucidation of problems of the kind here under consideration would, no doubt, be greatly advanced were the system of notifying measles generally adopted. At Sunderland, in 1885, the recorded case-mortality was 29 per cent.; at Hanley it was "not far short of 9 per cent."; and at Barnsley it was noted in the three epidemics, ending with the outbreak of 1891, that the type grew more and more severe. In these three towns, however, notification not being in force, the fatality cannot be precisely given.

Hirsch has particularly laid emphasis upon the fact that mistakes, in dieting and in therapeutic treatment, play an important part in causing some epidemics of measles to appear specially malignant. The often-quoted instances of the two hospitals in which outbreaks occurred during the American Civil War (when a case-mortality of 20 per cent. was observed), of the still higher case-mortality (40 per cent.) recorded in the Garde Mobile in Paris during the siege of 1871, and of the great fatality of the outbreak which is said to have destroyed nearly a fifth of the National Army in the Brazilio-Paraguayan war, clearly indicate the extent to which unfavourable conditions affecting the patients attacked may influence case-mortality.

A high fatality has been observed, too, when measles has been newly imported into communities previously free from it—on the banks of the Amazon, in 1749, whole tribes are said to have been cut off; and in Fiji, in 1874, one-fifth to one-fourth of the entire population is said to have perished: other similar experiences are on record. In some of the instances given the evidence clearly points to unfavourable conditions having been operative rather than to the existence of any special quality of the measles itself, as in some, at any rate, of the outbreaks above referred to, in which precautions were taken, the mortality was found not to be excessive. The group of examples first cited is, perhaps, more to the point than the second series, inasmuch as disturbing influences may come into play in the case of populations long exempt from the ravages of the disease. For one thing, there are no persons protected, and hence the age-distribution of attacks is unusual; again, it has been suggested that protection may be to some extent transmitted from generation to generation, and that greater destructiveness of measles is likely on this account to be manifested when the disease breaks out in communities previously free from it.

It is abundantly clear, however, that neglect and insanitary surroundings greatly affect the case-mortality observed in measles outbreaks. Other special circumstances may have to be taken into account. In Sunderland, for example, during the years immediately preceding the great epidemic of 1885 the number of births was in notable excess; the average for the decennium 1881–90 was about 5,818, but the number of births steadily increased during the early "eighties," and in 1883 and 1884 the births were 6,102 and 6,349 respectively. The number of susceptible children in recurring explosions of measles would be materially affected by this factor alone. A like variation, though a much less marked one, occurred in Barnsley just prior to 1891. In Hanley it appears that school influence was prominent during the outbreak of 1888–89. Again, the interval which has elapsed since the last epidemic materially influences the extent to which opportunity has been afforded for susceptible units to accumulate.

Influence of Season.—The seasonal curve of measles is remarkable inasmuch as it presents two maxima and two minima. The annexed figure shows that in the years 1841–1900 the winter maximum was the greater of the two; in the curve originally given by Buchan and Mitchell for the years 1845–74, this difference was accentuated. Davidson refers to the alteration in question in his paper on "Seasonal Fluctuations of Epidemic Diseases," in the *Epidemiological Society's Transactions*, 1896–97. He points out, moreover, contrasting epidemic

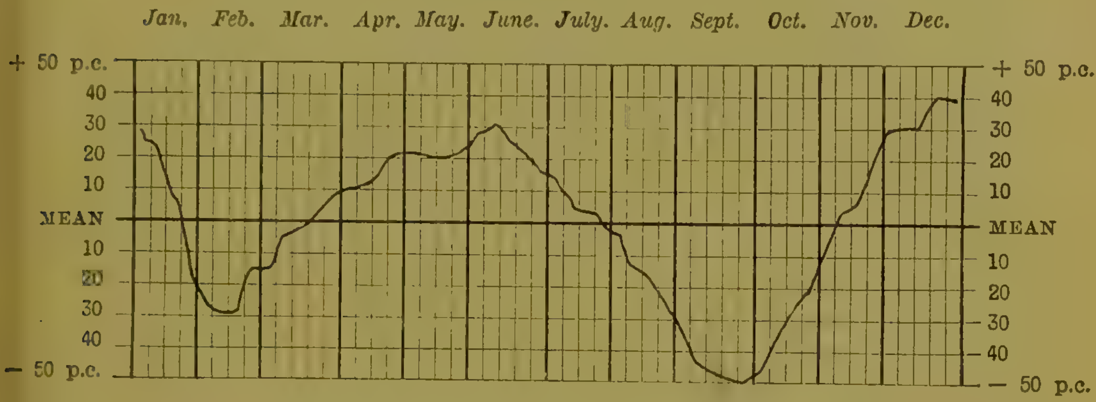

FIG. 89.—MEASLES IN LONDON (sixty years, 1841-1900).
The mean line represents an average weekly number of thirty-six deaths.
(*After Shirley Murphy.*)

years with non-epidemic years, that in the former "the force of the disease is seen to fall on the second quarter, in non-epidemic years on the fourth quarter." In the same paper it is noted how charts exhibiting combined monthly or weekly deaths for a series of years are apt to give an erroneous impression. The double rise does not, of course, occur in each year; the explosions occur biennially, or thereabouts, but are, as a rule, confined to the winter or spring months, and hence, when the figures for a series of years are considered, the maxima are found to present themselves in those months. Davidson attributes the change "from the winter to the spring type" to increased prevalence and fatality of the disease. It may be noted, however, that in London, with increasing aggregation of susceptible units, the conditions may be presumed to have tended of late years towards favouring explosions of measles at somewhat shorter intervals—say to the establishment of an eighteen months' in place of a biennial interval between recurring epidemics,—and this factor in itself may have affected the seasonal curve.

There has been much speculation as to the conditions which determine the occurrence of the explosions at more or less fixed times of the year. Hirsch rejects the explanation that change in habit of life (crowding in close rooms, for example, in colder seasons) explains this, as he says a like dependence upon season obtains as markedly in the tropics as in high latitudes. It has been suggested that climatic conditions operate by establishing a *locus minoris resistentiæ* in the body, thus increasing the liability to contract infection at particular seasons. Davidson concludes that the behaviour of measles and small-pox resembles that of respiratory diseases, and he cites in confirmation of his views the average monthly admissions of pneumonia in the General Hospital in Vienna. He states that "increased vulnerability of the air-passages determines to a large extent the seasonal prevalence of bronchitis, pneumonia, and sore throat," and he argues that "as the infection of measles and small-pox takes place through the air-passages, the increased vulnerability which determines the greater prevalence of respiratory diseases in winter and spring furnishes an adequate explanation of the epidemic spread of the former class of maladies at these seasons."

Spear, in reporting on the Hanley outbreak of 1888–89, noted that there was no evidence to show that a close connection existed between fatality and unfavourable weather, or other recorded meteorological conditions. Whitelegge thinks there is, as a rule, no increase of severity accompanying the seasonal exacerbations of measles prevalence. Davidson refers to two types of seasonal evolution in measles: in London, the Lancashire towns, and elsewhere the winter maximum is notably developed; the Scotch towns, on the other hand, show only a slight winter rise, but in them the June maximum is found to be particularly marked. This last-mentioned type occurs, too, in Paris, Berlin, Vienna, and in many American cities. The winter rise, indeed, tends to disappear altogether in southern regions, where the temperature in the winter months is high. Race, *per se*, seems to have but little influence in determining liability to attack by, or fatality from, measles. Hirsch says, however, that when the disease occurs in warm climates, diarrhœa is apt to prove a serious complication.

Influence of Age.—In this country the maximum death-rate, per million living, is exhibited at the age 1—2 years. The vast majority of deaths, some 98 per cent., occur in children under 10, and some 90 per cent. are those of infants under 5 years of age. The age 0—1 contributes, as a rule, about 21 per cent., the age 1—2 about 38 per cent. of the total deaths. The very young children constitute a larger percentage of those attacked in the great towns than is the case in sparsely populated areas. Age is a most important element in prognosis. In 3,181 cases treated in the Glasgow Fever Hospital during 1897–99, a case-mortality at all ages of 9·68 was observed. At 0—1 the fatality was 23·4 per cent.; at 1—2, 32·6 per cent.; at 2—3, 17·6 per cent.; at 3—4, 9·8 per cent.; and at 4—5, 3·7 per cent. From 5—10 the fatality was 3·2 per cent.; and from 10—15, 3·5 per cent. It is clear, therefore, that the proportion of children from 0—2 attacked in a particular epidemic may be expected to materially influence the general case-mortality observed.

Cause, Dissemination, and Prevention.—The measles organism has not been isolated. The disease spreads from person to person, the medium of infection being presumably, as a rule, the breath. The malady is highly infectious in its early catarrhal stages, and continues so throughout the eruptive period, and to a less extent during convalescence. The poison is probably conveyed, at times, by clothing, etc., but it has not been found to be spread by water, milk, or food, and the disease is not known to affect any of the lower animals. The question as to the desirability of applying the ordinary machinery of preventive methods to measles (notification, disinfection, etc.) will be later considered (*See* p. 537). Much benefit has resulted in numerous instances from school closure, in cases where the infants' departments, more particularly, of schools have been concerned in spreading the disease, and this even in the absence of any complete knowledge of the behaviour of measles in a community, such as notification would have afforded. In instances in which there has been complete co-operation between school and health authorities it has been found possible to obtain early information as to newly invaded households, and thus to safeguard the interests of the youthful population, and at the same time to limit, as far as practicable, interference with the education of the children.

Mumps.—This disease is said to have been known to the ancients, and to have been described by Hippocrates. At the present time it appears to occur in all parts of the inhabited globe. Climate seems to have little influence upon it. In this country it is more prevalent, as a rule, in the spring and autumn, and it most frequently attacks children and young adults, but the majority of the deaths are those of very young children. The fatality is insignificant, only some eighty deaths annually being registered, throughout the whole of England and Wales, as due to the disease; of these 68 per cent. occur in persons aged 0 to 5 years. The organism which causes the disease has not been isolated; infection is spread, as a rule, from person to person, and the breath is presumed to be the medium of its conveyance. The period of incubation is a particularly long one, usually from a fortnight to three weeks. The occurrence of second and even third attacks has been recorded, but it is generally assumed that one attack affords protection against subsequent invasion.

Plague.—It has been observed that certain circumstances recorded concerning the "very great destruction," described in the fifth and sixth chapters of the First Book of Samuel, are very suggestive of bubonic plague. The "emerods," of which mention is made, may well have been buboes, and, in the light of recent experience, the reference to the "mice" that "marred the land" is especially noteworthy. Hirsch refers to an outbreak in Libya, Egypt, and Syria, some two centuries before the Christian era. The great epidemic, which spread from Egypt over Europe in the latter part of the sixth century A.D., and which is known as the "Plague of Justinian," and the famous "Black Death" of the fourteenth century, were almost certainly outbreaks of bubonic plague; from the sixth to the seventeenth centuries the disease appears to have been repeatedly present in Europe.

The last great outbreak in this country was the Great Plague, which raged in London in 1665, destroying nearly 100,000 persons. The disease did not leave England altogether until 1679, and outbreaks still occurred in parts of the Continent, and especially in south-east Europe, throughout the eighteenth century. In 1841 plague was still present in Constantinople, but this prevalence came to be regarded after a time as the final European visitation. Between 1860 and 1880 evidence of renewed activity of plague was forthcoming from countries bordering on the Levant, and Netten Radcliffe reported on the matter (No. VII., New Series, Annual Report of the Medical Officer of the Privy Council and Local Government Board). In 1878–79 cases occurred in Astrakhan.

In certain parts of the world plague has apparently been almost constantly present in modern times. Bruce Low speaks of Assyr in Arabia, portions of Persia and Mesopotamia, Southern China, especially the province of Yunnan, and possibly parts of Central Africa as endemic centres of the disease. From 1879 onwards, for some years, the outbreaks of plague, which were heard of, were confined to Arabs, Bedouins, and nomadic tribes. In February, 1894, however, a severe visitation of the disease was manifested in Canton, and Hongkong was attacked in the following May. In both these instances the occurrence of plague cases was preceded by mortality among rats. Towards the end of 1896 plague appeared in Bombay, and it later spread to other parts of India, Calcutta being definitely ascertained to be attacked in the spring of 1898. Since 1896 cases of plague have been introduced at various seaports in this country, but the disease has not spread. In 1898 three fatal cases occurred in Vienna, due to infection from cultures of the plague bacillus, originally derived eighteen months previously from India. In 1899 the disease manifested a tendency to spread more widely; cases appeared for the first time, so far as is known, in America, notably in Brazil, Paraguay, and the Argentine Republic; moreover, an outbreak occurred at Oporto. Early in 1900, Sydney, in Australia, was attacked, and in the autumn cases occurred in Glasgow; in 1901 the malady obtained a footing in Capetown and other parts of South Africa.

The Plague Bacillus.—The micro-organism of plague was discovered by Kitasato and Yersin in 1894; it is usually found in pure culture in buboes, and can be demonstrated as a minute short bacillus, showing, as a rule, marked "bipolar staining." Its cultures on agar are fairly characteristic, and it is pathogenic to mice, rats, guinea-pigs, and rabbits. Guinea-pigs quickly develop considerable œdema at the site of inoculation, with consecutive glandular enlargement; they die in from two to five days, and plague bacilli are abundantly present in their organs and blood. The *Bacillus pestis* grows well at temperatures between 15° and 40° C., best in presence of oxygen, but also under anaerobic conditions. It does not, so far as is known, produce spores. The formation of stalactite-like filaments, as described by Haffkine, in broth cultures, is very characteristic.

The disappearance of plague with advancing civilisation in Europe, and the ability shown by the disease in recent years to attack the native quarters of Eastern cities, while Europeans enjoy comparative immunity, seem to indicate that there is some circumstance, connected with life under conditions of modern civilisation, which is inimical to plague. There has been much speculation as to this matter. The presence of dirt and overcrowding does not afford sufficient explanation in itself: various social customs—such, for example, as questions of clothing (going barefoot and the like), and methods of disposal of the dead (whether by burial at some depth from the surface, or by surface burial or other methods)—have been instanced as possible explanations; questions of altered relationship of communities to lower animals have also been mooted.

Of late years the fact that rats die in large numbers from plague has been brought into prominence; the mortality in these animals has in some instances been found to precede outbreaks of the disease in man. The distribution of the buboes in plague, the deep femoral glands being particularly frequently affected, suggested that inoculation was the principal mode of infection in man; in some instances scratches or abrasions which would account for the phenomena observed have been discovered, usually on the feet or toes; quite recently the theory has been advanced that the inoculation is effected in most instances by fleas. Simond found reason for concluding that infection could not be conveyed by dead rats after lapse of some hours from death; the infection, as he said, "evaporated": this he ascribed to the fact that the fleas leave the body of the rat when it becomes cold. Moreover, Simond found in certain instances papules or vesicles—"phlyctenules," as he called them—on the area corresponding to the bubo, and particularly on parts such as the dorsum of the foot where the skin is thin. Further, he detected plague bacilli in the phlyctenules, and in fleas from plague rats. The Plague Commissioners in their Report of 1901 express the opinion that the evidence adduced by Simond is inconclusive.

Animals fed upon plague cultures are attacked by the disease, and the possibility that man may also be infected by ingesta must not be lost sight of; moreover, plague bacilli have been demonstrated in the intestinal contents, and hence the excreta may presumably serve as a vehicle for spreading infection. Inhalation probably plays, in instances in which the pneumonic form of the disease is prevalent, an important part in connection with spread of plague.

Seasonal Influence.—The influence of season on plague is marked, but the question as to the meteorological factor mainly concerned in producing the conditions which favour its prevalence is by no means clear. In Western Europe plague in the past appears to have been a disease of late summer or autumn. In Bombay, 1896–99, two maxima and two minima appear in the seasonal curve. Moos (*Indian Plague Commission*, vol. iii.) gives reasons for concluding that the "more favourable the conditions for the virus to rise from the ground into the air, the greater is the mortality from plague"; or, as Buchan, to whom Moos's results were submitted, puts it, the curve showing the difference between the temperature of the soil at a depth of five feet, and the temperature of the air over the soil, agrees with the mortality curve. This association, as Buchan observes, is the more noteworthy, having regard to the fact that the principal maximum occurs when the weather is coldest and dryest, and the secondary maximum when the weather is moistest and wettest and the temperature very high.

Age and sex seem to have little influence in determining attack by plague. The incubation period is, generally, from two to eight days. The fatality varies greatly, it is said, in different epidemics; as a rule from 60 to 90 per cent. of those attacked die, but the mortality among Europeans has been, usually, less than this; moreover, a mild form of plague, "pestis ambulans," sometimes occurs. The most rapidly fatal variety of the disease is termed "pestis siderans"; the common form, that in which buboes develop, is known as bubonic plague; there are also the septicæmic and pneumonic forms. A mild kind of bubonic affection has been described as occurring in association with, or as preceding, outbreaks of true plague; to this affection the term "pestis minor" has been applied. It has not been clearly established that it is in any way related to true plague.

Prevention.—As regards plague importation, in addition to the usual measures adopted with regard to diseases to which the Order of the Local Government Board (*See* p. 529) applies, the question of rats has to be borne in mind. A circular letter of the Local Government Board, issued in May, 1901, deals with this subject and prescribes certain precautions, which should be taken on the arrival of a vessel (whereon, during the voyage, plague, or suspected plague, has occurred), to prevent rats from the ship reaching the shore, and as regards destruction of rats, etc. The desirability of making inquiry concerning rat-sickness, and of instituting, if necessary, bacteriological examination of sick rats, particularly in the case of vessels from infected ports, is specially insisted upon in this letter; it is further pointed out that rats when destroyed should not be handled, but should be at once cremated, and that the vessels should be disinfected, and measures be taken to prevent shore rats making their way to vessels lying in port.

In Glasgow, in 1900, efforts were directed towards tracing all persons exposed to infection, and house-to-house visitation in the invaded area was instituted; all "contacts" were kept under observation in a reception house, such observation, in order to cover the incubation period of the disease, extending over fourteen days. They were allowed to go to work, but were medically examined, each day, sometimes twice daily. Infected houses were evacuated, the "contacts" being removed, and the dwellings were then carefully disinfected. "Suspects," and actual cases of plague, were, of course, promptly removed to hospital. Rats were collected from various parts of the city and examined, but clear evidence that rats were affected in Glasgow was not forthcoming in 1900. The majority of the cases occurred in persons who had attended one or other of two "wakes," held over two persons presumed to have died of the disease.

In India, not merely infected houses, but entire villages and districts, have been evacuated, and the inhabitants segregated in camps, their houses being then either disinfected, or in some instances burnt to the ground. Again, persons coming from infected localities into an area not yet attacked, have been detained for a week or more before being allowed to proceed, and segregation camps have, with this object, been established in connection with railway stations, etc.

Persons recovering from plague should not be allowed to leave hospital for at least a month from the commencement of their illness. Rats and mice should be destroyed and their bodies burned; and it has been urged that this should be done as a matter of precaution before plague actually appears in a district. Concealment of cases constitutes a great difficulty in the East, and in India and elsewhere compulsory inspection of dead bodies has been insisted upon. Precautions as regards cleanliness are, of course, most essential for persons brought in contact with plague; scratches and abrasions on exposed parts of the body should be protected against the possibility of inoculation; and Manson suggests that those engaged on plague duty should "wear boots and have the legs protected by trousers tied tightly round the ankles, or better, by putties." Haffkine's prophylactic and various protective sera have been employed in India and elsewhere (*See* p. 340).

Pneumonia.—This disease was at one time regarded as due merely to exposure to cold, but of late years the opinion has steadily gained ground that acute lobar pneumonia, at any rate, is really a specific fever. It has been found, moreover, that epidemics of pneumonia sometimes occur, and that the disease then displays infectious property. Such outbreaks of pneumonia have apparently been observed on the Continent, and in America. Two epidemics were noted in India, in 1875 and 1882, and in this country an outbreak at Middlesborough was investigated by Ballard in 1888 (*See* p. 186), and another occurred at Scotter in Lincolnshire, in 1890.

Climate has little or no influence upon pneumonia, but with respect to season, it may be noted that mortality is greatest in this country in the winter and spring months. Coloured races are said to be specially susceptible. With regard to sex, the mortality is greater in males than females, and this is particularly the case between the ages 35 and 65. The extremes of life especially suffer from "pneumonia"; it should be noted, however, that the disease receiving this name which affects children and old persons is apt to differ, in symptoms and post-mortem appearances, from that met with at the intermediate ages. The pneumo-coccus of Fränkel and Weichselbaum can usually be demonstrated in the sputum and in the lung tissue in lobar pneumonia. It is generally regarded as the cause of lobar pneumonia, but the difficulty is that it is a widely distributed organism, and that it is even found in the saliva of healthy persons. Washbourn explained this on the assumption that "under ordinary circumstances the protective mechanism of the body prevents invasion; but should the cocci be introduced in very large numbers, or should the natural resistance of the body be lowered, invasion occurs and the disease develops." In the Middlesborough epidemic, as already mentioned, Klein was led to conclude that the cause of the disease was a bacillus which he called *Bacillus pneumoniæ*

Puerperal Fever.—This disease was well known to Hippocrates. It has assumed special importance in modern times, possibly in part as a result of the aggregation of women in lying-in hospitals. All that has been already said, concerning geographical distribution, seasonal prevalence and cyclical variations, in connection with erysipelas, is also true of puerperal fever. Since 1847 the puerperal fever deaths per 1,000 births, in this country, have ranged from 1·3 to 3·6 annually.

The recorded deaths in recent years have manifested a tendency to increase; probably this fact is due, in the main, to improved certification, as there is hardly any disease in which there appears to be greater liability to error, owing to deaths being returned under various headings. Moreover, since 1881, the Registrar-General has adopted the practice of writing for further details, in cases returned as pyæmia, septicæmia, and peritonitis in women of child-bearing age, and this has led to the inclusion of cases, as puerperal fever, which would otherwise have been overlooked (*See* p. 537). Since the introduction of antiseptic methods, puerperal fever has been almost banished from lying-in hospitals, and, having regard to this fact, a reduction in the recorded mortality from the disease might, *cæteris paribus*, have been anticipated.

Drainage defects have been observed in numerous instances, in connection with the occurrence of puerperal fever, and conditions of overcrowding, insufficient ventilation, and want of cleanliness undoubtedly favour spread of the disease.

Relapsing Fever.—The early history of this disease is enveloped in obscurity (*See* p. 375). Outbreaks occurred in Dublin from 1739 onwards; from 1799 accounts of the malady are forthcoming from Scotland; again in the great fever years, 1847–48, it was recognised in some of the English towns. In 1868–1873 it again appeared in England and Scotland, and Hirsch states that in London the earliest cases occurred "chiefly in a quarter inhabited by Irish and by poor Jewish families from Poland." Relapsing fever has been observed in other parts of Europe, notably in Russia and in Germany, and also in North America, India, China, and Egypt

The deaths recorded as due to the disease in this country, since 1869, have diminished in striking correspondence with the decline manifested by typhus deaths. Indeed, in its distribution in place and time relapsing fever closely approximates to typhus; the two diseases occur under like conditions, and often in association with one another; it is generally believed, however, that the one form of malady does not give rise to, and does not protect against, the other; moreover, the clinical distinctions between the two are well defined. The fatality in relapsing fever at all ages is about 4 per cent., but it markedly increases with advancing years. Season appears to have little influence in determining prevalence, but more cases, on the whole, occur in the colder months. The disease is rarely encountered except in association with overcrowding and destitution.

In 1873 Obermeyer found spirilla, during the febrile stage, in the blood of persons attacked by relapsing fever. These spirilla are very long, thin, actively motile, and show no appearance of being made up of shorter elements. They disappear from the peripheral circulation before the febrile stage comes to an end. Growth on artificial media has not been hitherto successfully demonstrated, but Vandyke Carter, in 1881, produced typical relapsing fever in the ape, by injection of blood containing spirilla, and the disease has also been developed in man by inoculation.

Rheumatic Fever.—The question of annual and seasonal influence in this disease was fully dealt with by Newsholme in the Milroy lectures of 1895. He found that there was a distinct relationship between deficient rainfall and prevalence of rheumatic fever, and that there was marked irregularity in the recorded mortality (as shown mainly by hospital statistics), with a tendency to special prevalence at intervals of from three to six years. It is probable that the disease, as Newsholme concludes, is due to a specific organism. Poynton and Paine isolated a diplococcus, in twelve successive cases of rheumatic fever, which produced, on intravenous inoculation into rabbits, the clinical appearances of that disease. The diplococcus was found with least difficulty in the connective tissues, and was obtained from the tonsils in rheumatic angina (*Lancet*, Sept. 22 and 29, 1900).

Rötheln.—The existence of a form of disease presenting some similarity to both measles and scarlet fever, but quite distinct from them, was already suspected more than a century ago. The opinion has, however, been entertained that this malady, to which the name Rötheln, or German measles, has been applied, must be regarded as a hybrid of scarlet fever and measles, and apart altogether from this hypothesis there can be no doubt that many cases of so-called German measles are really aberrant forms of one or other of the two more familiar diseases, or are mere instances of error in diagnosis. The generally accepted view, nowadays, is that a distinct specific malady does exist, and that it is capable of being distinguished by certain special characteristics which it possesses. Indeed, Dukes and others have of recent years maintained that there is yet another allied form of specific ailment to which the term "Fourth Disease" has been applied.

Rötheln is a comparatively rare disease; it has been noted that it is less markedly infectious than measles, and it is hardly ever fatal. Infection is probably conveyed by the breath; the period of incubation is said to be about a fortnight; the rash is, as a rule, present from the first onset of the malady; glandular enlargements, affecting particularly the posterior cervical glands, are sometimes present; the febrile disturbance is often out of proportion to the triviality of the symptoms; catarrhal affections are not marked, as is the case of measles; finally the rash differs in some respects from the eruptions developed in measles and scarlet fever. The period of infectiveness is said to last for about three weeks after the first appearance of the rash. The micro-organism which causes the malady has not been isolated, and nothing has been learnt concerning the spread of the disease by the agency of milk, or food, or as to its affecting any of the lower animals.

Scarlet Fever.—Little is known as regards the early history of scarlet fever. In the sixteenth century epidemics, of what may have been this disease, occurred in parts of Italy, and Ingrassias, in 1556, and Sennert, of Warsaw, in 1622, described cases of the malady. Sydenham, in 1676, wrote a chapter on it. He observes that it is scarcely worthy of the name of a disease, and makes no reference to sore throat in connection with it. Morton held that it was merely confluent measles, and throughout the eighteenth century there appears to have been a tendency to refer all but the milder forms of scarlet fever to the category of malignant sore throat. Thus Fothergill, in his account of the "putrid sore throat," written in 1748, speaks of a case in which a plentiful eruption of small pimples induced those about the patient to apprehend it was a common scarlet fever; again, some of the cases described by Huxham, of Plymouth, a few years later, as malignant ulcerous sore throat, were undoubtedly scarlet fever, as it is noted with regard to them that desquamation and dropsy occurred. Heberden, in his Commentaries, in discussing "angina and scarlet fever," says, "where it happens that the throat is full of little ulcers, attended with considerable pain, there the disease, though the skin be ever so red, is not denominated from this colour, but from the soreness of the throat, and obtains the name of the malignant sore throat; and many suppose that the two disorders differ in nature as well as in name. Of this let the reader judge when he has considered the histories of both."

In 1821 Bretonneau described and named diphtheria; but it was not until 1855 that scarlet fever was distinguished from diphtheria in the Registrar-General's returns. In 1859 a considerable prevalence of membranous sore throat occurred, and the mortality registered as due to diphtheria rose to 517 per million living, while that referred to scarlet fever was 976 per million living. From 1859 onwards, major prevalences of scarlet fever were developed at intervals of four or five years, the mortality in 1863 and 1864 was upwards of 1,400 per million living; in 1869 and 1870 the disease proved fatal to almost as great an extent; in 1874 the mortality exceeded 1,000 per million; again in 1878 it was 753 per million. Then followed a marked decline, with occasional exacerbations, but in 1887, a year of comparatively high mortality, the rate only reached 282 per million, and on the next occasion, when a maximum was attained, in 1893, the rate was only 235 per million. Thus "the nineties," as compared with "the eighties," and again "the eighties," as compared with "the seventies," and "the seventies," as compared with "the sixties," show marked diminution in the rate of mortality from scarlet fever. This diminution has, however, been accompanied from "the seventies" onwards by a steady though smaller increase in the registered mortality from diphtheria.

Geographical Distribution.—The disease especially prevails in North-West Europe and in North America; it is comparatively rare in Africa and Asia, but occurs in parts of those continents bordering on the Mediterranean. In this country it is much more destructive, as a rule, in cities than in rural areas, and it especially affects the industrial, and more particularly the mining counties. The explanation suggested by the Registrar-General, is that in these counties the population is more closely aggregated, and hence the spread of infection is facilitated. As he remarks, however, this "is not true as regards diphtheria, nor does it seem altogether true as regards measles."

The question of *periodicity* in scarlet fever has already been referred to. The *case-mortality* varies much in different epidemics, and has been said to range between 3 and 30 per cent. Graves, of Dublin, early in the last century, commented upon the marked variation in the fatality at different periods. In recent years the case-mortality observed in the Metropolitan Asylums Board Hospitals in London has steadily declined. For the six years (1887 to 1892) the average case-mortality was 8·35 per cent.; while for the six years (1891 to 1896) it was only 4·7 per cent. This decline, it should be noted, has been accompanied by a large increase, commencing in the early "eighties," and becoming very marked from 1887 onwards, in the proportion of deaths occurring in these hospitals, to the total deaths in London. Moreover, changes of nomenclature may be, in part at any rate, accountable for the decrease.

It is noteworthy that the marked diminution in the fatality from diphtheria, following upon the introduction of antitoxine, in 1895, finds in some respects a parallel in the case of scarlet fever. Shirley Murphy has shown that while comparison of two periods, 1888 to 1894 (years in which antitoxine serum was not used), and 1895 to 1898 (years in which it was used), shows, in the case of diphtheria, a reduction in the case-mortality, of cases treated in hospital, from 30·3 to 18·4 per cent., there has been almost as considerable a reduction, from 7 to 4·4 per cent., in the case-mortality of hospital cases of scarlet fever. It appears, however, on comparing hospital cases with those occurring throughout London generally, that there is a marked contrast in the behaviour of the two diseases, and this fact is of significance when it is borne in mind that the proportion, of the total cases of diphtheria in London, admitted into the hospitals, has been far greater in the later than in the earlier period. Shirley Murphy finds that, "whereas, both in 1892–94 and 1895–98, the fatality among cases of scarlet fever treated in Metropolitan Asylums Board hospitals has been greater than among cases notified in London not so treated, the fatality among cases of diphtheria treated in Metropolitan Asylums Board hospitals, which, in the period 1892–94, was greater than the fatality among cases in London not so treated, was, in the period of 1895–98, practically the same at 'all ages,' and much lower at the younger ages, than the fatality, in London, among cases not admitted to the hospitals of the Metropolitan

Asylums Board. In these considerations, and particularly in the lower fatality at the younger ages, in hospital treated cases, there seems to be clear indication that some special factor has been operative in diphtheria, and the explanation may in part, at any rate, be sought in the application of the antitoxine treatment in diphtheria cases."

Climate and Season.—The fact, that the disease appears unable to establish itself in the tropics, suggests that climate influences its prevalence. Ballard, some years ago, pointed out that in this country "a temperature above the average for the season, and a dry state of the atmosphere with little rain, favour the presence of scarlet fever more than the reverse conditions." Longstaff, in 1880, drew attention to the striking similarity of the curves depicting fluctuations in mortality, during the years 1855–1880, from diseases belonging to what he styled the "scarlatinal group." The diseases in question (pyæmia, puerperal fever, erysipelas, rheumatism of the heart, scarlatina, laryngitis, quinsy, croup, and cynanche maligna), exhibited, throughout these years, variations in recorded mortality in close correspondence with one another. The elevations and depressions, so well marked in the scarlatina mortality curve, were more or less traceable in all the others; there was also noticeable, in the case of each individual curve, a tendency to exhibit an inverse relationship to the rainfall, dry periods corresponding to increased mortality, and periods of heavy rainfall to diminished mortality. On bringing the investigation up to date, subsequent to 1890, the resemblances indicated were found to be not so closely maintained in the later period of years. The subject of the relation of diphtheria to rainfall has been recently elaborately investigated by Newsholme, in his work on "Epidemic Diphtheria."

The annexed figure depicts the London curve of mortality for the years 1861–1900. In New York the curve differs markedly from this, the maximum being in April and the minimum in September. It may here be noted that Whitelegge found, at Nottingham, that fewer cases of scarlet fever were notified on Wednesday than on any other day of the week, a fact which he attributed to diminished likelihood of infection, owing to the cessation of school attendances upon Sundays. The seasonal curve shows no trace of diminution of mortality following upon holidays, but the London curve of *notifications* for individual years presents, as a rule, as has been already mentioned, a well-marked "August depression," in correspondence with the cessation of school operations during the summer holidays.

Fatality.—The case-mortality of scarlet fever, as tested by hospital statistics, was found by Whitelegge to present variations corresponding with the cyclical fluctuations, in mortality from the disease, observed during the "sixties" and "seventies." As regards seasonal variations in case-mortality, it would appear from statistical records that the relationship is an inverse one, the disease being least fatal during the months when it is most prevalent. On the other hand Gresswell found evidence, from study of cases in one of the Metropolitan Asylums Board's hospitals, to the effect that the graver manifestations of the disease became more frequent and more marked during September, October, and November, and then underwent mitigation. Shirley Murphy has investigated the seasonal

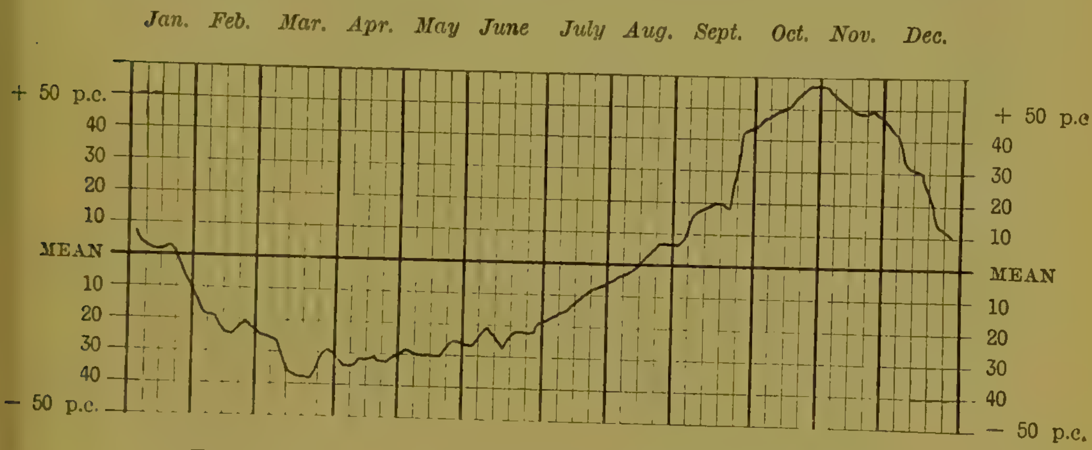

FIG. 90.—SCARLET FEVER IN LONDON (forty years, 1861–1900).
The mean line represents an average weekly number of thirty-seven deaths.
(*After Shirley Murphy.*)

variations in fatality as exhibited in London, and finds that the case-mortality is lowest from July to October. He has, moreover, pointed out that the figures show that there is a seasonal variation in the age-distribution of scarlet fever cases. Thus, children under 5 years of age constitute a greater proportion of the total cases in the early part of the year, and this proportion falls to a minimum in September, subsequently rising to the end of the year. "There is arrest of this fall in the month of August, due to the fact that children of the school age are not then contracting disease in schools, and that children under 5 constitute, therefore, a larger proportion of the total cases."

Influence of Age and Sex.—The influence exerted by age and sex upon liability to attack and upon mortality from scarlet fever, was examined in great detail by the Registrar-General in his Annual Report for 1886. He found that liability of the unprotected to infection was small in the first year of life, increased to a maximum in the fifth year or soon after, and then rapidly became smaller and smaller. The chance of an attack being fatal was greatest in infancy, it then diminished up to the end of the twenty-fifth year, after which it again somewhat increased. Females, speaking generally, were found to be more subject to attack than males; but attacks in males, though fewer, were more liable to terminate fatally. The actual mortality observed attained a maximum in the third year of life, the diminution at later ages being due (*a*) to the increased proportion in the population at each successive age-period, of persons protected by a previous attack; (*b*) to the diminution of liability to infection in successive age-periods, of those as yet unprotected; and (*c*) to the diminishing risk in successive age-periods, of an attack, should it occur, proving fatal. As the Registrar-General says, these results show, "independently of the plain fact that a very large proportion of persons go through life without ever contracting the disease, that the longer an attack is deferred the less likely it is to occur at all; and not only so, but that, even supposing it to occur eventually, the less likely it is to end fatally."

Dissemination.—The disease is probably not infectious until after the eruption appears; its infectivity is supposed to be pronounced when desquamation is in progress. Recent observations tend to discredit the hypothesis that the desquamating cuticle is mainly responsible for the spread of infection; probably the discharges from mucous surfaces must be regarded as more open to suspicion. The breath and the various secretions are often, no doubt, the means of conveying the disease; there are numerous instances recorded, too, in which clothing, etc., put aside for a time when the patient sickens, but not adequately disinfected, has appeared to possess the property of transmitting scarlet fever. Inquiry has shown that the malady exhibits no special incidence upon houses in the neighbourhood of fever hospitals, and infection cannot, therefore, be conveyed aerially for considerable distances, as is the case in small-pox. Scarlet fever has never been found to be spread by water; it is frequently, however, transmitted by the agency of infected milk (*See* p. 198).

Isolation.—The isolation of scarlet fever has for some years been extensively practised, particularly in this country, and as the system of removal to special hospitals, accompanied by disinfection of rooms occupied by the patient, clothing, etc., has been more and more perfected, the mortality from the disease has steadily declined. During the years 1870–90 isolation was mainly confined to the larger towns, but the decline in mortality had barely commenced in these large centres of population when it was also manifested throughout the country generally, including towns and rural districts in which no attempt at isolation had been made. This is hardly matter for surprise, inasmuch as the spread of the disease in sparsely populated districts is admittedly, to a considerable extent at any rate, facilitated by the importation of infection from more thickly populated areas, in which scarlet fever always, to a greater or less extent, prevails.

It has been further objected, however, that comparing one country with another, mortality has fallen in those which have not attempted to combat the disease by preventive measures, as well as in those that have. Dr. J. T. Wilson, in a thesis published as a supplement to "Public Health" (1897), concludes, on an extended survey of the movement of scarlet fever mortality, that some more widely operating influence than mere isolation must have been at work in bringing about the reduction that has taken place. Again, the fact that the enforcement of removal to hospital has not eradicated the disease has been commented upon. With regard to this argument, however, it may be urged that some of the factors which contribute to the spread of the malady may yet remain in uncontrolled operation; having regard to what has been already said concerning scarlet fever, it is abundantly clear that its diffusion is not merely a question of personal infection or of contact with infected clothing, etc. Moreover, as Newsholme points out, isolation and disinfection have not hitherto been fully operative "because diagnosis has been defective, carelessness has been prevalent, and isolation has been delayed and carried out in an insufficient number of cases, and because disinfection has often been effected in a perfunctory manner."

Return Cases.—A good deal of attention has been directed of late years to criticism of hospital administration in connection with the occurrence of "return cases" of scarlet fever and diphtheria. In instances in which a child has returned from a fever hospital, and shortly afterwards another inmate of the house has been attacked by the disease, it has, perhaps, not unnaturally been assumed that the second person was infected by the returned convalescent, and it has then further been concluded that the hospital administration has been at fault. The fact must not be lost sight of, however, that, having regard to the large scale on which isolation has been practised in recent years, a certain number of instances, in which the sequence of events referred to has occurred, might be expected to be forthcoming, apart altogether from infection by the hospital case; moreover, it is probable that some so-called "return cases" may be really attributable to newly bringing into use imperfectly disinfected garments. Again, "the possible influence of school attendance in its relation to alleged return cases is, perhaps, especially deserving of attention," and "the possibility of alleged return cases being part and parcel of a milk outbreak should also, of course, be borne in mind."

With regard to the influence in this connection of school operations, a report by T. W. Thompson on return cases of scarlatina (Twenty-fourth Annual Report of the Medical Officer of the Local Government Board) is particularly instructive. Questions as to the general character of the households from which patients were sent to hospital, and as to excess in them, of persons of the ages most susceptible to scarlatina, and of scholars at public elementary schools, were regarded, by this observer, as having had some share in determining the preponderating incidence of secondary scarlatina on particular households in Bromley and Beckenham, in the years 1892–4. He did not find "sufficient evidence to show the extent to which, if indeed at all, such cases were attributable to defective hospital administration," though he thought it not improbable that overcrowding of the hospital wards might have contributed to the production of secondary cases. He further drew attention to the influence of season, and to that of the stage of the epidemic, as probably having important concern with the occurrence of "return cases."

Dr. W. J. R. Simpson reported in 1899 to the Metropolitan Asylums Board on "Return Cases of Scarlatina and Diphtheria." He found that during the six months October 1st, 1898, to March 1st, 1899, 6,507 cases of scarlet fever and 3,275 cases of diphtheria were discharged from the Board's hospitals; during the same period there appeared, within a month, in houses to which discharged cases were returned, 253 fresh cases of scarlet fever and 86 of diphtheria. "There occurred at the same time in the districts of London 13,955 cases of scarlet fever and diphtheria, so that the 339 secondary cases arising in houses subsequent to the arrival of primary cases discharged from hospital, were equal to a percentage of 2·4 on the total number notified, or 2·8 for scarlet fever and 1·9 for diphtheria.* The incidence varied much in

* If during six months cases of scarlet fever or diphtheria occur, say, in 2,000 houses per month (*i.e.*, in 12,000 houses), it may be calculated how many reinvasions of houses involved during a particular monthly period might be expected, as a mere matter of coincidence, assuming that every house in London was equally likely to be invaded. Thus the total number

different parts of London, it attained a maximum in Battersea, where secondary cases of scarlet fever represented 8 per cent. of the total notified cases, and secondary cases of diphtheria amounted to 5 per cent. of the notified diphtheria cases.

On making personal inquiry concerning the 339 secondary cases, Simpson found that in 123, or 36 per cent., there was no evidence to support the conclusion that they were return cases; thus in some instances the secondary cases occurred immediately before the primary cases returned home; or, again, the secondary case was one of a different form of disease from that affecting the supposed primary case. In other instances some other probable source of infection was heard of—infected clothing, toys, etc.; and in the remaining cases there was no evidence "from either the condition of the primary case or in the circumstances under which the illness of the secondary case took place, to show that the infection was connected with the return home of the primary." Again in thirty-six cases the evidence was of a doubtful nature; while in seventeen others it was impossible to dissociate infected clothing, etc., or house infection, from personal infection.

There remained 159, or rather less than half the total number of cases, which Simpson classed as "probably due to personal infectivity of the primary case." He noted that the primary infective scarlet fever cases were more than twice as numerous as

of houses being taken as 600,000, the number of such re-invasions in six months would approximately be $\frac{2,000}{600,000} \times 12,000$, or 40. It is obvious that all the 600,000 houses are not equally likely to be invaded: many contain no susceptible persons, or even if there be susceptible persons in them there is no likelihood, owing to freedom of the locality in which the house is situated from disease, of infection being acquired. Having regard to the limitation of scarlet fever to particular areas, in milk outbreaks, school outbreaks, etc., and to the greater risk in localities where the population is closely aggregated and so on, it is clear the above-mentioned 40 must fall considerably short of the number which chance, and chance alone, would explain. It may be assumed, moreover, that a certain number of cases affect houses previously invaded owing to the persistence of some source of infection in the home environment, and quite independently of hospital influence. That something more than the mere play of chance is concerned in the production of "return cases" is, however, proved by the fact, that study of multiple notifications shows secondary cases are notified, from houses, more frequently during the period of eight weeks, from the eighth to the fifteenth week, after the notification of a first case, than they are during the eight weeks comprising the fourth to the seventh, and the sixteenth to the nineteenth weeks, after such first notification. This distribution in time suggests that returned hospital convalescents may in rare instances promote the spread of disease. Niven fully discusses the subject of "return cases" in his Annual Report for 1901.

the diphtheria cases; that the percentage of primary infective cases did not greatly vary when the eleven individual hospitals discharging cases were separately considered; and that the variation, such as it was, did not appear in any way to be connected with shorter detention of the patients in the hospitals concerned: further, that while only in rare instances was desquamation present in the primary infective cases, in at least four-fifths of these cases discharge from one or other mucous membrane was found to be present. Of the infective primary cases the majority had not been isolated for a specially brief period, and in one instance the supposed primary case had actually been detained eight months in hospital. Simpson attached much importance to the mucous discharges to which reference has been made, and he advanced the hypothesis that these discharges do not themselves possess infectious properties, unless it be by acting as suitable media and carriers for any possible infection that may come in contact with them. His reasons for thinking that the secretion, *per se*, is not infectious, but that it has been rendered infective by accidental contamination, are:—

1. That the ward itself is in an infective state.
2. That the infective property does not continue long when the patient returns home, though the discharge continues.
3. That when there is a recurrence of the discharge some time after the return home of the patient from hospital, the patient is not infective, and
4. That a large number of children with discharge from the ear or nose go home without infecting anyone else.

Simpson refers to the need of caution with regard to the use of warm baths immediately before discharge in winter, and to the desirability of issuing instructions to parents, so that suitable precautions may be taken when the patient returns home; he also thinks that more attention might be paid to the disinfection of clothes by steam, and advocates, on the whole, a reduction rather than an extension of the duration of the period of detention of scarlet fever and diphtheria cases in hospital. This report, and the observations made upon it by the medical superintendents of the various hospitals, were considered by a committee of the Royal College of Physicians. The committee commented on the small percentage of the cases found to have given rise to fresh infections, and considered that possibly too much importance had hitherto been attached to the infectivity of the skin during the later weeks of scarlatinal convalescence. With regard to the question of infectivity of the mucous discharges, the committee suggested that further inquiry should be made. "If," they say, "it can be proved that the discharge after a time constitutes simply the vehicle, as suggested by Dr. Simpson, and is not in its nature infective, as is usually believed, it is obvious that the practice of removing the patient from an infective environment for a short period before return to his home is one which should be adopted."

Other Preventive Measures.—The measures usually adopted in the treatment of the skin of scarlatina convalescents, bathing in warm water, thorough application of soap, etc., cleansing of the hair, and the like, may with advantage be supplemented by the use of antiseptic solutions to affected mucous surfaces. The nozzle of the syringe used, should, of course, be kept in a germicidal solution, so as to prevent spread of disease from one patient to another. The importance of disinfecting clothing, bedding, furniture, and the walls and floors of dwelling rooms, should, moreover, not be lost sight of. Having regard to the liability of milk to spread scarlatinal infection, this fluid should always be boiled or pasteurised before it is given to children.

Sleeping Sickness: African Lethargy.—This disease occurs in tropical West Africa, particularly on the Lower Congo, but also in the basins of the Niger and Senegal rivers. It may not be developed until some time after residence in a locality in which the disease is endemic, and thus an interval of as long, it is said, as seven years, may elapse between exposure to infection, in such a place, and the appearance of symptoms. At the onset of the malady an epileptiform attack sometimes occurs, gradually, lassitude, weakness and somnolence develop; muscular tremor, convulsions, anæsthesia, paralysis and maniacal attacks may be observed. Manson states that enlargement of the cervical glands and a papulo-vesicular eruption, commonly affecting the chest, are almost invariably present. He comments on the singular correspondence between the distribution of the disease, and that of *filaria perstans*, and suggests that this parasite may be in some way responsible for sleeping sickness.

Small-pox.—*History.*—There is considerable reason for supposing that small-pox prevailed in Hindustan and in China before the Christian era, and the practice of inoculation is said to have been introduced in the last-named country in 590 A.D. As regards Greece and Rome, the existence of outbreaks of the malady cannot be definitely proved or disproved. Rhazes, who died about 923 or 930 A.D., wrote a treatise on small-pox and measles, and it is clear that small-pox was well known to other Arabian physicians. In Europe in the middle ages the accounts given, in annals kept in various monasteries, make it probable that the disease from time to time prevailed. Certain early references in Irish records have in particular been cited in proof of this. In Iceland numerous outbreaks are said to have occurred from the thirteenth century onwards. In England, indications of a detailed and precise character are not forthcoming in the dark ages. In the Elizabethan period the disease was already well known, and the earliest Bills of Mortality show that small-pox was thoroughly established in London; indeed, from 1629 onwards it appears to have been constantly present.

The malady caused somewhat higher mortality in the eighteenth than in the seventeenth century; the highest proportion of deaths attributed to the disease was attained in 1796, when out of a thousand deaths from all causes included in "the bills," 184 were ascribed to small-pox. This proportion probably understates the actual facts, as it is doubtful whether deaths from small-pox under two years of age were included in the returns. There was a steady decline subsequent to the introduction of vaccination in 1798; but a considerable prevalence, though one of comparatively small proportions when gauged by the eighteenth-century standard, again occurred in 1838. Then followed rather more than thirty years of relative freedom from the disease, though during this time outbreaks, of comparatively small magnitude, developed at intervals of three to five years. In 1871 a considerable prevalence occurred, the death-rate per million in England and Wales being almost as high as it had been in 1838. In the years subsequent to 1871 small epidemics prevailed at intervals of four or five years, the last of this series of any considerable importance being that of 1885, when 104 persons per million in England and Wales died of small-pox. Then followed a period of markedly lessened prevalence of the disease, though in 1893 the mortality in England and Wales reached 49 per million living. In 1901-1902 small-pox again manifested ability to spread in London.

Geographical Distribution.—Small-pox has occurred from time to time over almost the whole inhabited globe, though in Australia and in New Zealand it has hitherto never attained anything like the proportions of an epidemic. In parts of Africa and of Asia it appears to be almost constantly present, and, in particular, Egypt, Nubia, Abyssinia, and the Soudan, on the one hand, and Persia, Arabia, and India, on the other, have been spoken of as endemic foci of the disease.

Seasonal Prevalence.—In this country, small-pox tends to be above the mean in the first half of the year, and below it in the latter half. In the East the spread of the malady appears

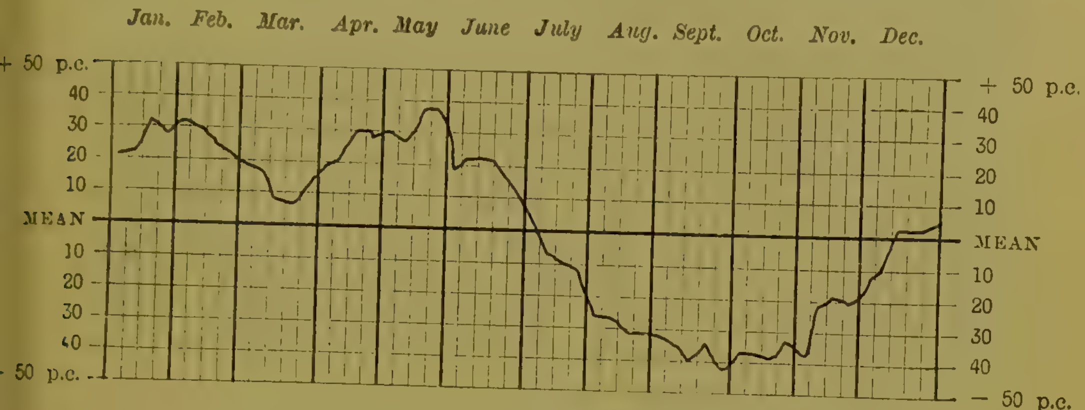

FIG. 91.—SMALL-POX IN LONDON (sixty years, 1841-1900).
The mean line represents an average weekly number of fourteen deaths.
(After Shirley Murphy.)

to be less marked in hot seasons, and to be favoured in cold seasons. *Soil and Climate* seem to have little or no influence upon small-pox. As regards *Race*, it may be noted that negroes are peculiarly susceptible.

Age and Sex.—Males suffer at almost all ages to a greater extent than females. The question of age-incidence is largely affected by the periodicity of epidemics, a point which has been already referred to. Moreover, the remarkable variations in age-incidence which have occurred, as vaccination has been more and more thoroughly and extensively put in practice, will have to be later considered.

Dissemination.—Infection is probably conveyed in most instances by the breath; it is also transmitted by clothing, rags, etc. The researches of Power have shown that the disease may be aerially transmitted through considerable distances, under certain favouring conditions, indeed a marked incidence of the malady upon persons living in houses situated even from three-quarters of a mile to a mile from a small-pox hospital, acting as an infecting centre, has been repeatedly observed (*See* p. 300).

The *incubation period* is usually twelve days, the initial symptoms commonly appearing on the thirteenth, and the rash on the fifteenth day. The latent period may be, however, longer or shorter than that specified, by four or five days, and the rash is sometimes delayed until the fourth day. The *case-mortality* of small-pox varies in different epidemics; the disease is said to be specially fatal when it affects populations it has not previously attacked. Age exerts considerable influence, the fatality being high in infancy, decreasing to a minimum between the tenth and the fifteenth years, and then increasing fairly steadily again as age advances. Hence the distribution in ages, of susceptible persons, in a particular population attacked, materially influences the fatality observed in individual outbreaks. In the eighteenth century Dr. Jurin collected particulars concerning some 18,000 cases, which showed an average case-mortality of 16 to 18 per cent. In the one instance—that of Aynho, in Northamptonshire—in which the ages at death are given, most of the cases occurred at from five to twenty-five years of age, and no mention is made of deaths under two years of age. McVail has suggested that "Jurin did not knowingly set down any deaths under two years old as due to small-pox," but relegated them to other headings, and that his percentages are irretrievably damaged by this omission. Whatever may be the correct interpretation of Jurin's statistics, there can be no question that the fatality of the disease among unvaccinated persons, as observed in hospitals since precise records have been collected, has been considerably higher than 18 per cent.; indeed, it has been found to be from 30 to 40 per cent. or more at all ages. The protection afforded by an attack of natural small-pox is considerable, but by no means absolute throughout life.

Inoculation of small-pox virus was found to be followed by the appearance of a small papule on the second day; this became vesicular, with evidence of depression, as a rule, in the centre of the vesicle, on the fifth day. On the seventh day the vesicles contained pus, and the central depression was more marked; an areola was developed, which enlarged, as a rule, up to the tenth day; within its area secondary pustules usually appeared. The pustule was commonly observed to dry up after about a fortnight, and the crusts separated from the end of the third to the beginning of the fifth week. Inoculation was introduced in this country in 1721, and the practice was gradually extended. One operator alone, Daniel Sutton, claimed, in 1796, that he had inoculated 100,000 persons. The "Suttonian method" appears to have consisted, essentially, in taking material exclusively from the "mother pustule"—*i.e.*, before the general eruption had appeared.

Vaccination.

The history of small-pox in the nineteenth century is intimately bound up with the subject of vaccination; and the influence which this last-named operation exerts upon the disease must be considered in detail.

The course run in an ordinary vaccination is as follows:—A small elevation develops on the second or third day. On the fifth or sixth day this pustule becomes a vesicle, and presents a slight central depression; but this does not become so marked as in the case of inoculation of the small-pox virus, and secondary pustules do not later appear, as has been noted to be usually the case in inoculation. The vaccine vesicle attains maturity on the eighth day, when it is full of clear lymph, and is surrounded by an areola, which may ultimately extend until its diameter is from one to three inches. About the tenth day the fluid of the vesicle, now opaque, begins to dry up, and a scab is formed, which separates, leaving a scar at the end of about three weeks. The phenomena in revaccination differ from those already described. The maximum effect may be produced on or before the fifth day; vesiculation may never be observed, or the vesicles, if formed, may abort, and the scabs may separate early. The areola extends, however, more widely, as a rule, and glandular enlargement and considerable febrile disturbance may be produced.

The incubation of vaccination is shorter than that of small-pox, and hence, according to Marson, successful vaccination, within three days of exposure to infection, may altogether prevent an attack of the disease, and, even as late as the sixth day, the attack may be distinctly modified. It was the practice until recently to vaccinate from arm to arm; an animal station, providing for vaccination directly from the calf, was established, however, by the English Government in 1881. Copeman, in 1891, called attention to the desirability of employing glycerinated lymph. The glycerine rapidly destroys extraneous organisms; but for a time the lymph still manifests ability to produce characteristic appearances, at the site of inoculation, and it is assumed that its protective properties are not materially impaired. Glycerinated calf lymph is now largely used for the purposes of vaccination.

The grounds for concluding that vaccination profoundly modifies, if it does not altogether prevent, a subsequent attack of small-pox, may be considered under the following heads:—

I. **The reasons which orginally led to the belief that vaccination affords protection against small-pox.**—Towards the end of the eighteenth century the notion was entertained, by dairymen and others in places where cow-pox prevailed, that persons who had suffered from cow-pox were protected against subsequent attack by small-pox. Benjamin Jesty, a Dorsetshire farmer, in 1774, inoculated his wife and sons with cow-pox material, with a view to affording them such protection. Edward Jenner, when an apprentice in Gloucestershire, about 1768, had heard of the belief held by the dairy folk, and he instituted a prolonged investigation into the matter, and at length, in 1798, published his "Inquiry into the Causes and Effects of the Variolæ Vaccinæ."

In this treatise he recorded nineteen instances, which he had observed of persons who had accidentally acquired cow-pox, and who appeared subsequently to be incapable of taking small-pox, their insusceptibility being deduced from their failing to contract the disease on being exposed to it, or from the fact that they did not respond to the "variolous test"—*i.e.*, to inoculation with small-pox material. Jenner, moreover, gave particulars concerning the inoculation of a boy (Phipps) with cow-pox material in 1796. He described the appearances produced at the site of inoculation, and the failure of the variolous test when tried six weeks later, and again, when applied after an interval of some months. Further, Jenner related how, in 1798, he inoculated a child with cow-pox material; from this child another child; from this again several children; from one of these a fourth in succession, and then a fifth. In three of these children the variolous test was applied with a negative result.

In 1799 Woodville and Pearson instituted an inquiry into the matter, and the practice of vaccination was gradually extended. Some of Woodville's cases developed a pustular eruption, and it would appear, therefore, that his results were complicated by the occurrence of small-pox infection, and that he was not dealing with cow-pox exclusively, but that a number of his patients were actually suffering from small-pox. The test of immunity was applied, however, in all instances, and no contrast was observed, as regarded the protection afforded, between the cases in which an eruption appeared, and those in which it did not. Moreover, as is noted in the Final Report of the Vaccination Commission, 1896, "admitting the error introduced by the pustular cases, it must be remembered that the error was of brief duration; the pustular cases relatively numerous at the outset, in the experience of Woodville, and in that of some other observers, soon became exceptional in the experience of all. Within one or two years the error was recognised, and it was generally acknowledged that inoculated cow-pox differed clearly from inoculated small-pox, in being, as a rule, unaccompanied by an eruption of pustules, and especially in not being contagious."

The College of Physicians reported on vaccination to the

House of Commons in 1807, and as the result of their inquiry, "felt it to be their duty strongly to recommend the practice of vaccination." Further, vaccination was extensively practised on the Continent. Thus, as McVail remarks, "all over the civilised world thousands of persons who had not undergone a certain preliminary operation were inoculated with the virus of small-pox, and with a very small percentage of failures all received the disease; and simultaneously all over the civilised world, thousands of persons who had undergone the preliminary operation in question, were also inoculated with the virus of small-pox, and with a very small percentage of exceptions all resisted the disease." It has been observed that the tests applied by the early vaccinators were "equal in value to the experiments carried on in the biological laboratories of the present day; while in number they were infinitely greater."

II. The behaviour of small-pox subsequent to the introduction of vaccination.—In the Final Report of 1896, this matter is discussed under two heads; the earlier period (1800 to 1825) being first dealt with, and then the period since 1825.

A. The London "bills" and the records of small-pox mortality which are forthcoming from other parts of the country, the Swedish figures which date from 1774, those of Copenhagen, which extend back to 1750, and the available statistics relating to other countries of Western Europe and to the United States, all indicate that the first quarter of the nineteenth century was marked by a great diminution of small-pox deaths. In Sweden, "from 1801 onwards, there is a fall, becoming great after 1809." In Copenhagen "small-pox was prevalent up to 1801, then suddenly declined; indeed, for a while it quite disappeared, no deaths being recorded between the years 1810 and 1824."

It has been urged that the introduction of vaccination tended to cause the abandonment of inoculation, and that inasmuch as inoculation had increased the amount of small-pox, the diminution of the disease, in the first quarter of the nineteenth century, is explicable as resulting from decrease of inoculation. The Vaccination Commissioners deal with this objection in paragraphs 64—75 of their Final Report. They point out that the increase of mortality from small-pox during the eighteenth century occurred in its first quarter, when there was no inoculation at all, and during the second quarter, when there was very little, to as great or an even greater extent than during the third quarter, when inoculation was most prevalent. Moreover, as they note, it should be borne in mind that inoculated small-pox was, on the whole, much less fatal than the naturally acquired disease; and they refer to records which indicate that inoculation, when carefully practised, may materially diminish mortality from small-pox. They say "the general conclusion which may be drawn seems to be that inoculation had a double influence, the one favourable, the other unfavourable, as regards small-pox, and owing to the conflict between these two influences it produced but little effect upon the prevalence of, or mortality from, small-pox."

Another suggestion which has been made is that the decline of small-pox, which followed the introduction of vaccination, was due to improved sanitary conditions; a similar diminution did not, however, occur in the case of measles, but, on the other hand, there was a marked falling off in the number of deaths returned as being caused by "fevers." As regards this last-mentioned phenomenon, however, altered nomenclature was probably largely operative; indeed, "scarcely any heading in the bills can be less safely trusted as an indication of the conditions affecting disease"; further, the decline was observed not merely in this country, but in other countries where the sanitary conditions were widely different (*See also* p. 430).

The Commissioners in summarising the evidence say, "The decline in question followed upon the introduction of the practice of vaccination. The records of Western Europe and the United States show that, in all places whence returns were obtained, the introduction of vaccination was followed by a decline of small-pox, the decline becoming especially apparent after the lapse of such time as may be supposed to be necessary for the due spread of the practice; moreover, the spread of the practice and the decline of the disease do not stand as two phenomena simply following the same course, but without any tie joining the two; the experimental evidence offered at the time—namely, that the class of vaccinated persons did not take small-pox, by way either of exposure to natural contagion or of inoculation, as the unvaccinated did—connects the two and points to the spread of the practice as the cause of the decline."

It further appears, from such information as is available, that in countries where vaccination did not become general the decline did not occur; and, with regard to the objection that the decline observed was out of all proportion to the amount of vaccination that prevailed, it has to be borne in mind that, in the early part of the last century, only a small portion of the population needed to be protected by vaccination, inasmuch as at that time large numbers of persons had been rendered immune by previous attacks of small-pox, either natural or inoculated.

B. The statistical data which have accumulated, during the last three quarters of the nineteenth century, afford a mass of material for study in connection with the protective influence of vaccination against small-pox. In England and Wales the registration of deaths commenced in 1837, in Scotland in 1855, and in Ireland not until 1864. In the later years of the century, observations made at small-pox hospitals and special reports upon particular outbreaks of the disease became available. The facts may be examined under several heads.

(*a*.) Vaccination Legislation and Small-pox Mortality.—In 1840 an Act was passed to extend the practice of vaccination, by which the guardians and overseers of parishes were empowered to contract for the performance of vaccination. The same Act made inoculation of small-pox illegal. In 1841 it was enacted that the expenses of carrying out the Act of 1840 should be chargeable to the poor-rate, but that no disability or disqualification should attach to any person vaccinated by the parish officer, or to whom surgical or medical assistance, incident to the vaccination, was rendered by him.

In 1853 vaccination was made compulsory and enforceable by penalty, but no adequate machinery for carrying the law into effect was yet provided. The Act of 1867 authorised the appointment of paid vaccination officers, and the Act of 1871 made the appointment of such officers compulsory in all Unions. From 1872 onwards records have been kept by the Local Government Board showing the amount of vaccination, performed within a certain period of birth, in children whose births are registered during each year. The published tables exhibit, for each year, the number of births and give the figures relating to those successfully vaccinated, those certified as insusceptible, or as having had small-pox, and also the number of those dying unvaccinated, or having vaccination postponed by medical certificate.

The children not finally accounted for, including cases postponed, constituted, as a rule, from 1872 to 1883, rather less than 5 per cent. of the births; the percentage then gradually increased to 22·3 in 1896. In 1897 the increase was for the first time checked, the percentage in that year being 21·6. The diminution in the percentage of children vaccinated since 1883 "did not, of course, necessarily result at once in a diminished proportion of the population who had at some time in their lives been vaccinated." Broadly speaking, the proportion of children primarily vaccinated steadily grew from 1840 onwards, with an augmented rate of increase after 1853, and again, even more notably, after the years from 1868 to 1872. The proportion must, however, have diminished from shortly before the year 1890, onwards.

There has been in England and Wales a notable decline in the small-pox death-rate; in "the fifties" as compared with the earlier period, and in "the sixties" as compared with "the fifties." In 1871 and 1872 the death-rates were in marked excess, attaining to figures comparable with those of the earliest years of the registration period; in the remaining years of "the seventies" the decline was again continued, and it became more marked in "the eighties" and in the closing years of the century.

A table was prepared by the Registrar-General, and printed in his Forty-third Annual Report (p. xxii.), in illustration of the changes which had occurred in the death-rate from small-pox at successive periods of life. This table, brought up to date, was presented to the Vaccination Commission, and is here given.

MEAN ANNUAL DEATHS FROM SMALL-POX AT SUCCESSIVE LIFE PERIODS, PER MILLION, LIVING AT EACH LIFE PERIOD, 1847–53, 1854–71, AND 1872–87.

Period.	All ages.	0–5.	5–10.	10–15.	15–25.	25–45.	45 and upwards.
1. Vaccination optional, 1847–53*	305	1,617	337	94	109	66	22
2. Vaccination obligatory but not efficiently enforced, 1854–71 ...	223	817	243	88	163	131	52
3. Vaccination obligatory but more efficiently enforced by vaccination officers, 1872–87	114	242	120	69	122	107	47

The arrangement of this table has been made the subject of much criticism. The division into periods, adopted by the Registrar-General, has been said to tell in favour of vaccination inasmuch as the prevalence of 1871 and 1872 falls largely within the second period, whereas it is urged it should have been included in the third period. Having regard to the fact that a large proportion of those attacked in 1871–72 were persons of the higher ages, and that many of them were born before 1853, when vaccination was optional, the contention appears to be beside the mark; indeed, for the purpose of examination of age-periods attacked, which was the

* In this table the period of optional vaccination begins with 1847, not with 1838, because the deaths were not abstracted in combination with ages until 1847.

question the Registrar-General had in view, the classification adopted seems altogether free from objection. With regard to the "suggestion" which has been made that the division should be made by the law of 1867, and not by that of 1871, the inclusion or exclusion, of the figures of the 1871 outbreak, can of course be shown to affect the figures of groups of a few years, surrounding, and including or excluding, that date; speaking generally, however, there has been, since 1838, a marked though irregular decline in the death-rate from small-pox, though this decline has not been shared alike by the population at every age; indeed, at higher ages there has been actual increase in the death-rate. This question of altered age-incidence will be further considered almost immediately.

In Scotland, gratuitous vaccination had been provided since 1848, but it was not until 1863 that vaccination was made compulsory. Returns, relating to the primary vaccination of children, show that between 1864 and 1893 the number unaccounted for was only about 3 per cent., with, in later years, a slight increase to over 4 per cent. From 1855–64 the small-pox mortality varied between 11 and 58 per 100,000 living; after this there was a marked decline; then there was marked prevalence during the years 1871–74, followed by a sudden decline; and no considerable prevalence again occurred during the remaining years of the century.

In Ireland, in 1840–41, as in England and Wales, provision was made for vaccination. The law was amended in 1851 and 1858, but it was not until 1863 that vaccination was made compulsory. Further Acts were passed in 1878 and 1879. Approximate figures relating to the death-rate in Ireland are available for 1831–41, 1841–51, and 1851–61, the average annual rates per 100,000 living being 73, 49, and 21 in those periods. From 1864 onwards the deaths are precisely recorded, and show marked decline after 1864, then a rise corresponding to that noted in England and Scotland in the years 1871 and those immediately succeeding, and then again decline, with some irregularity, but becoming particularly marked after 1880.

The Vaccination Commissioners, in their Final Report, say—"It seems to us scarcely possible to deny that, speaking generally of the British Isles, a more vaccinated population has exhibited a diminished mortality from small-pox. It was not, of course, to be expected that this should be seen year by year, or that the correspondence should be exact, even assuming vaccination to be the principal cause of this diminished mortality. We have already pointed out that small-pox tends at times to become epidemic, *i.e.*, to spread more readily than at other times. The occurrence of the conditions, whatever they may be, which cause the disease to be thus epidemic has, of course, no relation to the state of the population as regards vaccination, even conceding to the full that it has a protective effect. The only result of widespread vaccination, in a case where small-pox became epidemic, would be to render the extent of the epidemic more limited, and its fatality less than it would otherwise be. All that we should anticipate, then, would be a general correspondence over a long series of years between a vaccinated condition of the people and a diminished mortality from small-pox."

It has been sought to find explanation of the decline which has occurred, in altered conditions of life and particularly in improvement of sanitary conditions. But, while influences which may have told in favour of a reduction of mortality have been at work, other influences which have undoubtedly had an opposite effect, such as increased aggregation of the population in towns, and greater facilities of intercommunication between different localities, have also been operative. Again, there has not been marked reduction of mortality in measles and whooping-cough, diseases which may be regarded as being comparable with small-pox. In the case of scarlet fever there has been, it is true, a notable decline, but this only commenced about the year 1880, and there are other circumstances which indicate that it in no way corresponds to the decline in small-pox mortality now in question; in particular the fact should be borne in mind that there has been of late years marked increase in the mortality registered as due to diphtheria; furthermore, the scarlet fever decline stands in close association with the carrying into more and more complete effect of an elaborate system of dealing with scarlet fever cases. In the case of "fevers," too, the mortality has notably diminished; but here again altered nomenclature has undoubtedly been largely operative. Moreover, the causes which have mainly contributed to the diminution of malaria, and of typhus and enteric fever, have been to a large extent determined, and the facts which have been brought to light altogether discredit any attempt to institute comparison between the behaviour of these diseases and that of small-pox. Finally, the decline in small-pox mortality has been attributed to measures of isolation. Doubtless this factor has been largely operative in recent years, but it cannot be held to explain the phenomena of the extended period which has been passed in review.

(*b.*) The Altered Age-Incidence of Small-pox.—The remarkable facts which have been brought to light by study of the statistics of small-pox mortality in relation to age, yield altogether unmistakable evidence of the protective power of vaccination, while, at the same time, they indicate that the immunity afforded is not, as was at one time supposed, of a permanent character, but that after the lapse of some nine or ten years the protection against attack by small-pox becomes lessened. The influence of the operation in modifying the nature of the malady if it is contracted is, however, still manifested, as will be seen later, for a more lengthened period, and indeed, it would appear, throughout life.

This question of altered age-incidence has already been cursorily referred to. The discussion of the facts in detail is given in paragraphs 168—201 of the Final Report; only some of the main points can be here touched upon. The Commissioners give the following table:—

England and Wales: Deaths from Small-pox at certain Age Periods to 1,000 Deaths from Small-pox at All Ages.

—	Under 1.	1—5.	5—10.	10—15.	15—25.	25—45.	45 and upwards.
1848-54 ...	251	426	130	33	75	67	18
1855-59 ...	231	328	144	37	117	112	31
1860-64 ...	237	313	108	42	123	133	44
1865-69 ...	231	314	103	33	126	145	48
1870-74 ...	143	169	140	58	200	224	66
1875-79 ...	112	129	113	72	218	266	90
1880-84 ...	113	122	98	68	216	286	97
1885-89 ...	112	81	54	51	229	344	129
1890-94 ...	166	117	50	26	131	338	172

They comment as follows upon these figures:—

"The first point calling for notice is that in the period 1855-59, as compared with the earlier period, there was a considerable diminution in the share of small-pox mortality borne by those between one and five years of age. In the earlier period it was 426, in the later 328. As regards those under one year of age the share fell from 251 to 231. It must, of course, be remembered that, whatever the prevalence of vaccination amongst children, the age-period under one year will always contain a considerable unvaccinated class. We are naturally led to inquire whether there is anything in the history of vaccination to account for the remarkable change we have adverted to. In the year 1853 vaccination was made compulsory, and, though no sufficient means were provided for rendering the law effectual, it cannot be doubted that it was calculated to increase vaccination in the subsequent years.

The next marked change is seen in the quinquennium 1870 74. The proportion of small-pox mortality borne by those under one year of age decreased from 231 to 143, and by those between one and five years of age from 314 to 169. We have already called attention to the fact that in 1867 power was given to the guardians to appoint vaccination officers, and that advantage was taken of this from time to time by different Unions, though a large number remained without such officers until after 1871, when their appointment was made compulsory. There can be no doubt that the effect of this legislation was to cause an increasing extension of the practice of vaccination in 1868 and subsequent years, and very largely to increase the amount of vaccination in and subsequently to the year 1871. The effect of this would be at once felt in the earliest age-periods, and at a period correspondingly later in the succeeding age-periods. We have already pointed out the marked change in the incidence below five years of age in the quinquennium 1870–74, and it will be seen that in subsequent quinquennia there was a diminished incidence in the age-periods 5—10 and 10—15, and later still in the period 15—25. During the last quinquennium there has been some increase in the incidence of the disease in the first two life-periods. This has been coincident with some diminution in the practice of vaccination."

On examination of the figures for a later quinquennium, 1895-99, it transpires that while the incidence on the age 0—1 had somewhat diminished (108 as compared with 166), the incidence on the age-period 1—5 had increased from 117 to 154, and the next age, 5—10, showed marked increase from 50 to 133. The figures for the remaining age-groups are 26, 107, 332, and 140. The wave of increased incidence had thus extended along the line and, in 1895–99, was already manifesting influence in the case of older children, the lapse of time having given opportunity for the growing vaccination default of the late "eighties" and early "nineties" to affect the death-rate at the ages 5—10 in the years 1894–99.

The Final Report also presents particulars concerning mortality at the several age-periods in a somewhat different form, the death-rates per million living in England and Wales being tabulated for the seven years 1848-54, and for each decennium since that date. The figures for the seven years 1848-54 unavoidably include chicken-pox deaths, and it may be noted that such deaths are also included in the figures relating to the years 1848-54 in the previous table. This fact does not, however, materially affect the conclusions drawn, as the number of chicken-pox deaths, in those years, was beyond all question insignificant in comparison with the small-pox deaths.

England and Wales: Deaths per Million Living.

——		Under 5.	5—10.	10—15.	15—25.	25—45.	45 and upwards.
1848-54	...	1,514	323	91	110	69	24
1855-64	...	788·8	209·5	68·7	118·9	87·8	36·2
1865-74	...	782·5	333·2	142·3	267·2	220·7	87·5
1875-84	...	127·8	62·9	46·4	82·4	76·6	33·9
1885-94	...	50·2	14·9	11·1	24·0	31·6	19·0

With regard to this table the Commissioners say:—"It will be observed that in the decennium 1855-64 there was a very large diminution of the mortality at the age-period under five years, a considerable, though smaller, diminution at the next age-period, and some diminution at the age-period 10—15. Supposing the compulsory law of 1853 to have augmented to some extent infantile vaccination, its effect would be felt in the class under 5 years of age during the greater part of the decennium. It would affect the class aged 5—10 years during the smaller part of the decennium, and the class aged 10—15 only during the last year or two. The next decennium, 1865-74, included the years of the great epidemic, to which allusion has already been made. Its effects are apparent in most of the mortality rates of those years. As compared with the preceding decennium, there was a very great increase of mortality at all the later age-periods. It is noteworthy that as regards those under 5 years of age the mortality was actually less, though very slightly so, than in the preceding decennium. And though there was increased mortality in the next age-period, the increase was less than in the later age-period. It is impossible not to be struck by this fact, when it is remembered that in 1867, and again in 1871, laws were passed calculated to increase the amount of infantile vaccination. The more stringent enforcement of the practice under these laws would considerably affect the class under 5 years of age during the decennium 1865-74, and the effect of the Act of 1867 would be felt to some, though only to a slight, extent in the class aged 5—10. Again, in the next decennium, 1875-84, the fall was very great in the mortality in the first two age-periods; it was reduced to 127·8 and 62·9 as compared with 1,514 and 323 in the years 1848-54, or with 788·8 and 209·5, making the comparison with the decennium 1855-64, when chicken-pox was not included. The results of the legislation of 1867 and 1871 would affect the class under 5 during almost the whole of this decennium, and would largely affect those in the next age-period. It would influence sensibly the class between 10 and 15 years of age, and slightly the next higher age-period. It would be without effect in the classes over 25 years of age. We find the mortality rate in these classes 76·6 and 33·9, being actually higher than in the years 1848-54, for which the figures are 69 and 24, and not much below the figures for the next decennium, viz., 87·8 and 36·2. Comparing, on the other hand, the rates at the age-periods 10—15 and 15—25, the figures are 46·4 and 82·4 as against 91 and 110 for the years 1848-54, and 68·7 and 118·9 for the next decennium. In the decennium 1885-94 there was much less small-pox than in either of the preceding terms of years with which we have been dealing. Isolation and measures of that description were, no doubt, having their effect. The decrease was, however, largest in the age-periods which would be most affected by the results of the legislation to which we have directed attention. Comparing the first and last terms of years, the reduction in the first three age-periods was from 1,514, 323, and 91 to 50·2, 14·9, and 11·1, in the age-period 15—25 from 110 to 24, and in the two highest age-periods from 69 and 24 to 31 and 19 only."

The statistics available in the case of Scotland and of Ireland present the same general features as those just commented upon. From Scotland, moreover, a very striking additional piece of confirmatory evidence is forthcoming. The Scotch Act requires that vaccination shall be performed within six months of birth. In England, until the Act of 1898 was passed, the operation was required to be performed within three months of birth. On contrasting, in the case of Scotland, the period 1855-63, the nine years prior to the Vaccination Act, with the period 1864-87, the twenty-four years subsequent to the Vaccination Act, it transpires that "the proportion of deaths borne by those under six months, who would be in both periods (substantially) an unvaccinated class, was almost exactly the same" (139 per 1,000 deaths at all ages in the earlier period, and 138 per 1,000 deaths at all ages in the later period). The proportion borne by those between six months and a year, and between one and five years, in the later period as compared with the earlier, was, however, "greatly diminished" (from 153 to 47 per 1,000 deaths at all ages, in the case of those between six months and a year, and from 413 to 137 per 1,000 deaths at all ages, in the case of those between one and five years of age). There was a slight increase (from 90 to 95) in the proportion per 1,000 deaths at all ages, but this increase was due, as is stated in the Final

Report, "to the very large decrease in the proportion borne by those of an earlier age, and not to any increase of the mean mortality in the class aged five to ten in the later period, for the mean annual death-rate per million fell greatly, viz., from 244 to 86." At ages above ten, the mean annual death-rate was about the same in the two periods. The complete table from which these figures are taken is given in paragraph 174 of the Final Report.

The Final Report also contains a detailed discussion of the facts as to age-incidence, in six recent outbreaks, investigated by various observers, in Warrington, Sheffield, London, Dewsbury, Gloucester, and Leicester. In Leicester and Gloucester the child population was very ill-vaccinated, and the proportion of deaths borne by children, 0–10, was found to be high (71·4 and 64·5 per cent. of total deaths). In London and Dewsbury the child population was less ill-vaccinated, and the proportions in question were less high (51·8 in Dewsbury and 36·8 in London); it is noted that "the proportion of the unvaccinated in Dewsbury, may with confidence be asserted to have been greater than in London." In Warrington and Sheffield the child population was well vaccinated, and in those towns the proportion of deaths borne by children, 0—10, was low (25·6 and 22·5 per cent. of total deaths).

It has been sought to find explanation of the altered age-incidence of small-pox on the supposition that improved sanitary conditions have been operative. But a like altered incidence has not been observed in measles, whooping-cough, and scarlet fever. Tables, printed in the supplement to the Thirty-fifth Annual Report of the Registrar-General, have been appealed to as showing that, "whilst in Liverpool the percentage of deaths from small-pox expected under five years was 63·5 in 'healthy districts' it was only 25·5"; here, it is suggested, is proof of the effect of improved sanitary conditions upon age-incidence in small-pox. It is clear, however (*See* paragraph 197 of the Final Report), that the main influence at work is not any "sanitary condition," as the term is ordinarily understood, but proximity of population. In a large town, in which people are closely aggregated, the chances of contracting small-pox, measles, etc., are of course greater than in "healthy districts," which include, in the main, rural areas, in which the population is sparsely distributed.

The tables referred to also show, with regard to both measles and scarlet fever, that a larger proportion of deaths under five years of age occurs in Liverpool than in the case of "healthy districts." Again, "the comparison made between Liverpool and 'healthy districts' necessarily involves a fallacy unless it be borne in mind that, of a million born alive, a much larger number will attain ages beyond five years in 'healthy districts' than in a large town like Liverpool. The tables, indeed, show that 824,590 persons are estimated as living beyond the age of five years in the former, as compared with 539,630 in the latter. Hence, in the case of a disease such as small-pox, which is fatal at all ages, it necessarily follows that a larger proportion of deaths will occur, at ages above five years, in healthy districts than in Liverpool. The theory that "improved sanitary conditions" bring about the altered age-incidence in small-pox, therefore, proves on examination to be based on a misconception. The increased aggregation of persons in towns, which is so conspicuous a phenomenon of the nineteenth century, must have tended to increase the incidence of small-pox on younger ages, *i.e.*, to have actually acted in opposition to the influences which have thrown the excessive incidence of the disease upon the higher ages.

Stress has been laid on the fact that an altered age-incidence has been observed in the case of "fevers." This term, prior to 1869, included typhus fever, infantile fever, and remittent fever. Altered nomenclature and improved diagnosis have, no doubt, largely affected the returns of fever deaths. Enteric fever has been differentiated from the general fever group, and of late years typhus has become well-nigh extinct. It is of interest to note that, since 1880, remittent fever deaths, in children aged 0—5, have been taken out of the "fevers" group and relegated to enteric fever, and the use of the term "infantile fever" in classification has been abandoned. The percentages of deaths under five to deaths at all ages, in the case of typhus and typhoid, during four successive periods of five years since 1870 are as follows:—

	1871–75.	1876–80.	1881–85.	1886–90.
Typhus	6·4	6·1	3·5	3·4
Typhoid	17·4	16·0	9·3	7·5

These percentages show a sudden fall in the third period as compared with the second; the figures for the first and second periods, and for the third and fourth periods, being, however, in tolerably close agreement. The coincidence in point of time of this fall with the altered practice in regard to the classification of "fever deaths" is noteworthy. It is clear, then, that no change has occurred in the age-incidence of fevers which is in any way comparable with the change in the age-incidence of small-pox.

Appeal has further been made to the fact that the age-incidence of influenza differed somewhat, in the outbreak of 1890-91, from that observed in the outbreak of 1847–48. The comparison is based on the figures of only two years in each case, and the likelihood of error arising from the insufficiency of the data relied upon, is intensified, in dealing with the particular malady in question, by the fact that the cause of death may have been variously ascribed to pneumonia, bronchitis, and other headings, as well as to "influenza" itself. Moreover, the altered incidence, even for the limited periods considered, is not at all comparable to that observed in small-pox, which, be it noted, has been manifested over a long period of years. It is obviously irrational to assume that, because one or other variation is observed in the age-incidence of other diseases, therefore a notable and sustained alteration in the age-incidence of small-pox can be dismissed from further consideration.

(*c.*) The Behaviour of Small-pox in the Vaccinated as compared with the Unvaccinated.

(i.) *Case-mortality.*—Mr. Marson, formerly Superintendent of the Highgate Small-pox Hospital, collected, during thirty-two years, particulars in respect of nearly 20,000 cases of small-pox. He found that the case-mortality among the unvaccinated was about 35 per cent.; while in those with four or more vaccine cicatrices it was only about 1 per cent. Dr. Gayton, who analysed the facts relating to upwards of 10,000 cases in Metropolitan Asylums Board hospitals, obtained similar results. Marson's and Gayton's tables will be more particularly referred to in connection with the protective influence of various degrees of vaccination. Sweeting collected particulars concerning 2,584 cases admitted to the Fulham Hospital between 1880 and 1885. His statistics corroborate the conclusions drawn from the other series of observations.

The six recent epidemics, commented upon in the Final Report, teach the same lesson. They include, taken in all, 11,065 attacks of small-pox, with 35·4 per cent. case-mortality in the unvaccinated, and 5·2 per cent. case-mortality in the rest of the population. Restricting attention to children under ten, the case-mortality in the unvaccinated was 36 per cent., while that in the remainder was 2·7 per cent. only. The objection has been raised that the unvaccinated class includes children under three months, in the case of whom an attack of the disease might be expected to be specially severe. The particulars collected enable such children to be excluded from the comparison instituted, and the figures then work out at a case-mortality of 30·3 per cent. in the unvaccinated, and only 2·8 per cent. in the vaccinated. "The contrast," it is noted, "is the more striking when it is remembered that all the doubtful cases are included in the vaccinated class, though many of them had in all probability never been successfully vaccinated."

It has been sought to explain these remarkable phenomena on the ground that the unvaccinated, as a class, are mainly drawn from the poorer and more neglected portion of the population. To some extent varying social conditions have no doubt been operative, but the difference observed is far too great to be thus accounted for. Moreover, "the disparity in the death-rate of those classed as vaccinated and unvaccinated was, in the six epidemics, greater nearer the date of vaccination than it was at a later period." The hospital statistics confirm this.

Again, it has been said the unvaccinated class includes children whose vaccination has been postponed for medical reasons. The number of such cases is, however, very small, and the postponement does not necessarily imply that the child is not ultimately vaccinated, or that if it remains unvaccinated, and is attacked by small-pox, it will, because of the fact that it suffered from some ailment in infancy, be less capable of resisting small-pox.

(ii.) *Attack-rate.*—This question was investigated on a vast scale by Barry, in the Sheffield outbreak. From his results it transpires that, in Sheffield, the attack-rate among the unvaccinated was at least five times as great as among the vaccinated; while, restricting attention to children under ten, the attack-rate among the unvaccinated was fifteen or more times as great as among the vaccinated. In the Sheffield outbreak, and in four others, the facts as to persons resident in "invaded houses," who were attacked by small-pox after the occurrence of the first case in the house, were also ascertained. The following table, which appears in the Final Report, gives the results obtained:—

—	Attack-rate under 10.		Attack-rate over 10.	
	Vaccinated.	Unvaccinated.	Vaccinated.	Unvaccinated.
Sheffield ...	7·9	67·6	28·3	53·6
Warrington .	4·4	54·5	29·9	57·6
Dewsbury ...	10·2	50·8	27·7	53·4
Leicester ...	2·5	35·3	22·2	47·6
Gloucester ...	8·8	46·3	32·2	50·0

(iii.) *Severity of Type.*—This question was also made the subject of statistical study by Barry. The facts as to cases of disease, coming under treatment in the Sheffield hospitals, were presented by him in the form of the diagram which is reproduced on the opposite page.

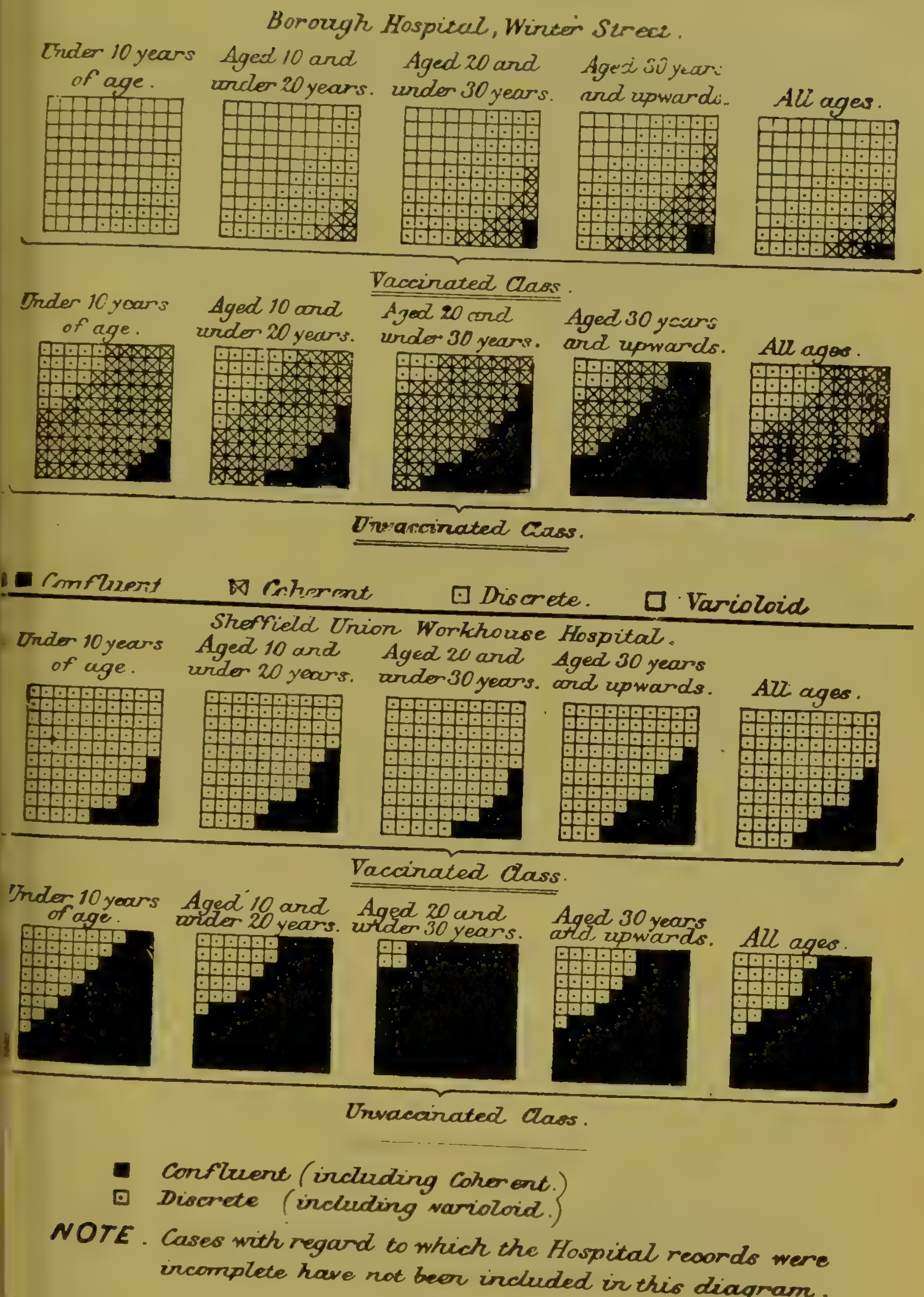

FIG. 92.

Proportion of cases of Small-pox of different types which occurred in persons of the "Vaccinated" and "Unvaccinated" classes respectively, at all and certain specified ages, in the Winter Street and Sheffield Union Workhouse Hospitals.

The following table, from the Final Report, gives the percentages in Sheffield and in three other outbreaks, the cases being grouped under the headings milder (including varioloid and discrete) and severer (including coherent and confluent):—

		Milder.	Severer.
Sheffield ...	Vaccinated	82·8	17·2
	Unvaccinated	18·5	81·5
Dewsbury	Vaccinated	82·0	18·0
	Unvaccinated	23·1	76·9
Leicester ...	Vaccinated	81·4	18·6
	Unvaccinated	27·2	72·8
Warrington	Vaccinated	78·2	21·8
	Unvaccinated	29·4	70·6

The study, therefore, of case-mortality, attack-rate, and type of disease, in the vaccinated and unvaccinated, points unmistakably to the conclusion that vaccination materially affects the behaviour of small-pox. Especially noteworthy as regards each of the three tests is the fact that "the difference between the two classes is much more marked in the case of children under ten years of age, who are nearer the period of vaccination, than it is in the case of persons of more advanced years."

(*d.*) Case-Mortality and Severity of Type amongst Vaccinated Persons with Vaccination Marks of Different Quality.—This question was first raised by the publication of Marson's observations on 3,094 cases of post-vaccinal small-pox occurring between 1836 and 1851. "Marson's Statistics" were later extended so as to include further experience of 10,661 cases occurring between 1852 and 1867.

Marson's Statistics.

Cases of Small-pox classified according to the vaccination marks borne by each patient respectively.	Percentage of deaths in each class respectively uncorrected.		Percentage of deaths in each class respectively corrected.*	
	1836–51.	1852–67.	1836–51.	1852–67.
1. Stated to have been vaccinated but having no cicatrix	25·5	40·3	21·7	39·4
2. Having one vaccine cicatrix ..	9·2	14·8	7·6	13·8
3. Having two vaccine cicatrices ...	6·3	8·7	4·13	7·7
4. Having three vaccine cicatrices ...	3·6	3·7	1·8	3·0
5. Having four or more vaccine cicatrices	1·1	1·9	0·7	0·9
Unvaccinated	37·5	35·7	35·5	34·9

* The terms "uncorrected" and "corrected" are used to signify the inclusion or exclusion of those fatal cases of small-pox in which the patient suffered from some other disease which was superadded to the small-pox.

Gayton tabulated the results obtained by him, between 1873 and 1884, on an analysis of 10,403 cases, in a somewhat different manner, and it will be noted that he gave for the first time the facts with regard to different age-periods.

GAYTON'S TABLE.

Ages. Years.	Vaccinated with good marks.			Vaccinated with imperfect marks.			Vaccinated, but no marks visible.			Not vaccinated.		
	Cases.	Deaths.	Per cent.	Cases.	Deaths.	Per cent.	Cases.	Deaths.	Per cent.	Cases.	Deaths.	Per cent
0— 2 ...	4	0	0	32	3	9	22	[illegible]	41	276	181	66
2— 5 ...	57	0	0	150	18	12	96	38	40	401	202	50
5—10 ...	206	2	1	532	27	5	207	40	19	510	180	35
10—15 ...	439	5	1	939	32	3	214	42	20	317	74	23
15—20 ...	606	12	2	1,037	66	6	205	39	19	204	86	42
20—25 ...	389	11	3	843	100	13	167	56	34	174	83	48
25—30 ...	189	12	6	529	80	15	116	35	30	105	56	53
30—40 ...	147	14	10	526	78	15	137	49	36	103	42	41
40—50 ...	29	4	14	186	33	18	85	24	28	49	21	43
50	19	2	11	80	18	22½	46	20	43	30	13	43
All ages...	2,085	62	3	4,854	455	9	1,295	352	27	2,169	938	43

Sweeting proceeded on somewhat similar lines; his table is given on p. 75 of the Final Report. The same subject was examined in great detail by Barry at Sheffield, and by other observers in more recent outbreaks (paragraphs 273–287 of the Final Report). Taken altogether, the number of cases classified, according to the character of vaccination marks found on the patients, exceeds 20,000. Combining the later results (to the exclusion of Marson's figures), it transpires that the case-mortalities obtained are, 6·2 per cent. with one mark, 5·8 per cent. with two marks, 3·7 per cent. with three marks, and 2·2 per cent. with four marks. Some attention has been paid of late years to the area of scarring and to the degree of foveation observed, and evidence that the protection afforded depends upon the extent of the area covered by the marks has been obtained.

(*e.*) REVACCINATION.—Barry at Sheffield ascertained that the attack-rate among revaccinated persons was ·04 per cent. (27 attacks among 64,431 persons), as compared with 1·55 per cent. in the entire population. The attack-rate among persons who had previously suffered from small-pox was ·13 per cent., a distinctly higher rate than that in the revaccinated. Detailed inquiries as to the police force, post-office officials, etc., in Sheffield were also made by Barry, and these and similar experiences yielded by other recent epidemics, show how marked is the protection resulting from recent vaccination.

Quite conclusive evidence of the value of revaccination is afforded in the case of hospital staffs, nurses, and attendants. The facts as to Leicester, Homerton, Fulham, and Highgate are given in paragraphs 319–322 of the Final Report. Two accounts, forthcoming from Dublin and from Paris, which had been supposed to tell against the general experience in this country, are dealt with in paragraphs 323–328. At the Mile-end Infirmary, in 1902, thirty-one of the forty-two members of the nursing staff had been revaccinated before the outbreak of small-pox in London; four others were revaccinated on January 28 and 29, two unsuccessfully. None of these thirty-five contracted small-pox. The remaining seven were all attacked. Of these, three were not revaccinated, and the rest sickened with small-pox in two days (two cases) three days and six days respectively after vaccination.

The statistics of small-pox mortality in the British army and navy, and in the postal service, are analysed in paragraphs 331–340 of the Final Report; their bearing on the question of revaccination should be noted. An extraordinary difference was observed in the mortality from small-pox in the German and French armies during 1870–71. In the Prussian army vaccination was supposed to have been compulsory on joining, since 1834, and there is no doubt the German army, as a whole, was better vaccinated than the French army, and that the former, as compared with the latter, suffered to a very much less extent, during the years in question, from small-pox.

Very striking evidence of the value of revaccination is afforded by a study of the effect of the law of 1874, which made revaccination compulsory throughout Prussia. Since this law came into operation small-pox has been almost entirely banished from that country. In "*Blattern und Schutzpockenimpfung*," a publication issued by the German Imperial Health Office, diagrams are given illustrating the striking contrast between the behaviour of the disease in Prussia and Austria, and again in certain German towns as compared with other large cities of Europe; further, the facts as to prevalence and mortality from the disease in the Prussian, Austrian, and French armies, since 1867, are given, and the contrast between the former and the two latter forces, since 1874, is apparent; again, the differing mortalities in successive years in the army, and in the civil population, in Prussia, since 1834, are also exhibited.

Specially noteworthy, moreover, is the fact that of 1,194 small-pox deaths occurring in the German Empire (1886–1898), 511 were those of children under two years of age. Thus, in this vaccinated and revaccinated community, small-pox has shown a remarkable tendency to prove fatal at this age-period. The German law requires vaccination to be performed prior to the completion of the calendar year following the year of birth of the child. Of the 511 children, 15 were returned as vaccinated, 138 as unvaccinated, and of the remaining 358, whose condition as to vaccination was not stated, the large majority, having regard to their age at death, must have escaped being protected by vaccination.

It has been urged that evidence unfavourable to revaccination is furnished by the fact that the mortality of males in this country (1851–80) exceeds that of females (and the argument has been applied, too, in the case of Germany), whereas more males may be assumed to be revaccinated than females. It must, of course, be borne in mind that the male population is more exposed to contagion than the female, and the better revaccination of males does not altogether counterbalance this greater risk. It is interesting to observe that the ratio of male to female mortality in 1871–80, as compared with 1851–60, decreases at ages higher than those belonging to the age-group 10—15 (presumably owing to greater prevalence of revaccination). With regard to Germany, it may be further noted that 938 out of a total of 1194, or 79 per cent., of the deaths which occurred during the years 1886–98 were those of persons residing near the frontiers or in seaports.

III. **The Relationship between Vaccinia and Variola.**—Jenner's view was that cow-pox was small-pox occurring in the cow. An argument urged in evidence before the Commission was to the effect that inasmuch as cow-pox and small-pox were two different diseases, it was therefore *à priori* improbable that one would confer immunity against the other. The attempt to communicate small-pox to the cow by way of the respiratory or digestive systems has not been crowned with success. In certain instances, however, results of a positive kind have followed upon the inoculation of small-pox material in the cow.

The Final Report states that the experiments in question may be relegated to three categories. The first of these includes cases in which vesicles resembling vaccine vesicles were produced, the matter from which, when carried through a second or third remove in the cow, and then transferred to man, gave results indistinguishable from those of ordinary vaccination. Such experiments have been conducted by numerous observers, including Thiele (1838), Ceely (1840), Badcock (1840-60), Voigt (1881), Haccius and Eternod (1890), King (1891), Simpson (1892), and Hime (1892).

In the second category are placed the experiments of Klein and Copeman, who obtained, on inoculation, not a distinct vesicle, but merely a thickening and reddening of the wound. Lymph obtained from the site of the operation, in a second, third, and fourth remove in cows, produced more and more marked thickening and reddening, and lymph from the fourth cow produced typical vaccinia in a child. Klein's observations were made in 1892, and Copeman obtained similar results in the same year.

The third category includes the experiments of Chauveau and others, who found that small-pox inoculated in the cow "gave rise to a specific effect, which was not cow-pox, but was of the nature of small-pox."

As regards the cases in which results indistinguishable from those of vaccination were obtained, it has been suggested that there might have been accidental introduction of cow-pox matter into the wound; but this source of error was carefully guarded against in the later experiments, and the conclusion arrived at, in the Final Report, is that this accident could not have occurred in all the successful cases, and that a transformation of small-pox into cow-pox really took place. It would appear that one condition, favourable to the transformation, is that the animal used should be a calf not more than three or four months old.

It remains to be pointed out that while each one of the tests which have been applied, to ascertain whether vaccination has a protective effect, yields an affirmative answer, in order to estimate their value it is necessary to consider them in conjunction. As is pointed out in the Final Report, "the greater the number of tests employed, and the greater the number of cases to which they are applied, the more certain is it that the play of chance or the influence of other causes will be excluded, and the more safely may the conclusions to which they lead be acted upon. The cumulative force of a number of pieces of evidence all pointing in the same direction is very great indeed."

The nature and extent of the injurious effects alleged to result from vaccination have been the subject of much inquiry. Many diseases have, at one time or another, been attributed to the practice of vaccination; but examination of records of mortality affords no evidence that prevalence, of any of the maladies specified, has been increased to an appreciable extent by the practice of vaccination. In individual cases injury and even death have, however, been ascribed to the operation, and doubtless in a few instances the vaccination wound has served, as any other wound might have done, as a means of introducing germs of disease into the body.

During the years 1886-91, 279 deaths were associated with the operation of vaccination: in many of these undoubtedly no causal relationship was demonstrable; but, on the other hand, it may be that a few cases, in which the vaccination wound permitted of germs obtaining access to the body, escaped being returned in certificates as due to vaccination. On the assumption that the one group of cases counterbalances the other, the deaths must be taken to have been in the proportion of one to 14,159 primary vaccinations. In Scotland the proportion of cases in which death was stated to be due to vaccination, during the years 1883–90, was less than this, being only one to 38,872 primary vaccinations.

Among the fatal maladies connected with vaccination, erysipelas accounts for nearly half the total deaths, and this disease, in conjunction with "blood poisoning" and allied conditions, monopolises two-thirds of the deaths. Erysipelas is a very fatal disease in infancy, and, inasmuch as 2,000 children per million die of erysipelas, during the first three months of life, it might be anticipated that a certain number of deaths would occur in children shortly after they were vaccinated, without there being any connection between the disease and the vaccination wound. In many instances, moreover, in which the facts have been made the subject of careful inquiry, it has been demonstrated, having regard to length of incubation period or to other circumstances, that the supposed connection was merely apparent; it has sometimes happened, when vaccination has been postponed for one or other reason, that a diseased condition has manifested itself, which would certainly have been attributed to the vaccination, if the operation had been performed at the appointed time.

In the Final Report attention is called to some of the possible causes of mischief in cases in which erysipelas has been associated with the act of vaccination. In some instances erysipelas was prevalent in the vicinity; in others the child was living under extremely insanitary conditions; again, in particular cases there was evidence of want of care and attention, and it was found that the wound had been rubbed by articles of dress, or that substances had been applied to it which might have acted as vehicles for the contagion. It has been suggested that the practice of opening the vesicles on the eighth day introduces an element of risk, but the conclusion arrived at by the Commissioners with regard to this is "that it is almost wholly an imaginary danger." These considerations suggest that, by the adoption of antiseptic precautions and the use of carefully prepared lymph, the number of inflamed arms and of cases of erysipelas may be reduced to the point of insignificance.

In very rare instances syphilis appears to have been transmitted by vaccination. The infrequency of such a sequence of events is evidenced by the fact that it was generally believed by the medical profession, until comparatively recent years, that such transmission could not occur; but, on the Continent more particularly, cases in connection with arm-to-arm vaccination among soldiers, or with the use of lymph from syphilitic infants, have been recorded, and the possibility of infection being conveyed in the manner indicated is now accepted. Inquiry was made, on behalf of the Commission, concerning a number of supposed cases, but in almost all instances the alleged connection was proved not to exist. The subject is fully considered in paragraphs 425 to 430 of the Final Report, and the conclusion is arrived at that "where the antecedents of the vaccinifer are fully ascertained, and due care is used, the risk may for practical purposes be regarded as absent." There is absolute freedom from risk of syphilis when calf-lymph is used.

Other Preventive Measures.

Appreciation of the value of isolation in preventing the spread of small-pox has greatly grown of late years. Account has already been given (*See* p. 300) of the investigations of Power with regard to the use of intra-urban hospitals, and the decline of small-pox in London since 1885 need not be again alluded to. Reference may, however, be here made to what is known as the "Leicester system." In the town named the plan of quarantining the inmates of an infected house, in addition to isolating the patient, was originated in 1875. In the absence of power of compulsory removal, persuasion was, as a rule, found to be successful. Compensation for loss of work was given in some instances. Dr. Tomkins, of Leicester, "though, like his predecessors, regretting the increasing disuse of vaccination, bore testimony in his annual reports to the efficacy of the measures adopted in Leicester."

The conclusions expressed in the Final Report of the Vaccination Commission are: that the evidence "is inconclusive as to the relative merits of quarantine in hospital, or supervision of the exposed at their homes," and that "the influence of prompt isolation of the patient appears to overshadow any superior efficacy the one method may have had over the other": again, it is stated with regard to the system of isolation generally, that "what it can accomplish as an auxiliary to vaccination is one thing; whether it can be relied upon in its stead is quite another thing"; at the same time, "even admitting fully the protective effect of vaccination, it does not diminish the importance of measures of isolation or dispense with their necessity." (*See* the Final Report, p. 131.) Hence, the more general provision of isolation hospitals is advocated by the Commissioners, and they recommend that power should be given to sanitary authorities to give compensation for loss of wages, and generally to incur expenditure in connection with isolation, etc.

A noteworthy feature of small-pox outbreaks in recent years has been the way in which the disease has been introduced and spread by persons of the vagrant class. Among the recommendations contained in the Final Report (p. 132) were several dealing with the necessity of making common shelters subject to the law relating to common lodging-houses, and of giving special powers to local authorities for the purpose of controlling the spread of small-pox in such houses.

The Vaccination Act of 1898.

This Act modifies previously existing legislation in certain respects. It provides that the age before which a child must be vaccinated shall be raised from three to six months. A parent may avoid having his child vaccinated if within four months of the birth he satisfies a magistrate that he entertains a conscientious objection to the operation, on the ground that it would be prejudicial to the health of the child. A certificate is then given, which the parent must transmit within seven days to the vaccination officer. A person can be only once penalised for non-compliance with an order directing him to have his child vaccinated, and defaulters, if imprisoned, must be treated as first-class misdemeanants. It is made the duty of the public vaccinator, if the parent requires it, to attend the child at its own home; he must so attend, after giving at least twenty-four hours' notice, if the child is not vaccinated within four months of its birth; he must offer to use glycerinated calf-lymph, or other lymph supplied by the Local Government Board, and he must keep registers showing the origin of the lymph used. If, owing to the condition of the house, or to the existence of infectious disease in the neighbourhood, he deems it necessary to do so, he may give a certificate of postponement, and he must inform the medical officer of the district of the course taken.

At times of small-pox prevalence, the Local Government Board may require the guardians to provide vaccination stations, and may modify the duties of the public vaccinator with regard to visiting, otherwise than by request. A register must be kept by every sanitary authority maintaining a hospital for small-pox, showing the condition, as to vaccination, of patients admitted. Vaccination must be performed within six months of birth, save in those instances in which a magistrate's certificate is obtained, or the child dies or is attacked by small-pox, or three or more unsuccessful attempts to vaccinate have been made, or a medical certificate of postponement (to have effect for two months at a time) is given.

The administration of the Acts is still vested in the Poor Law authorities. Instructions have been issued by the Local Government Board, dealing with precautions as to cleanliness, sterilisation of instruments, etc., and requiring the public vaccinator to "aim at producing four separate good-sized vesicles, or groups of vesicles, not less than half an inch from one another." Revaccination is not made compulsory, but persons over twelve (or over ten if there is immediate danger of small-pox), are to be revaccinated gratuitously.

As regards repetition of proceedings the present position is governed by Section 2 of the Act of 1898. A parent may be convicted under Section 29 of the Act of 1867, and when the child attains the age of four years, if the law is still not complied with, an order may be obtained directing the parent or guardian to have the child vaccinated; if the order is disobeyed the parent may be convicted and fined, and no further proceedings can be taken. Alternatively, proceedings may in the first instance be taken under Section 31 of the Act of 1867, and an order made; if that order be disobeyed a conviction may follow, but no further proceedings can be taken, even after the age of four years is attained.

Tetanus.—This malady, though common in hot climates, is of comparatively rare occurrence in this country, but it is one of special importance inasmuch as study of it has thrown much light upon bacteriological questions. Carle and Rattone first demonstrated that it was an inoculable disease. Nicolaier, in 1884, showed that garden earth, introduced subcutaneously in the mouse or rabbit, was capable of producing typical tetanus; he also described the specific organism though he did not obtain it in pure culture. Kitasato later isolated the anaerobic tetanus bacillus. The subject of tetanus antitoxine has already been referred to (*See* p. 342). It has been noted that tetanus not uncommonly affects persons who have to do with horses, and the question as to an equine origin of the disease has been raised. Nothing has been definitely proved, however, with regard to this theory.

Tropical Fevers, etc.—In addition to the febrile diseases of warm climates, considered under special headings, there can be no question that there are other maladies, the "unclassed fevers," as Manson terms them, which are prone to occur in various parts of the tropics. The following clinical types were described by Crombie in India:—A *simple continued fever*, common in towns (Bombay fever, Calcutta fever, etc.); a *low fever*, which could not be checked by quinine, but was almost invariably benefited by change of air; *a non-malarial remittent* (unfortunately named, as the fever is often continuously high), presenting considerable resemblance to enteric, but in which many of the special symptoms of the last-named disease are not developed. To these Manson adds a *double continued fever* observed by him in Amoy and Hongkong.

There are other diseases which specially affect particular regions. The *river fever of Japan*, Manson describes as "characterised by the presence on the skin of an initial eschar, followed by an ulcer, lymphatitis, fever, an erythematous eruption, bronchitis, and conjunctivitis"; the unknown virus of the disease, he says, "doubtless enters in the first instance at the site of the primary eschar." In *Nasha fever*, which occurs more particularly in Bengal, congestion of the mucous membrane of the nasal septum is a prominent symptom. *Kalar azar* prevails in Assam; progressive debility, anæmia, and darkening of the complexion are the most striking features in this disease. *Epidemic dropsy* occurred, 1877–80, in Calcutta, and was described by McLeod; the same malady broke out elsewhere in the years named, and appeared in 1878 in Mauritius, having been imported from Calcutta. The disease presented some resemblance to the wet form of beri-beri, but was less chronic in its course, less fatal, and the nervous phenomena of beri-beri were not observed; moreover, an erythematous exanthem has been described in epidemic dropsy. *Infantile biliary cirrhosis* (a disease characterised by great hepatic enlargement, fever, jaundice, and ascites) has been observed in infants, in some of the large towns of India, in recent years. A somewhat similar malady, *Ponos*, is endemic in certain islands of the Grecian archipelago. *Sprue* (*Psilosis linguæ*) is common in Europeans living in the tropics. In this disease the mouth and tongue present superficial lesions (erosions and aphthous patches); dyspepsia and diarrhœa are also present. The stools are copious, pale grey in colour and evil-smelling, and at times exacerbations with more acute watery diarrhœa occur. Manson regards this malady as "an expression of exhaustion of the glandular structures subserving digestion," due to special conditions met with in tropical countries. It has also been held to be due to some as yet unidentified specific organism.

Tuberculosis.—This disease, under its various forms (tubercular phthisis, tubercular meningitis, tubercular peritonitis, tabes mesenterica, general tuberculosis, etc.), constitutes the chief cause of mortality in this country. It is, moreover, widely distributed over the globe, although, as a rule, more prevalent in temperate regions. Humidity is found, other things being equal, to favour its existence. Very cold countries and elevated regions are comparatively free from the disease, which is especially found to prevail in overcrowded localities. As regards season, phthisis mortality is greatest in March, April, and May, and least in August, September, and October. With respect to race, it may be said that none appears exempt; the Jews are commonly stated to enjoy a relative immunity, but the question has never been made the subject of very precise inquiry.

The recorded mortality from phthisis in England and Wales has steadily diminished since registration of deaths was established in 1837. The average death-rates per million living, for quinquennial periods, have declined from 3,880 for the years 1838–42, to 1,635 for the years 1886–90. That this decline is in part attributable to altered nomenclature is probable. Newsholme has pointed out that, in the early years of registration, "consumption" or "phthisis" seems to have been the name given to the malady causing death, in a large number of instances associated with wasting, but in which there was no tubercular disease. On the other hand, as he says, there has in recent years "been an increasing tendency to register deaths as due to tuberculosis, or general tuberculosis, which would formerly have been returned as phthisis." It is, probable, therefore, "that the death-rate from phthisis pulmonalis was formerly considerably overstated, and that it is now being somewhat understated." It cannot be doubted, however, making all allowance for the alterations in question, that there has been a great decline in the phthisis death-rate.

Age and Sex.—The deaths among males exceed those among females, at the higher ages. On comparison of the period 1861–70 with the period 1891–95, it is found that the behaviour of phthisis as regards sex appears to have altered somewhat: the mortality in both sexes has declined, but in females to a notably greater extent than in males; while, in the earlier period, female mortality was in excess of male mortality, up to thirty-five years of age, in the later period it already falls below male mortality, between twenty and twenty-five years of age. With regard to age, the deaths registered per million living at each age (1891–95) as due to phthisis diminish from the first to the fifth year, at five to ten they are at their minimum, and they then increase up to the age-period thirty-five to forty-five, after which they steadily decrease. The question of changes of mortality from 1851–95, under the headings "all forms of tubercular disease," "phthisis," "tabes mesenterica," etc., has been fully considered by Tatham, Appendix C, Royal Commission on Tuberculosis, 1898 (*See also* p. 205).

Dissemination and Prevention.—The hereditary transmission of phthisis was at one time a generally accepted doctrine. The change of opinion with regard to this matter, of late years, is evidenced by the fact that Koch stated, in 1901, that hereditary tuberculosis "is extremely rare, and we are at liberty, in considering our practical measures, to leave this origin entirely out of account." The discovery of the *Bacillus tuberculosis* by Koch, in 1882, no doubt did much to discredit the heredity hypothesis; but supporters of the doctrine could still fall back upon a supposed transmission of a conformation of body predisposing to attack by the disease. As Newsholme says, however, it is "certain that the largest share of what was formerly ascribed to heredity, was really caused by an environment of exposure to tuberculous infection, often continued over a long series of years."

The experience of the Prudential Insurance Company of America, based on twelve years' mortality statistics relating to 40,000 lives refused on first application to the company, shows that "of those rejected on account of actual consumption, 36 per cent. had died; while of those rejected for family history—*i.e.*, on the ground of a supposed hereditary predisposition to consumption—only 9 per cent. had terminated by death." Newsholme concludes, therefore, that there should be no difficulty, in the light of these figures, in accepting an applicant with a family history of phthisis, provided he be in good health and "has not been exposed in recent years to household infection of tuberculosis."

With Koch's discovery of the bacillus, in 1882, and the study of the similar forms of disease met with in lower animals, and especially in the bovine species, attention became particularly directed to the possibility of the spread of tuberculosis by food. This matter has already been referred to in connection with meat and milk. The influence of soil and of overcrowding, lack of ventilation, etc., upon phthisis mortality have also been already considered. Newsholme is inclined to attribute the reduction of phthisis mortality, which has been observed in the last half-century, to the following measures, placed in the order of importance:—

1. Improved nutrition of the population;
2. Improved housing of the population; and
3. The drying of the soil.

There remains to be considered the contagiousness of phthisis. Some thirty years ago a number of instances of supposed transmission of phthisis from husband to wife were recorded by various observers. Longstaff (*Studies in Statistics*) pointed out that numbers of such occurrences might be anticipated as a mere matter of chance, having regard to the fact that phthisis is a common disease, and that it particularly affects the adult ages. Moreover, the rarity of attack among medical men and nurses in consumption hospitals was noted, and was held to show that the infective power of the disease could not be very great. Since the discovery of the bacillus the question has, however, again come to the front.

Koch holds that the sputa of consumptive patients constitute the "main source" of infection, and that measures for combating tuberculosis must aim at the prevention of the dangers arising from its diffusion by this means. In New York, attention has been called to the disproportionate extent to which deaths tend to recur again and again in particular tenement-houses; it is claimed that by notification of cases, and disinfection of infected rooms, etc., the mortality in that city has, in the course of a few years, been markedly reduced. The importance attached to infection by dried sputa is such that the most stringent precautions have been taken in some American cities with regard to this matter.

The question of notification of phthisis has already been referred to. Where voluntary notification is encouraged, it becomes possible to disinfect and cleanse all infected rooms, to give instructions to the patient and the friends as to any precautions which should be taken, and to deal with any conditions in the environment of the patient which may have favoured the development of the malady. Recent annual reports, of the medical officers of health of Brighton and Manchester, show the kind of work which it is possible to carry out. Another measure, which has been much advocated of late years, is the founding of sanatoria for consumptives. Koch in his address, in 1901, pointed out that, having in view the limited extent of the operation of such establishments in Germany in that year, the effect produced must be "so small that a material influence on the retrogression of tuberculosis in general is not yet to be expected of them." At the same time he considered it would be possible to render sanatoria considerably more efficient, and he said, "if their number become great, and if they perform their functions properly, they may materially aid the strictly sanitary measures in the conflict with tuberculosis."

Typhus Fever.—It is only since the year 1869 that typhus fever has been separately distinguished in the Registrar-General's

Returns, but it has probably existed for many centuries, playing its part more particularly during times of war or famine, for prevalence of the malady has been generally found, in later times, to be favoured by conditions of overcrowding and destitution. The "spotted fever" of jails, and some, at any rate, of the recorded outbreaks of "famine fever" and "camp fever," were probably instances of what would now be called typhus, but the likelihood of relapsing fever having prevailed in times of famine, or of enteric fever having devastated camps, must not be lost sight of. (For the history of the differentiation between typhus and enteric fever, *see* the last-named disease.)

Passing over earlier and more doubtful outbreaks, it is clear that, from the sixteenth century to the early part of the nineteenth, typhus prevailed extensively in Europe. Hirsch gives 1815 as the date of close of this "period of typhus," and states that since then, only once (*viz.*, in 1846–47) did the disease attain, on European soil, "the same general diffusion which the history of pestilence presents to us so often in former centuries." In 1847 the deaths from fever (including enteric and simple and ill-defined fever) in this country exceeded 30,000, a number notably in excess of that in any subsequent year. From 1849–63 the fever deaths never reached 20,000; in each of the years 1864–66 they were, however, somewhat in excess of that number. In 1869, the first year of differentiation of members of the fever group, 4,281 deaths from typhus were recorded, giving a death-rate of 193 per million living; the rate then fell fairly steadily, descending in 1876 below 50 per million living; the fall was slightly checked in 1882–83, but since 1885 it has been less than 10, and in 1898 and 1899 it only amounted to 1 per million living.

Ireland has been a particularly favourite seat of the disease in past times, and during recent years typhus in England has mainly been observed in Liverpool, or in other towns, under circumstances suggesting the possibility of infection having been brought either from Ireland or from abroad. Typhus is, in the main, a disease of temperate climates; outside Europe it has prevailed in Persia, North China, Egypt, and North America. It is stated that it has only obtained a footing in the tropics in elevated localities, and at the colder seasons of the year. In this country the disease has shown some preference for the winter and spring months, but it has occurred at all times of the year, in no specially noteworthy relation to season.

The case-mortality rapidly increases with advancing life; Murchison gives the average fatality for all ages as 10 per cent., but between forty and fifty, fifty and sixty, and over sixty, it exceeded 40, 50, and 60 per cent. respectively. The micro-organism of typhus has not been isolated, and nothing is known concerning its dissemination by water, milk and food, or its occurrence in the lower animals. Infection is presumed to be conveyed by the breath, or by emanations from the skin, and a peculiar odour is described as being noticeable in typhus cases. For conveyance of infection close proximity has been held to be necessary, and it is generally believed that removal to a distance, of a few feet only, from the patient interposes an insuperable barrier to spread of the disease. The period of incubation is given by Murchison as being about twelve days; he considered the disease to be specially infectious from the end of the first week of the illness up to the time of convalescence.

Whooping-Cough.—The history of this disease cannot, it appears, be traced further back than the year 1578. It undoubtedly prevailed in England in the seventeenth century. At the present time it is distributed all over the inhabited globe; cold and damp, however, specially favour its prevalence, and the tropics are comparatively free from it. In England and Wales the mortality has ranged, during the years in which registration has been in force, from some 400 to 700 deaths, per million living, annually. The mortality caused by it is thus very considerable; it particularly falls upon the first year of life, at which age-period nearly half the deaths occur, and some 90 per cent. of the total deaths are those of children under five years. The variations from year to year in recorded mortality are not very great, and no definite law of epidemic recurrence is apparent on study of annual figures. In Sweden, however, from 1774 onwards, cyclical variations, with an interval between the major prevalences of some four or five years, were manifested.

The case-mortality is said to be about 5 per cent. The seasonal

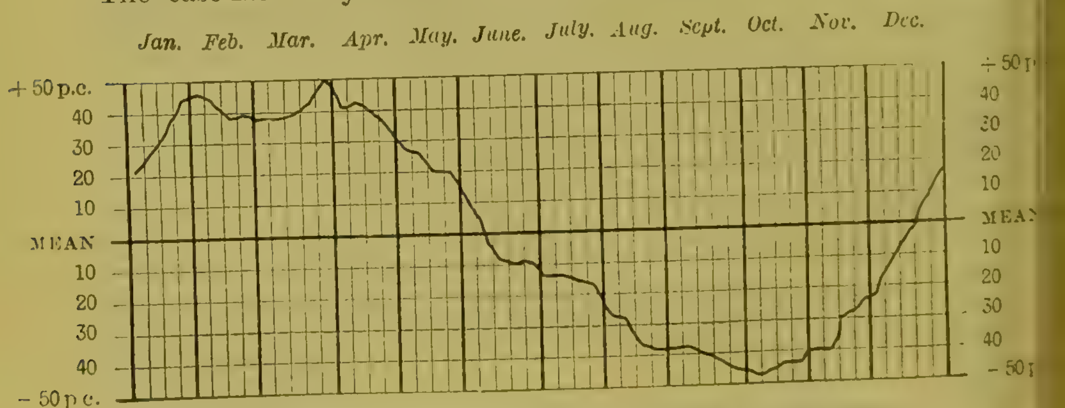

FIG. 93.—WHOOPING-COUGH IN LONDON (sixty years, 1841-1900).
The mean line represents an average weekly number of forty-six deaths.
(*After Shirley Murphy.*)

curve shows a maximum mortality in April, and a minimum in September. The period of incubation is said to be from four to seven days (or even fourteen days); the disease is infectious from the very commencement, and continues, as a rule, to be so for six or eight weeks. The micro-organism of whooping-cough has not been isolated, and there is no evidence that the disease is spread by water, milk, or food, or that it affects any of the lower animals; the breath is probably the ordinary medium of infection, and the malady is also said to have been conveyed by clothing, etc. The disease may be spread in connection with gatherings of children, as for example in schools, but, owing to its incidence upon young infants, the question of school closure less frequently presents itself in association with whooping-cough than it does, for example, in measles. Shirley Murphy has shown that, as in the case of diphtheria, there has been in more recent decades, when compared with 1861–70, relative increase of incidence of mortality both in measles and whooping-cough on ages 3—4, 4—5, and 5—10. There has also been relative increase of incidence of mortality on the first two years of life in measles and whooping-cough; this is probably attributable to greater opportunity of infection due to increased density of population.

The Registrar-General in his Annual Report for 1891 discusses the diseases to which infants succumb. He says (p. xvi.), "Very notable is the comparative immunity of infants in the earlier months from the several zymotic diseases. The earliest to declare itself is whooping-cough, which is the assigned cause of some deaths even in the first month, but becomes much more frequent later on; next comes measles, but with no great number of deaths until the eighth or ninth month is reached, after which it takes many victims; while scarlet fever is still later in its appearance, and scarcely carries off any infants at all in their first year." This peculiarity in the behaviour of whooping-cough is specially noteworthy; it renders the application to it of the preventive measures, adopted in the case of other zymotic diseases, particularly difficult. Whooping-cough has been scheduled as a notifiable disease in a few instances (*See* p. 536), but no serious attempt to control its spread has hitherto been made.

Yellow Fever.—This disease has two endemic centres—the West Indies, and Sierra Leone with adjoining portions of the West Coast of Africa. From these epidemics from time to time extend, but they are notably limited in their power of diffusion by meteorological conditions, as the disease requires for its spread a temperature of over 75° F. Thus from the West Indies the wave of prevalence may proceed northwards to California and to other States, mainly the Southern States of the Union, and may extend as far south as Buenos Ayres. Yellow fever has been imported into Southern Europe, and cases have occurred in Brest, St. Nazaire, and Swansea, but the disease has never really established itself even in Spain. In the neighbourhood of Swansea, in 1865, some twenty cases, fourteen of which were fatal, were developed.

There has been much speculation as to whether Africa, or Mexico and the West Indies constitutes the original home of the disease. The history of yellow fever dates back to 1699 at Vera Cruz, and there is no recorded outbreak in West Africa until nearly one hundred years later, but the question of priority of claim cannot be pronounced upon with certainty. Manson suggests that the construction and use of a Central American canal is likely to lead to extension of the disease to Asia. He explains the fact that it has not been introduced there hitherto on the ground that the trade route from the West Indies to China and India has not been a direct one, but "has passed by a long circuit either to the north or to the south."

The disease is chiefly prevalent at the hot season of the year, and it appears, as a rule, to be favoured by humidity. It affects coast towns, notably those with much-polluted harbours; it haunts, as Manson says, "the sea front where the sewage discharges." It persistently affects particular localities, and soil probably plays a part in determining this peculiarity. As in the case of beri-beri, ship outbreaks occur. The fatality varies in different epidemics—in unacclimatised adults it may be 60 per cent. or more. Males are more often affected than females, and it is especially fatal among the intemperate; probably the question of alcohol determines the greater attack- and death-rates in males. The incubation period varies from one to three days. One attack usually confers protection. In cities in which the disease is almost constantly present the cases to a large extent occur among strangers; the mortality among permanent residents is comparatively low—under 10 per cent. In New Orleans, during epidemics, children die in large numbers, and this is explained by the fact that, "unlike the children in endemic areas they are not acclimatised." The immunity of residents in endemic areas has been held to be transmitted by heredity; a more probable hypothesis is that it is acquired by undergoing a mild, unrecognised attack of yellow fever.

Many attempts have been made to isolate the germ of yellow fever. Freire believed it to be an organism which he isolated and termed the *Cryptococcus xanthogenicus.* Finlay, of Havannah, claims to have discovered the true organism, and he holds that the mosquito is mainly concerned in spreading the disease. Sanarelli in 1897 isolated a motile bacillus, the *Bacillus icteroides*, which he cultivated and showed to be pathogenic in animals; moreover, cultures are said to have produced yellow fever in man. The organism is agglutinated by the serum of a person suffering from yellow fever, and Sanarelli claims to have obtained a protective serum by treatment of horses. The question as to the interpretation of Sanarelli's results is still *sub judice.*

Unacclimatised persons who visit yellow fever localities should avoid the poorer and low-lying parts of the town, as filth and overcrowding are said to favour the spread of the disease. Sailors should not be allowed to go on shore. If yellow fever break out on board ship, the best plan is to make with all speed for a region of comparatively low temperature. The United States Army Commission made a number of important observations with regard to yellow fever, in the island of Cuba, during the years 1900 and 1901. An account of their proceedings is given in a paper by Surgeon Walter Reed, which appeared in the *Journal of Hygiene*, Vol. II., No. 2. They found that the disease was inoculable, the specific agent being present in the blood, at least during the first, second, and third days of the attack; successful results were, moreover, obtained with bacteria-free serum filtrate. Attempts to convey infection by fomites were uniformly unsuccessful, but a species of mosquito, *Stegomyia fasciata*, if previously fed on yellow fever blood, was, after the lapse of an interval of twelve days or more, found capable of transmitting infection. The adoption of a system of quarantining affected persons in rooms protected with wire screens, so as to exclude mosquitoes from access to them, while at the same time efforts were made to destroy all mosquitoes within a given radius of each case, was attended with marked success. The spread of yellow fever in Havana, during the year March 1st, 1901 to March 1st, 1902, *i.e.*, subsequent to the putting in practice of this stamping out process, was inconsiderable, and this despite the fact that more than 35,000 deaths were caused by the disease in that town between 1853 and 1900.

CHAPTER X.

DISINFECTION.

It is necessary to distinguish between deodorants, antiseptics, and disinfectants. Deodorants merely destroy or overpower unpleasant smells. Antiseptics retard the growth of organisms, but do not necessarily kill them. The term "disinfectant" should be limited to substances capable of destroying the germs of disease. But here there is the difficulty that it is only in certain instances that the organisms can be isolated and experimented with; again the knowledge which is available shows that while some are comparatively readily destroyed, others are much more resistant. The late Sir George Buchanan wrote, in 1885, in connection with Dr. Parsons' inquiry concerning disinfection by heat: "Dr. Parsons has had a care to take destruction of the most stable known infective matter as the test of true disinfection"; and this of course is the only safe guide in the existing state of knowledge.

The importance of light and fresh air as germicidal agents must not be lost sight of; again, much can be done in the way of mere mechanical removal, for the purpose of subsequent destruction by fire, of articles of small value, the wall-paper after stripping it from the walls, etc.; moreover, scrubbing and cleansing operations should by no means be disregarded. These agencies may be looked upon as important auxiliaries. The chief measures relied upon in disinfection, however, are the application of heat or of chemical disinfectants.

Disinfection by Heat.—Heat may be most effectually applied by burning or boiling. Articles which are too valuable to burn, or which would be spoiled by immersion in boiling water, must be subjected to the action of heat in special forms of apparatus. Until quite recently exposure to dry heat was commonly practised; but experiments made by Koch and his assistants, in 1881, cast great doubt upon the reliability of hot air disinfection. They ascertained that spore-free bacteria were destroyed on exposure to 212° F. for an hour and a half, but that spores were killed only after remaining three hours in hot air at 284° F. The penetrating power of dry heat was found to be little marked, and in order to secure adequate disinfection in the case of bundles of clothes, pillows, etc., prolonged exposure (three to four hours) to a temperature of 284° F. was necessary, and most of the materials to be disinfected were found to be more or less injured by such exposure. Parsons and Klein in this country conducted similar investigations. Parsons, in his report (Fourteenth Annual Report of the Medical Officer of the Local Government Board) says—"It has been well remarked that bedding, blankets, etc., are the highest outcomes of the ingenuity of man to check the passage of heat from one side of the object to the other. It is no wonder, therefore, that they should be found difficult of penetration by heat." His experiments showed that "to procure the penetration by heat of bulky articles of badly conducting material, high-pressure steam is the agent *par excellence*."

The penetrating power of steam heat is due to more than one cause. Parsons puts in the forefront "the large amount of latent heat contained in steam." When, as he says, "an object is heated, by being placed in hot dry air, not only is no latent heat yielded up to it by the air, but, on the other hand, before the object can attain the temperature of 212° F., any water which it may contain must be evaporated." Again, the fact that condensation of steam makes way for more steam, has important influence. Thus he says: "When steam penetrates into the interstices of a cold body it undergoes condensation in imparting its latent heat as aforesaid to the body. When condensed into water it occupies only a very small fraction (about $\frac{1}{1300}$) of its former volume. To fill the vacuum thus formed more steam presses forward, in its turn yielding up its heat and becoming condensed, and so on until the whole mass has been penetrated. On the other hand, hot air, in yielding up its heat, undergoes contraction in volume, it is true, but only to a very small extent as compared with that undergone by steam in condensing into water."

Other influences referred to by Parsons as tending to facilitate the penetrative power of steam, are the fact that heat is evolved in moistening hygroscopic substances; that the specific heat of steam is greater than that of air; and that the diffusive power of steam exceeds that of air (the diffusion of two gases into one another taking place with a velocity inversely as the square roots of their respective densities)—all sources of advantage on the side of steam. Finally, steam can be used under pressure, and the effect of intermitting the pressure can be brought into play. Here, as Parsons says, "we have a means of considerably increasing the penetrative power of steam, by displacing the cold air remaining in the interstices of the material."

Very careful consideration was given by Parsons to the question of the liability to injury of articles disinfected by heat. The modes in which such injury may occur are classified by him as follows:—

1. Scorching or partial decomposition of organic substances by heat. In its incipient stages this manifests itself by changes of colour, changes of texture, and weakening of strength.
2. Overdrying, rendering materials brittle.
3. Fixing of stains, so that they will not wash out.
4. Melting of fusible substances, such as wax and varnish.
5. Alterations in colour, gloss, etc., of dyed and finished goods.
6. Shrinkage and felting together of woollen materials.
7. Wetting.

The first two modes of injury were common in the days of dry-heat apparatus; with steam they are comparatively unimportant. As regards the third, it is well known that dyers and calico printers use high-pressure steam for the very purpose of fixing their colours. This property of heat is, therefore, as Parsons says, "an inconvenient one from our present point of view." Linen soiled with blood, fæcal matter, etc., "cannot be disinfected by heat, not even by boiling water, without indelibly fixing the stains." The only alternatives are to put up with damage to this extent, or to make suitable arrangements (with all proper precautions against spreading infection) for first soaking such linen in cold or tepid water, in order to remove the stains, and then subsequently disinfecting by steam or by exposure to boiling water. To prevent the fourth class of injury, all fusible and inflammable substances should obviously be removed prior to use of the steam disinfecting apparatus. Dry heat is less likely than steam heat to cause injury in the ways indicated under heads five, six, and seven, and hence it is still sometimes used for disinfecting books, and articles made of leather, etc., which steam heat would injure.

Ransom's self-regulating hot-air apparatus is fully described in Parsons' report, as being one of the best of its kind, and it may be employed for the purpose indicated; but complete reliance cannot be placed upon penetration of the heat. In cases where articles cannot be satisfactorily disinfected, the best plan is to burn them. It has been suggested that books should be exposed to formaldehyde, and this plan is sometimes adopted, the books being suspended and their pages subjected as far as practicable to the action of the disinfectant. Injuries caused by "shrinkage," "felting together, and loss of elasticity and fluffiness, upon which the warmth and softness of woollen materials depends," and damage by "wetting," which may produce shrinkage and cause colours to run, cannot be altogether obviated in steam disinfection. By careful use of suitable appliances, however, such injuries may be reduced to a minimum, and various devices for displacing the steam and drying the articles before they are removed from the steam disinfector have been employed.

The steam disinfectors in common use at the present time are adapted either for the use of current steam or of steam under pressure; again, the steam may be saturated or superheated. High-pressure steam (10 to 30 lbs. to the square inch) possesses considerable penetrating power, and the time of exposure necessary is therefore lessened; moreover, the pressure can be raised and lowered, thus greatly favouring penetration. A temperature of 115° to 120° C. can be obtained in high-pressure stoves, and the period of exposure of articles in them can be reduced to half an hour or even fifteen minutes. In some modern appliances a partial vacuum is produced, by directing a jet of steam across the orifice of an opening communicating with the disinfecting chamber, before steam is admitted to the latter, and by this means the subsequent penetration is greatly facilitated; or, after the disinfection has been effected, a vacuum may be created, and dry hot air then drawn into the chamber, so as to remove any condensed moisture from the disinfected materials, and enable them to be restored to their owners in a dry condition.

The use of steam at low pressure (3 to 5 lbs. to the square inch) has been advocated on the ground that the cost of construction in appliances made to resist high pressure is considerable, and that the advantage of the higher pressure *per se* is not specially obvious, provided the considerations to which reference has been made (penetration, drying of goods, etc.) are duly observed in carrying out disinfection at lower pressures. In some stoves steam without pressure is used, and here, while the penetration per unit of time is less, the current of steam gradually drives before it the air contained in the materials to be disinfected, and thus secures in the long run more complete penetration than can be obtained with steam confined under pressure, unless adequate provision for escape of the steam from time to time, and for alternations of pressure, be made.

The distinction between superheated and saturated steam is an important one. Saturated steam, ever ready to condense on coming in contact with an object cooler than itself, constitutes a most efficient penetrating agency, but when it is used there is a tendency to wetting of the materials disinfected. On the other hand, superheated steam, *i.e.*, steam raised above the temperature at which condensation (at the pressure which obtains) occurs, cannot condense until deprived by conduction of a portion of its heat. Hence, with superheated steam there is less liability to wetting and damage of disinfected materials; but, on the other hand, the penetrating advantages offered by steam heat are now to a large extent in abeyance, as the superheated steam merely behaves as hot air would do, imparting heat by conduction, and no longer possessing the ability to become at once condensed on being brought into contact with a cool object. In practice, however, the extent to which steam is superheated is not, as a rule, sufficiently great to prevent condensation occurring.

In Washington Lyon's apparatus, an elliptical chamber is used possessing an outer jacket. Steam at 15 or more lbs. pressure is admitted to this outer jacket, the walls of the chamber and its contents are thus heated, and then steam at a somewhat lower pressure is introduced into the chamber itself. The amount of condensation is lessened by the use of the outer jacket, the steam in the chamber being kept slightly superheated. A steam exhaust, moreover, is commonly used, as aforesaid, to produce a vacuum before the entry of the steam, and so favour penetration; the exhaust may again be put in operation after disinfection, this being followed up by admission of hot air to dry the disinfected materials. This form of apparatus is one of the best, but also one of the most costly.

Reck's stove does not possess the outer jacket. It is a low-pressure stove and comparatively inexpensive, but longer exposure of the materials to be disinfected is necessary. A device employed in this apparatus is the introduction of a cold shower of water, after disinfection, into the chamber (avoiding, of course, the articles it contains), in order to rapidly condense the steam. Air then enters to fill the partial vacuum formed, and drying of the disinfected articles can be thus effected.

The Equifex Disinfector has no outer jacket; it can be obtained adapted for either high or low pressure. In Thresh's disinfector steam given off from a boiler containing a calcium chloride solution is used; thus the steam is somewhat super-heated without employing pressure, for the boiling-point of the solution is higher than that of water; the temperature of the steam evolved is about 105° C. In the last-named forms of apparatus, as in those first mentioned, the disinfected articles are usually dried, by one or other means, at the termination of the disinfection, and before being removed from the stove.

It is important that disinfected materials should not be again contaminated, by being brought in contact with infected materials, hence it is usual to design the disinfecting station in such a way that the room to which the infected goods are brought is aerially disconnected from that from which disinfected goods are removed, the disinfecting apparatus being built into the wall separating the two distinct portions of the establishment. Moreover, the covered conveyances which bring infected materials to the station should be altogether distinct from those taking disinfected articles from it. Again, attendants should not pass from one part of the building to the other; and, indeed, every precaution should be taken to prevent intercommunication between the infected and non-infected sides of the premises.

A destructor or incinerator should be available at the disinfecting station, and it is a great advantage if a laundry for dealing with infected linen is also provided. In London it is usual to erect on the same site a shelter to accommodate persons "who have been compelled to leave their dwellings for the purpose of enabling such dwellings to be disinfected by the sanitary authority." The duty of making such provision has been imposed on sanitary authorities under Section 60 (4) Public Health (London) Act, 1891. In the country, generally, there is no obligation to make such provision unless the Infectious Diseases (Prevention) Act, 1890, is in force (*See* p. 539).

Chemical Disinfectants.—Disinfection by the application of various chemical substances remains to be considered. There are many chemical disinfectants, so called. If the term be limited, however, to those which are capable, in a brief space of time, of destroying the most stable known infective matter, the number is very small. Koch experimented with threads soaked in cultivations of anthrax spores, which he placed for measured periods of time in various solutions, and he found that rapid and complete action, with destruction of the spores in the course of twenty-four hours, was manifested in only a very small number of instances, including the cases in which he used solutions of chlorine, iodine, and bromine water, a 5 per cent. solution of permanganate of potash, a 5 per cent. solution of carbolic acid, and a solution containing only one part in 20,000 of perchloride of mercury. Other disinfectants either took a longer time to kill the spores or did not kill them at all; belonging to this group were 5 per cent. solutions of the following substances:—Chloride of lime, chloride of zinc, sulphate of copper, sulphate of iron, and boracic acid.

It appears, then, that by far the most powerful disinfectant, according to these experiments, is *perchloride of mercury;* a solution containing one part of this reagent in 1,000 parts of water possesses the ability to kill anthrax spores in a few minutes. An important point in connection with the use of perchloride of mercury is that it coagulates albuminous substances, and consequently, when material containing such substances in any quantity is to be disinfected, the perchloride of mercury solution must be added in considerable excess, in order to make up for the waste caused by the coagulation. Again, perchloride of mercury is a very powerful poison, and caution requires to be exercised in using it. The solution may with advantage be coloured in order to prevent any possibility of mistake, and the following formula is often employed :—Mercuric chloride, ½ oz.; hydrochloric acid, 1 oz.; aniline blue, 5 grains; water, 3 gallons.

The *phenols* and *cresols* are obtained in the distillation of tar. Pure phenol (carbolic acid) has the formula C_6H_6O. Cresol or cresylic acid is methyl-phenol, C_7H_8O. Ordinary commercial carbolic acid is in the main a mixture of ortho-, meta-, and para-cresols. Cresol is found to possess slightly greater disinfecting property than pure phenol. Izal is a comparatively new product, which is extracted from an oil formed in the distillation of coke. It is a cream-like emulsion, and appears to contain, or to be allied to, cresol. Jeyes' fluid, creolin, and saprol are further examples of cresol-containing preparations. A 10 per cent. admixture of izal with water has been found to be capable of destroying anthrax spores in twenty minutes.

It has recently been shown that chinosol, a yellow crystalline substance belonging to the quinoline group, which is non-poisonous, and which does not coagulate albumen, possesses marked disinfectant properties. Formalin is an aqueous solution of formaldehyde (to be immediately referred to) concentrated so as to contain about 40 per cent. Perchloride of mercury, formalin, and chinosol have been largely employed as spray disinfectants—an Equifex sprayer, or other form of apparatus, which will discharge the fluid upon the surface to be disinfected, with considerable velocity, and in as finely divided a state as possible, being used. Chloride of lime, sodium hypochlorite, lime, sulphates of copper, iron, and zinc, and chloride of zinc (which forms the main ingredient of Burnett's fluid) have all been tried as disinfectants, but they cannot be regarded as so satisfactory as mercuric chloride and the phenols and cresols.

In employing chemical disinfectants it is important to ensure their being added to the infected material in adequate quantity, and it must be borne in mind that it is the percentage of disinfectant, in the entire bulk of material, which determines the sufficiency of disinfecting power, and not the percentage in the added disinfecting fluid. Again, the disinfectant should remain in contact with the infected material for a sufficient time to enable it to produce the desired effect. Chemical disinfectants are generally applied in a liquid form. Disinfecting powders are, however, sometimes used; many of them are of but little value. Calvert's carbolic acid powder and Macdougall's powder are said to possess the advantage that they do not contain lime, as do many inefficient carbolic acid powders.

Gaseous Disinfectants are often employed for the practice of fumigation, more particularly in connection with "room disinfection." The notion entertained, in the past, has undoubtedly been that all that was requisite was to secure disinfection of the air of the room. With acceptance, however, of the particulate nature of infective material, and study of the physical properties of micro-organisms, it has been realised that but little in the way of practical "disinfection" can be accomplished in this way. It is not, of course, the organisms floating at a particular time in the air of a room that should be thought of as specially important; these are inconsiderable in number in comparison with the total number of organisms present, and the mere destruction of the air-borne germs is a matter of comparatively little moment, the object to be attained being to deal as far as possible with all the organisms in the room. Hence dirt and dust of all kinds—that in chinks and crevices, as well as that suspended in the air or lying superficially—require to be disinfected. Again, infective secretions and excretions are not unlikely to have soaked or penetrated, into situations in which there is little or no likelihood of their being followed up and acted upon by gases evolved in the process of fumigation.

Modern advocates of fumigation methods, if they recognise the inability of gases to penetrate, can only claim that their object in employing them is to destroy the organisms which happen to occupy exposed situations. Unfortunately this is not generally understood, and fumigation is often regarded as being in itself a sufficient means of disinfecting a room and the articles contained in it. In many instances no other form of disinfection is practised, and even when this is not the case there is often a tendency to attach an exaggerated importance to fumigation.

Other methods of room-disinfection, however, have been, especially of late years, from time to time adopted. In Germany the plan of cleansing the surface of walls, etc., by rubbing them down with crumb of bread has been extensively employed; and in Paris and elsewhere reliance is placed upon the use of disinfectant solutions, which are applied systematically to walls, etc., to the exclusion of the use of gaseous disinfectants. In Paris, perchloride of mercury has been largely employed in the form of spray, but it cannot be applied to many metallic and other objects without causing injury, and the poisonous character of the liquid has been objected to as a possible source of danger. In some instances symptoms of mercurial poisoning are stated to have occurred among persons engaged in the work of disinfection. It appears likely that disinfection will, as time goes on, be increasingly carried out on lines similar to these. At the present time, however, in England, gaseous disinfection is very extensively practised, and sulphurous acid, chlorine, or formic aldehyde are generally relied upon.

Sulphurous Acid—Sulphur Dioxide.—This gas may be generated by burning ordinary roll sulphur in an iron vessel, the ignition of the sulphur being favoured by moistening it with a little spirit; or sulphur candles, made by mixing sulphur with inflammable material, may be used. Again, carbon bisulphide may be burnt in an ordinary benzoline lamp, sulphur dioxide being thus evolved. These methods are all, to a large extent, superseded at the present time by the use of cylinders containing liquefied sulphur dioxide, this method being much more convenient, though rather more costly.

As the gas is about twice as dense as atmospheric air, it is well to arrange for its being liberated at some height in the room, and bronze or gilded objects should be removed and disinfected by application of carbolic acid, as the sulphur fumes would tarnish them. All outlets must be carefully closed, including the fireplace; cracks must be pasted over with paper, and the room converted, as far as possible, into a hermetically sealed chamber. At least 2 lbs. of sulphur (or two 20-oz. cylinders of the liquefied gas) should be used for every 1,000 cubic feet of space. The room can then be made to contain about 2 per cent. of the gas, and it should be kept sealed for twenty-four hours.

If the work has been thoroughly done, there may be difficulty in entering the room to ventilate it; in that case a towel well wetted with washing soda may be used to protect the mouth of the operator. After the room has been properly ventilated, the articles in it should be removed to the wash-tub or to the disinfecting chamber; the walls should be stripped; the floor thoroughly scrubbed; and it is desirable that articles of furniture should be well wiped with a cloth wetted with some suitable liquid disinfectant, care being taken not to cause unnecessary injury, as, for example, by the application of perchloride of mercury to metallic surfaces.

Chlorine is more expensive and more difficult to use than sulphurous acid; on the other hand, its disinfecting capacities are somewhat more marked. Metal objects and silk materials are likely to be damaged by it, and its bleaching properties are more considerable than those of sulphurous acid. It is generated by treating bleaching powder with sulphuric acid or hydrochloric acid. Two pounds of bleaching powder and one pound of commercial hydrochloric acid should be used for every 1,000 cubic feet of space. The gas may be advantageously generated in more than one part of the room, and the receptacles should be placed high up, as chlorine, like sulphurous acid, is dense, and diffuses badly. Caution is, of course, necessary in arranging for escape from the room immediately the evolution of the gas is started; and if difficulty be experienced in re-entering, a towel soaked in a weak solution of ammonia may be placed over the mouth.

The chlorine takes up hydrogen from water, eliminating nascent oxygen, upon which its disinfecting power depends. The presence of moisture is therefore of importance, and it may be noted that this is also true as regards the use of sulphurous acid. Hence in some places it is the practice to fill the room with steam before proceeding to fumigate. It has been recommended that chlorine should be evolved by first thoroughly washing the exposed surfaces in the room with 1 in 100 solution of bleaching powder and then saturating the air of the room with acid fumes.

In the case of both sulphurous acid and chlorine it is, however, even under the most favourable conditions, only the less resistant forms of germs which are likely to be destroyed, and those only if they are exposed to the action of the fumes. Hence fumigation can only be looked upon as a preliminary proceeding, and after the use of chlorine, as after the employment of sulphurous acid, further measures of disinfection should be rigorously practised. The unsatisfactory nature of the bactericidal effects observed in the cases of chlorine and sulphurous acid has led to numerous attempts being made to obtain a more reliable form of gaseous disinfectant. Of the various gases tried, only one—formic aldehyde—need be mentioned.

Formic aldehyde (CHOH, aldehyde of methyl) has come largely into use in the last few years. It possesses some slight superiority to the aforementioned gases from a germ-destroying point of view; moreover, it is less dense, and diffuses more readily; further, its irritating effects on the respiratory mucous membrane are less marked, and it is thus more easy to work with.

It is a pungent gas, and its aqueous solution can be concentrated until it contains 40 per cent. of the aldehyde. The liquid is then known as formalin. If concentration is continued beyond this point, a polymeric form of the aldehyde—paraformaldehyde—is precipitated as a white solid. This substance has been made up into tabloids, "paraform" tabloids, which can be volatilised in a lamp which has been designed for the purpose. Roux and Baudet advocate, however, the use of a solution of the gas in calcium chloride, the mixture being known as "formochlorol"; when this mixture is heated under pressure in an autoclave, the gas evolved is said to be practically dry, and to show no tendency to polymerise, and to this they attach importance.

Wynter Blyth in 1897 found that "as a disinfecting gas" formic aldehyde was far superior to sulphurous acid. Kenwood states that when the atmosphere is charged with "from ½ to 2 per cent. of the vapour of formic aldehyde the disinfection of all surfaces is complete and rapid, and that this holds good under the ordinary conditions of temperature and moisture obtaining in living-rooms." He advocated the use of from ½ to 1 litre of "formochlorol" for every 1,000 feet of cubic space. The standard of "disinfection" adopted, however, in Kenwood's experiments, it should be noted, was that represented by ability to destroy "non-spore bacteria of comparatively easy destructibility," so that complete reliance cannot be placed upon the method for effectually dealing with more resistant organisms.

Drs. Klein, Houston, and Gordon reported to the London County Council in 1902 upon the value of various disinfectants, under the ordinary conditions of their use in dwelling-houses. They tested the operation of four fluid disinfectants—carbolic acid, permanganate of soda, bleaching powder, and corrosive sublimate, and two gaseous disinfectants—formalin and sulphurous acid. The organisms experimented with included anthrax spores, the bacilli of tubercle, diphtheria, and enteric fever, and the vibrio of cholera; cultures of the microbes distributed in broth, in milk, or in melted gelatine (in the case of tubercle bacilli, tubercular sputum was used) were liberally applied to four different sorts of material, in ordinary practice requiring to be disinfected, viz., cloth, unvarnished or unpainted wood, linen, and wall-paper; these materials were then exposed to the action of the disinfectants, and the result was tested by cultural and inoculation experiments. It was found that the resistant anthrax spores "were only destroyed with certainty by perchloride of mercury" (1 in 1,000, with twenty-four hours' exposure), the other disinfectants either failing to destroy them or being uncertain, "and almost invariably failing when wood and cloth* were the materials to be disinfected." In the case of the tubercle bacillus, carbolic acid (5 per cent. solution, with twenty-four hours' exposure) and perchloride of mercury "were the only disinfectants efficacious on each occasion"; neither formalin nor sulphurous acid manifested ability to deal with wood or cloth infected with this bacillus. Formalin vapour, however, showed to greater advantage than sulphurous acid in the case of tubercular sputum dried on linen and paper. The gaseous disinfectants proved effectual in the case of the remaining organisms, save in one experiment in which even the little resistant bacillus typhosus, exposed on wood or cloth, was not destroyed by formalin.

* The contrast observed between wood and thick cloth on the one hand and linen and paper on the other was attributed to the fact "that the microbe-containing mixtures soaked into the materials first named."

CHAPTER XI.

VITAL STATISTICS.

Rates.—The rate, at which births, deaths, etc., occur in a particular community, is usually expressed in terms of a year and a thousand persons living. Thus :—

$$\text{Annual death-rate} = \frac{\text{number of deaths in the year}}{\text{population in the middle of the year}} \times 1,000.$$

In calculating weekly, quarterly, etc., death-rates, the standards employed are still the year and 1,000 persons living. Hence, a weekly death-rate, x, signifies not that x deaths per 1,000 living occurred during the week, but that, had the rate of mortality during the week been maintained for a year, x deaths per 1,000 living would have been recorded. Again, a "quarterly birth-rate" of 32 implies that 8, not 32, births per 1,000 living occurred, during the quarter in question.

The following remarks concerning death-rates were made by Dr. Farr :—"The simple process of comparing the deaths in a given time, out of a given number living, is a modern discovery ; and as some individuals died at all ages in the healthiest, or attained the highest ages in the unhealthiest classes, and epidemics desolated the country as well as towns, though to less extent, the unaided reason was baffled in its attempt to unravel the intricate facts, and to draw conclusions which could justify or stimulate public interference. If the law of nature had been that all the inhabitants of an unhealthy place attained the age of 40 years, and of a healthy place the age of 50 years, and then invariably died, the difference would have been perceived in two or three generations : but the law of nature was different ; in both cases infants died at the breast, men perished in the prime of life, and old men grew grey with age : the proportions only varied, and the difference was in the average duration of life, which varied from 20 to 50 years and yet remained undetermined." He added that it was not realised, for example, before the first report of the Registrar-General appeared, how considerable was the difference between the mean duration of life in the east districts (25—30 years) and that in the west districts (40—50 years) of the metropolis.

The main caution to be borne in mind in using rates, is that while they constitute a weapon of enormous value, provided the facts be sufficiently numerous and the period reviewed extend over a sufficient length of time, the liability to error is increasingly greater as they are calculated on smaller and smaller figures.*

Population.—Before calculating rates it is necessary to ascertain the populations upon which they are to be estimated. The first census was taken in this country in 1801, and a fresh census has been taken every ten years since; the details ascertained have varied somewhat in the different enumerations, and there has been, on the whole, a tendency to add to the particulars collected. This tendency will, no doubt, continue as time goes on, but it has been necessary to proceed by degrees, for, as Noel Humphreys has pointed out, "in England, at any rate," census statistics "are simply the tabulated results of facts furnished by householders," and "the imperfect education of a large proportion of householders in this country necessarily impairs the accuracy of much of the information collected"; he cites, for example, the information given with regard to occupations; speaking generally, the more detailed the information sought, the greater become the possibilities of error.

The following inaccuracies with regard to "ages" should be particularly noted. Children in their first, second, and third year are often returned as one, two, or three years old; thus, in the first year of life especially, the census gives too low a figure. Again, there is a tendency to return ages as some multiple of ten, for as Ogle, in the Report on the 1891 Census, noted, it is necessary to realise that "not improbably the greater number of adults do not know their precise

* It is a familiar device, therefore, with apologists for insanitary conditions to reduce the number of facts under review to such an extent as to confuse the issue. Thus, in a particular population living in an "insanitary area," the phthisis death-rate may be excessive, but this high rate, while apparent enough for the whole population, may not be so obvious on limiting consideration to particular houses in the area. If it can be elicited, for example, that only two deaths from phthisis occurred in a row of houses, occupied by forty persons, during a period of five years, such a discovery may be used to minimise the significance of the high rate in the entire population. The particular figures in question give, as a matter of fact, for the forty persons, a greatly excessive phthisis death-rate (10 per 1,000 per annum). It would, however, have been possible, by excluding the houses in which the deaths occurred, to show that no deaths at all could be associated with the remaining houses. Of course, but little importance can in any case be attached to a death-rate from one particular cause of death, based on a population of only forty persons when it relates to a period of but five years.

age, and can only state it approximately." Again, there is a certain amount of wilful misstatement of age; thus, as Farr pointed out, the number of girls aged 10—15 at the 1841 census fell short by more than 25,000 of the number of young women returned at the age-period 20—25 in the 1851 census; the fact suggests that, "in 1841 and 1851, heads of families returned several thousands of ladies of the higher ages at the age of 20—25." Finally, persons at advanced ages are very apt to overstate their age. This question will be seen to assume importance in connection with life tables.

Inasmuch as the population is enumerated at the end of the first quarter of census years, an estimate is necessary to determine the number at the middle of the year (*i.e.*, at the end of the second quarter). Moreover, estimates must be made of the populations at the middle of intercensal years, and in making the calculation it is assumed that the population increases or decreases in geometrical progression.

On this assumption the rates of quarterly increase and of annual increase are determined from the known rate of decennial increase. Thus, if the census populations be P and P^1, the rate of decennial increase $= \frac{P^1}{P}$, the rate of annual increase $= \sqrt[10]{\frac{P^1}{P}}$, and that of quarterly increase $= \sqrt[40]{\frac{P^1}{P}}$.

$$\text{Hence log ratio of decennial increase} = \log P^1 - \log P.$$

$$\text{log ratio of annual increase...} = \frac{\log P^1 - \log P.}{10}$$

$$\text{and log ratio of quarterly increase} = \frac{\log P^1 - \log P.}{40}$$

Thus, it may be necessary, for example, given the census populations of 1891 and 1901, to find the population at the middle of 1904. Here the population at the census of 1901 must be multiplied by the ratio of quarterly increase, and again by the cube of the ratio of annual increase, since, from the time of taking the 1901 census to the middle of 1904, one quarter of a year and three whole years have elapsed. Taking logarithms, therefore—the log of the population required = log population at census of 1901 + log ratio of quarterly increase + 3 times log ratio of annual increase.

The length of the interval between successive censuses is apt to prove a source of difficulty. In London an intermediate census was taken for the first time in 1896, at the end of five years from the 1891 enumeration. The 1896 census did not, however, cover the whole ground of an ordinary census. The estimation of a population over a period of ten years without definite ascertainment of its actual numbers in the interval may yield startling results.

Thus the Liverpool death-rate was supposed to have fallen from 26·7 in 1881 to 23·6 in 1890, the population of the city being estimated on the assumption that the increase of the previous decade had been maintained. As a matter of fact, it was found, in 1891, that the population had actually decreased, and that the death-rate, instead of falling to 23·6, had risen to 27·8. To some extent estimated populations may be checked by noting variations in the birth-rate, or in the number of inhabited houses as ascertained from the rate books.

Births must (since 1874) be registered within forty-two days of their occurrence. Still-births are not included in the returns in this country. The birth-rate is only slightly affected by season; there is a tendency for a maximum to occur in June and July, and a minimum in February or March. Social position has marked influence, the main factor being apparently the later ages at which the well-to-do marry. There has been in most countries, during the years of registration, a general tendency to decline in the birth-rate; this decline has been particularly noticeable in France and in parts of the United States. Newsholme considers that postponement of marriage and increased proportion of celibacy "only account for a share of the decreased birth-rate," and he holds that explanation of the phenomenon is to be sought "in some other cause or causes in operation throughout the civilised world."

More males are born than females; during the years 1838–47, 1,050 males were born to every 1,000 females in this country, but since that time the proportion has gradually declined, until in 1891–95 it was only 1,036 males to 1,000 females.

Marriages.—The marriage-rate is usually stated in terms of 1,000 persons living; a more accurate method is to calculate it on the number of marriageable persons over fifteen years of age. The marriage-rate is always higher in towns than in the country, and it is markedly influenced by national prosperity. Having attained a maximum of 17·6 in 1873, it has shown a tendency on the whole to decline since that date, though there have been signs of recovery in the rate of late years. The mean age at marriage has risen since 1873, and the proportion of marriages under age has shown steady diminution, from 82 men and 223 women who were minors per 1,000 marriages in the years 1871–75, to 56 men and 183 women who were minors per 1,000 marriages in the years 1891–95. It may be noted that in the early years of registration about one out of every three men, and one out of every two women married, were unable to sign the marriage register. The proportion has steadily diminished to less than 5 per cent. in both sexes; the proportion of women signing the marriage register with marks is still slightly in excess of that of men.

Deaths must be registered within five days of their occurrence. When a person who dies has been attended by a registered medical practitioner it is the duty of such practitioner to certify the cause of death. In 1895 the causes of 91·68 per cent. of the total deaths in England and Wales were certified by registered medical practitioners. The absence of a certificate does not necessarily involve the holding of an inquest; the registrar may, save in certain circumstances, accept the statement of the person who informed him of the death, as to the cause.

A Committee of the House of Commons was appointed to consider the question of death certification, and reported in 1893. The Committee recommended that, in each sanitary district, a registered medical practitioner should be appointed as public medical certifier of the cause of death, in cases in which a certificate from a medical practitioner in attendance was not forthcoming. The Committee made a number of other suggestions, but effect has not yet been given to their recommendations.

The effect of emigration and immigration upon the death-rate in a locality is marked; hence the low death-rate of growing towns, whose population is being continually added to by numbers of young adults from country districts. In some localities the proportion of domestic servants, whose lives are, generally speaking, "good lives," is sufficiently large to materially influence the death-rate. Moreover, in the case of domestic servants, it is often found that when illness occurs the patient returns home, and her death, should the illness prove fatal, is registered there, and is thus not credited to the district in which she has been living.

Out-lying institutions and non-residents.—Public institutions are also sources of disturbance of death-rates. In order to obviate the difficulties in question, it is desirable that the deaths of strangers who happen to die in the district should be excluded, and that those of persons who belong to the district, but who die outside it, should be included. The correction is difficult to make in its entirety, but to some extent the source of error can be removed. In London each sanitary authority is supplied quarterly, from Somerset House, with particulars of the deaths belonging to it, which have occurred in outlying institutions, and in the statistics published by the Registrar-General relating to the thirty-three great towns the deaths of non-residents occurring in county hospitals, county asylums, hospitals for infectious diseases, and convalescent homes, are excluded from the deaths returned as belonging to the sub-districts in which such institutions are situated.

In particular instances, unless correction for outlying institutions and for non-residents be made, most fallacious conclusions are likely to be drawn. Thus an urban registration district containing a large general hospital, whose patients are only in small part drawn from the registration district itself, may show great excess of mortality, unless regard be paid to the question of the hospital deaths. On the other hand, the practice of isolating small-pox cases at a distance from centres of population may result, during times of small-pox prevalence, in practically no increase in a particular district in the death-rate due to this cause, unless regard be paid to the small-pox deaths occurring in the isolation hospital, which may happen to be situated in a registration district distinct from that to which the deaths really belong.

Infant mortality should always be estimated in proportion to every thousand births, inasmuch as the census returns relating to the first year of life are, as has been seen, particularly untrustworthy. Strictly speaking, the mean of the births of the current and the preceding year, or the births of the first half of the current and the last half of the preceding year, should be taken as giving the true infantile population; as a rule, however, this more accurate method is not adopted, and the births of the current year are taken. The infantile mortality is often appealed to as a test of "sanitary condition." In particular towns high infant mortalities, even exceeding 200 per 1,000 births, recur year after year. In London the average infant mortality is about 155 per 1,000. In the Fifty-fourth Annual Report of the Registrar-General (*See* p. 445), the subject of infant mortality is discussed.

Neglect on the part of parents plays an important part in connection with infant mortality. Dr. G. Reid has drawn attention to the influence thus exerted in connection with employment of married women in factories in Staffordshire. He found that the infant mortality, in three groups of towns, followed the order in which the groups were arranged, from the point of view of number of women engaged in work away from home. It has been suggested that the observed coincidence is really due to the operation of other factors, inasmuch as populations can be selected, from other parts of the country, in which high infant mortality exists in association with comparatively little employment of women in factories. The question raised in connection with the Staffordshire figures is, however, one to which importance must be attached.

There can, of course, be no doubt that other influences are also at work—improper feeding in particular is largely accountable for high infant mortality. Newsholme comments upon the striking statement that has been made that "during the sufferings and starvation connected with the siege of Paris in 1870–71, while the general mortality was doubled, that of infants is said to have been reduced by about 40 per cent., owing to mothers being obliged to suckle their infants." The same increase of adult and diminution of infant mortality was seen during the Lancashire cotton famine, when, as Newsholme notes, mothers were not at work at the mills. Two further points may be referred to: Year after year considerably more than 1,000 infants are "overlaid," *i.e.*, suffocated in bed. Ogle pointed out (53rd Annual Report of the Reg.-Genl., p. xv.) that these deaths are specially frequent on Saturday nights, and suggested that drunkenness of the parents probably exerted influence in this connection. Again, Farr has shown that the number of deaths of illegitimate infants, per 1,000 illegitimate births, is in marked excess of the number of deaths of legitimate infants, per 1,000 legitimate births.

The influence of birth-rate on death-rate has been much discussed. Alterations in the birth-rate, by affecting the age constitution of a population, affect the death-rate; thus, a high birth-rate, other things being equal, in a particular year, by causing immediate increase in the number of young children, whose rate of mortality is high, might be expected to increase the death-rate for a year or two. On the other hand, however, if the birth-rate continue high, after a few years the population comes to possess an unusual proportion of persons who have weathered the storms of infancy, and whose rate of mortality is now low. Thus, a high birth-rate, continued for a number of years, might be expected to produce a low death-rate. As a matter of fact, in many instances in which high birth-rates occur, other conditions which affect death-rates more than the birth-rate itself does also obtain, and hence the influence of the birth-rate *per se* is often obscured. Thus, in crowded urban districts, occupied by poor people, high birth-rates and high death-rates often co-exist. The high death-rate in such cases obtains, notwithstanding the favourable age-distribution of the population produced by the high birth-rate, and is probably due to insanitary conditions. It has been pointed out that low birth-rates, continued for a number of years, have been observed to be associated with low death-rates. In France, however, a low birth-rate co-exists with a somewhat high death-rate. In that country the low birth-rate has been very long-continued, and the proportion of persons at advanced ages (attended by high mortality) is in such marked excess of the normal proportion as to adversely influence the death-rate.

Combined death-rates.—In obtaining the combined death-rate of two districts, it is, of course, necessary to take into account the relative sizes of the populations. Thus, if one population consist of 10,000 persons with a death-rate of 20 per 1,000, and the other of

50,000 persons with a death-rate of 15 per 1,000, the combined death-rate is obtained by applying the total deaths 200 + 750, *i.e.*, 950, to the total population 60,000. The death-rate is then 15·8. It would be absurd, of course, to regard the mean of the two death-rates, 17·5, as the combined death-rate, save in the case in which the two populations happened to be equal.

Influence of Age and Sex.—The death-rates in the two sexes and at different age-groups are given on page 479. It will be seen that the variations are considerable.

The tendency of the two sexes to suffer to a differing extent, from various diseases, must be noted. It is probably largely influenced by the degree of exposure to the conditions favourable to the development of certain maladies, and is also in part due to differences in predisposition. The excess of male mortality in small-pox, typhus, hydrophobia, glanders, anthrax, syphilis, gonorrhœa, and alcoholism is clearly in the main due to the former cause. On the other hand, puerperal fever and diseases incidental to child-birth are, of course, limited to females. Cancer, again, is more fatal among women than men. Measles and diarrhœa show excess among males under five; after five, measles mortality, and after ten, scarlet fever mortality, is greater in females. Diphtheria shows notable excess in females; here, again, greater exposure to infection, in connection with attendance on the sick, may be in part accountable. Nervous diseases, diabetes, tabes mesenterica, tubercular meningitis, and rickets are more fatal in males. Erysipelas, rheumatism, and anæmia cause higher mortality in females, as does also whooping-cough. The mortality from phthisis showed, until 1860, excess among females, after the first few years of life up to the forty-fifth. This higher mortality in females has receded gradually, from the forty-fifth year, as time has gone on. In the decade (1871–80) the higher female mortality only reached to the thirty-fifth year, and in the decade (1881–90) only to the twenty-fifth.

The influence of age upon mortality from particular diseases has been strikingly illustrated by Farr (Supplement to the Thirty-fifth Annual Report), in his account of the "*March of an English Generation through Life.*" He there follows the progress of 1,000,000 children, and notes the diseases which affect them as their age advances. "The first thing to observe," he says, "is that the fatality children encounter is primarily due to changes in themselves." Of the million some "have been born prematurely; they are feeble; they are unfinished; the molecules and fibres of brain, muscle, bone, are loosely strung together; the heart and the blood on which life depends, have undergone a complete revolution; the lungs are only just called into play. The baby is helpless; for his food and all his wants he depends on others." Out of a million 149,493 die in the first year of age. "In the second year of life pneumonia, bronchitis, and convulsions are still the prevalent and most fatal diseases; many also die then of measles, whooping-cough, scarlatina, and diarrhœa. Scarlet fever asserts its supremacy in the second, third, fourth, and fifth years of age. Whooping-cough is at its maximum in the first year, measles in the second, scarlatina in the third and fourth years." The deaths from all causes, under the age of five years, are 263,182; in the healthy districts only 175,410; but in Liverpool 460,370, or "nearly half the number born, died in the five years following their birth."

At the age 5—10 the total deaths are only 34,309; scarlatina is the "principal plague of this age." At 10—15 the deaths are fewer than at any other age—phthisis accounts for about one-fifth of them. At 15—20 mortality increases, especially among women, of whom 5,263 die of consumption (phthisis); a few women already die in child-birth. At 20—25 nearly half the deaths are caused by phthisis; 1,100 women die in child-birth. At 25—35 consumption is the most fatal disease and is the cause of 27,134 deaths; at 35—40 "phthisis still predominates, fever still snatches its many victims, and the brain, heart, lungs, and bowels become more and more the seats of destructive disease; 564 persons commit suicide, 3,280 die violent deaths, 2,907 of them men and 373 women; 2,516 mothers die in child-birth." In the period 45—55, "the middle arch of life," the million lives are reduced to half a million; cancer, already fatal before, now destroys 4,583 lives. In the period 55—65 cancer kills 5,998, consumption 10,445. "The diseases most to be dreaded and guarded against, especially by men, are affections of the lungs and heart, of which 23,659 and 17,081 persons die. Diseases of the brain are fatal to 15,678; diseases of the stomach and intestines and liver are fatal to 11,400." Only 309,029 persons enter the period 65—75, and 161,124 leave it alive, the same classes of disease as were fatal from 55—65 prevail. Only 38,565 leave the next period, 75—85, alive; 2,153 live to 95, and 223 to 100. "Such and so various," says Farr, "are the settings of 40,858,184 years of English life." The account of which the above is a brief abstract, was written, it must be remembered, about the year 1875, and the figures used are those of the English Life Table, No. 3, to be presently referred to.

Correction for Age and Sex Distribution.—As has been already noted, in connection with the influence of the birth-rate upon the death-rate, modifications in the age and sex distribution of a population materially influence its death-rate. The Registrar-General began, in 1883 (Annual Summary), to apply a method of correcting the recorded death-rate of the great towns for age and sex distribution.* This method can, of course, be applied to other populations, and it is often employed. The principle adopted is the construction for each town of a *standard death-rate—i.e.*, a rate-calculated on the hypothesis that the deaths at each age-period, in each sex, occur at the same rates as those obtaining, not in the town itself, but in England and Wales, during the latest available decennial period. Thus, to the population of the particular town, rates of mortality in the country as a whole, are applied, and the result, the *standard death-rate* of the town, differs from the actual death-rate in the whole country, to a greater or less extent, according as the age and sex distribution in the town are more or less abnormal. As an example of the method of calculating a standard death-rate, the following table, which gives the necessary data in a particular instance, that of the town of Huddersfield, may be quoted from Newsholme's "Elements of Vital Statistics":—

Ages.	Mean Annual Death-rate in England and Wales, 1881-90, per 1,000 living at each group of ages.†		Population of Huddersfield in 1891.		Calculated Number of Deaths in Huddersfield.‡	
	Males.	Females.	Males.	Females.	Males.	Females.
Under 5...	61·59	51·95	4,551	4,785	280	249
5 ...	5·35	5·27	4,691	5,081	25	27
10 ...	2·96	3.11	5,113	5,165	15	16
15 ...	4·33	4·42	4,905	5,549	21	25
20 ...	5·73	5·54	4,541	5,461	26	30
25 ...	7·78	7·41	7,466	8,834	58	65
35 ...	12·41	10·61	5,576	6,265	69	66
45 ...	19·36	15·09	3,944	4,649	76	70
55 ...	34·69	28·45	2,393	3,017	83	86
65 ...	70·39	60·36	1,128	1,590	79	96
75 and upwards...	162·62	147·98	250	466	41	69
Totals ...			44,558	50,862	773	799
			95,420		1,572	

* For an alternative method which can be employed when the death-rates at age-periods, in populations whose recorded death-rate is to be corrected, are available, *See* Supplement to the Forty-fifth Annual Report, pp. xvii to xix.

† The death-rates for England and Wales are the means of the annual death-rates in 1881-90 (Reg.-Gen. Fifty-fourth Annual Report, Tables 11 and 12).

‡ The "calculated deaths" are taken to whole numbers only.

It will be found that the number of deaths so calculated, 1572, only yields a death-rate of 16·47, whereas the death-rate of England and Wales (1881–90) was 19·15. The Huddersfield population is thus far more favourably constituted, as regards age and sex distribution, than the population of England and Wales generally; for in place of a death-rate of 19·15, which is that yielded on application of the England and Wales rates to the England and Wales population, the Huddersfield population, on having the same rates applied to it, yields only a "standard rate" of 16·47.

The standard death-rates of the thirty-three great towns are found to vary considerably. The lowest standard death-rate was that of Huddersfield, just referred to; while the highest standard death-rate was that of Norwich, which was 19·99. Some of the towns yield standard death-rates differing but little from that of England and Wales; for the most part the standard death-rates in the towns fall short of this, owing to divergences (from the England and Wales age and sex distribution of population) in these towns, of such a kind as to render them likely, *à priori*, to have a lower death-rate than that of England and Wales. The standard death-rate for the population of the thirty-three towns taken altogether is only 17·72; that of England and Wales, less the thirty-three towns, being 19·46.

The Registrar-General divides the standard death-rate in England and Wales by the standard death-rate in each town, and calls the result obtained the *factor for correction* for the particular town, *i.e.*, it is the figure by which the recorded death-rate should be multiplied in order to correct for variations of age and sex distribution. When the recorded death-rate of a town is multiplied by the factor for correction, the result is the *corrected death-rate* for that town. Again, the Registrar-General gives for each town a *comparative mortality figure*, which represents its corrected death-rate for the particular year in question, compared with the recorded death-rate at all ages in England and Wales taken as 1,000. Thus, in Huddersfield in 1900 the recorded death-rate was 16·78; this must be multiplied by $\frac{19{\cdot}15}{16{\cdot}47}$, *i.e.*, 1·1627 (the factor for correction), in order to obtain the corrected death-rate, which proves to be 19·51. On comparing this with the England and Wales rate, 19·15, it is found that it stands to it in the proportion 1,018 to 1,000. Hence 1,018 is the comparative mortality figure for Huddersfield for 1900.

The following Table gives the results obtained for the year 1900 in the thirty-three great towns (Table A, Annual Summary for 1900, p. iv.):—

Towns in order of their corrected Death-rates.	Standard Death-rate.	Factor for Correction for Sex and Age Distribution.	Recorded Death-rate, 1900.	Corrected Death-rate, 1900.	Comparative Mortality Figure, 1900.
Cols.	1	2	3	4	5
England and Wales ...	19·15	1·0000	18·31	18·31	1,000
England and Wales, less the 33 towns	19·46	0·9340	17·61	17·33	946
Thirty-three towns ...	17·72	1·0806	19·54	21·11	1,153
Croydon	18·37	1·0424	14·60	15·22	831
Cardiff	17·16	1·1159	13·77	15·37	839
Norwich	19·99	0·9579	17·57	16·83	919
West Ham	17·75	1·0788	15·93	17·19	939
Bristol	18·45	1·0379	16·66	17·29	944
Portsmouth	18·73	1·0224	17·28	17·67	965
Brighton	18·94	1·0110	17·84	18·04	985
Birkenhead	17·42	1·0993	16·82	18·49	1,010
Swansea	17·53	1·0924	17·07	18·65	1,019
Bradford	16·81	1·1391	16·41	18·69	1,021
Burnley	16·67	1·1487	16·30	18·72	1,022
Leicester	17·64	1·0855	17·43	18·92	1,033
Derby	17·36	1·1031	17·46	19·26	1,052
Huddersfield	16·47	1·1627	16·78	19·51	1,066
London	17·97	1·0656	18·79	20·02	1 093
Halifax	17·20	1·1133	18·12	20·17	1,102
Plymouth	19·70	0·9720	20·80	20·22	1,104
Gateshead	17·83	1·0740	19·02	20·43	1,116
Nottingham	17·81	1·0752	19·10	20·54	1,122
Hull	18·23	1·0504	19·75	20·75	1,133
Newcastle-upon-Tyne ..	17·58	1·0892	19·51	21·25	1,161
Bolton	16·90	1·1331	19·45	22·04	1,204
Leeds	17·28	1·1082	20·00	22·16	1,210
Oldham	16·72	1·1453	19·55	22·39	1,223
Sunderland	18·25	1·0493	21·41	22·47	1,227
Blackburn	17·05	1·1231	20·48	23·00	1,256
Wolverhampton... ..	18·30	1·0464	22·51	23·55	1 286
Birmingham	17·33	1·1050	21·53	23·79	1,299
Sheffield	17·22	1·1120	22·59	25·12	1,372
Preston	17·42	1·0993	24·03	26·42	1,443
Manchester	16·90	1·1331	24·13	27·34	1,493
Liverpool	17·44	1·0980	25·66	28·17	1,539
Salford	17·03	1·1244	25·10	28·22	1,541

Causes of Death.—In this country the tabulation of causes of death was commenced in 1593, when the weekly bills of christenings and burials were instituted by the parish clerks of London. The series was continued uninterruptedly from the year 1603. At first the plague was distinguished, and then other diseases and casualties. A glance at the entries in "the bills" (chrisomes, worms, teething, moldshot-head, liver-grown, canker, thrush, etc.), and comparison of them with the nomenclature of a modern hospital report (or with the third edition, being the second revision, of the Nomenclature of the Royal College of Physicians of London, which appeared in 1896, and in accordance with which death-returns are or should be now made), shows, as Sir John Simon says, how great an advance has been effected as regards accurate definition of the cause of death. "Pathological anatomy, chemistry, the stethoscope and other instruments of investigation" have, of course, "greatly facilitated the analysis of diseases."

The Registrar-General adopts eight chief divisions of diseases each with sub-sections. The first group of febrile or zymotic diseases comprises miasmatic, diarrhœal, malarial, zoogenous, venereal, and septic diseases. The remaining groups include five which are headed parasitic, dietetic, constitutional, developmental and local diseases together with "violence" and, finally, "ill-defined and not specified" causes. It is important to note as regards zymotic diseases, that it is common to apply the term *zymotic death-rate*, not to the mortality from the entire zymotic group of the Registrar-General, but to the death-rate from what are styled the seven principal zymotic diseases—small-pox, measles, scarlet fever, diphtheria (including membranous croup), whooping-cough, "fever" (typhus, simple continued, and enteric), and diarrhœa (including cholera). In certain minor particulars, as Newsholme says, the Registrar-General's classification is not abreast of medical knowledge. He instances, for example, the need of transferring tubercular diseases, and almost certainly rheumatic fever, from constitutional to infective diseases, and tetanus to the same group from diseases of the nervous system.

In death certificates headings such as dropsy, convulsions, palsy, etc., often appear. Farr held that refusal to accept such terms would tend to foster "reckless conjecture" in making returns; it was, however, he said, desirable that the use of the names of symptoms should be avoided "wherever the names of diseases or of causes of symptoms could with reasonable certainty be substituted." The form of death certificate in use provides for the insertion of a primary and secondary cause of death; these, it is suggested, should be entered "in the order of their appearance, and not in the presumed order of their importance." In classifying the death, however, only one cause can be selected. In making this selection zymotic diseases are to be preferred to other diseases, specific to non-specific, and primary to secondary diseases.

In 1881 a system of making further inquiries in doubtful cases was instituted by the Registrar-General; particulars as to the results obtained are given on p. 18 of the Annual Report for 1895. Faulty diagnosis, the desire not to hurt the susceptibilities of relatives, and lack of uniformity in nomenclature, are still frequent sources of fallacy. As Newsholme says, there is "a fashion even in the names of diseases." Again, to quote Noel Humphreys: "Causes of death in the death register are necessarily little more than the more or less trustworthy guesses of a large body of more or less skilful observers, except in the small proportion of cases in which these guesses are corroborated or modified by post-mortem examinations. Statistics of causes of death should, therefore, be compiled with caution and without any attempt at over-elaboration of detail. Still greater caution should be used in drawing inferences and deductions from a comparison of the results for a series of years. Changes of nomenclature and of classification add materially to the difficulties in the way of useful comparison of such statistics for different periods of years."

Particular instances of the need for exercise of such caution have already been given in commenting upon variations in the recorded mortality from certain special causes of disease. Improved diagnosis is no doubt mainly accountable for the diminution in the mortality recorded from croup, convulsions, simple continued fever, and ill-defined causes, and is largely responsible, at any rate, for the increase in the mortality recorded from cancer, diabetes, urinary diseases, and puerperal fever. In phthisis both improved diagnosis and preventive measures have doubtless played a part. The latter are presumably mainly accountable for the reduction in small-pox, scarlet fever, diarrhœa, typhus, and enteric fever. It is noteworthy that in measles and whooping-cough, diseases in which preventive measures have not as yet been seriously attempted, the registered mortality continues to be high. Noel Humphreys further says: "The materials with which Dr. Farr had to work nearly fifty years ago were defective enough to have discouraged a less sanguine and indefatigable statistician; but while he was able from time to time to improve the quality of his materials, few will venture to deny the value of the results he obtained . . . . even in the early years of his service. . . . In vital statistics all students must learn to use imperfect materials, and yet to guard, as far as possible, against fallacious results."

In the accompanying table the annual death-rates from the principal zymotic diseases and the infant mortality, in England and Wales, during a series of years are given :—

Period.	Annual mortality per million persons living from the principal zymotic diseases.										Annual Mortality of Infants under one year of age to 1,000 Births.
	Small-pox.	Measles.	Scarlet Fever.	Diphtheria.	Whooping-Cough.	Typhus.	Enteric Fever.	Simple and Ill-defined Fever.	Diarrhœa and Dysentery.	Cholera.	
1850	262	398	753		437	865			760	50	146
1851	389	521	753		440	997			941	63	154
1852	401	320	1,035		440	1,022			1,117	76	158
1853	171	266	853		609	1,008			874	240	160
1854	151	498	995		525	1,015			1,181	1,080	157
1855	131	391	894	20	541	875			754	44	151
1856	116	373	705	32	483	847			793	40	144
1857	202	310	652	82	526	983			1,189	[illegible]	156
1858	329	476	1,212	339	598	918			787	35	158
1859	193	485	976	517	456	806			1,001	45	153
1860	136	479	485	261	429	652			544	16	148
1861	64	450	451	225	612	767			1,002	42	153
1862	78	481	728	241	602	919			597	25	142
1863	286	550	1,478	315	547	874			775	39	149
1864	364	397	1,418	261	409	960			832	45	153
1865	301	405	837	196	409	1,089			1,164	61	160
1866	139	511	545	140	736	986			853	672	160
1867	114	304	567	120	548	778			960	43	153
1868	91	528	996	137	419	895			1,405	68	155
1869	67	464	1,244	117	493	193	390	239	935	32	156
1870	113	335	1,446	120	529	147	388	233	1,161	47	160
1871	1,012	408	815	111	455	121	371	186	1,094	38	158
1872	821	368	515	93	596	80	377	145	995	35	150
1873	93	316	562	108	411	70	376	132	962	32	149
1874	88	517	1,050	150	437	74	374	130	923	25	151
1875	35	257	851	142	594	62	371	108	1,028	23	158
1876	99	408	691	129	432	48	309	81	917	25	146
1877	173	366	585	111	460	45	279	78	619	13	136
1878	74	310	753	140	710	36	306	71	1,003	25	152
1879	21	362	694	120	503	21	231	58	452	8	135
1880	25	478	675	109	530	21	261	58	1,171	31	153
1881	119	280	548	121	415	21	212	44	558	12	130
1882	50	483	521	152	579	36	229	39	653	13	141
1883	36	350	475	158	393	33	228	36	598	15	137
1884	82	419	402	186	425	12	236	28	978	30	147
1885	103	533	233	164	481	12	175	24	492	11	138
1886	11	436	218	149	470	9	184	22	899	19	149
1887	19	602	282	160	404	8	185	18	727	17	145
1888	37	347	226	171	436	6	172	15	455	[illegible]	136
1889	1	518	235	189	430	5	176	15	648	12	144
1890	0	439	242	179	478	5	179	13	505	14	151
1891	2	436	170	173	468	5	168	11	469	11	149
1892	15	459	190	222	454	3	137	8	505	15	148
1893	48	373	234	318	342	5	228	9	952	45	159
1894	27	390	167	291	410	4	159	7	349	8	137
1895	7	377	149	259	315	2	175	5	871	28	161
1896	17	570	177	291	429	2	166	5	544	18	148
1897	0	407	147	245	366	2	155	4	836	31	156
1898	8	419	112	243	322	1	181	4	919	35	160
1899	5	313	117	291	317	1	198	4	933	38	163
1900	3	394	119	290	355	1	173	4	710	17	154

Occupation and Mortality.—In the Supplements to the Thirty-fifth, Forty-fifth, and Fifty-fifth Annual Reports of the Registrar-General, which deal with the statistics of 1861–70, 1871–80, and 1881–90 this subject has been investigated by Drs. Farr, Ogle, and Tatham respectively. In each instance attention has been particularly directed to the ages 25 to 65, in males, as being those in which the influence of occupation has been especially exerted. Owing to the fact that in different occupations there are great variations in age-distribution, within the age limits 25 to 65, the plan has been devised of calculating the death-rates for each occupation in a standard population, made up of that number of males, aged 25 to 65, in the population generally, among whom 1,000 deaths would occur annually. Tatham, taking the 1891 census, and the deaths of the years 1890–92, as a basis, found that 1,000 deaths might be expected yearly in a standard male population consisting of 22,586 aged 25 to 35, 17,418 aged 35 to 45, 12,885 aged 45 to 55, and 8,326 aged 55 to 65. Applying, then, the death-rate at each of these four age-groups, as ascertained for a given occupation, to the standard population, a number is obtained which is called the *comparative mortality figure* for the occupation in question. For all males the figure is, of course, 1,000; for males in selected healthy districts it is 679; for occupied males, 953; for unoccupied males, 2,215.

Among special occupations the following may be mentioned in the order of their comparative mortality figures, as calculated by Tatham on the four age-groups already specified. Clergyman, priest, minister stands first on the list (533): thereupon, follow—gardener, nurseryman, seedsman (553); schoolmaster, teacher (604); labourer, etc., in agricultural districts (666); barrister, solicitor (821); shopkeeper (859); medical practitioner (966); tailor (989); printer (1,096); plumber, painter, glazier (1,120); innkeeper, inn, hotel-servant (1,659); potter, earthenware, etc., manufacturer (1,706); and file-maker (1,810).

Occupational mortality was also dealt with by Ogle (Supplement to the Forty-fifth Annual Report) from the point of view of special causes of death, and the results of a more elaborate inquiry made into this matter by Tatham appear in the Supplement to the Fifty-fifth Annual Report of the Registrar-General. The statistics relating to 100 selected occupational groups are given in Part II. of the latter Supplement. The effects of chronic lead-poisoning and of alcoholic excess, in the case of different occupations, are specially considered, and the facts elicited, with regard to occupations in which dust-laden air is breathed, are exhaustively analysed. The mortality figure of the agriculturist from phthisis and diseases of the respiratory system being taken at 100, it may be stated, quoting some of the examples given, that the corresponding figures for coal-miner and corn-miller are 166, and for baker or confectioner, and for blacksmith 177; the tinworker stands at 204, the leadworker at 247, the stone quarrier at 261, the lead-miner at 319, the file-maker at 373, the tin-miner at 400, the cutler or scissors maker at 407, and the potter or earthenware manufacturer at 453.

The sources of error in statistics of occupation are many. To begin with, the way in which occupations are described in the census depends, as already noted, largely on the intelligence of the householders who make the returns; again, particulars regarding occupation in death-certificates are often very vague. Another point to be borne in mind is that masters and workmen, distributors and producers, were not distinguished till 1891, and in the census of that year the attempt made to direct the attention of householders to this question does not appear to have been completely successful. Further, as Ogle pointed out, some trades require great strength, and must be abandoned by persons in failing health, who are transferred to, and swell, the mortality in other occupations. Finally, some trades can never be taken up at all by weakly persons, and thus consist from the outset of picked men upon whom any ill effects, produced by the occupation, are likely to be less marked than they would be on the average individual.

Sickness Rates.—The attempt to obtain records of sickness of all kinds, attended at the public expense, was inaugurated in 1857 by the Metropolitan Association of Medical Officers of Health. A similar attempt was made in 1860 in Manchester and Salford. These attempts did much to pave the way for the notification of infectious diseases (*See* p. 534). Notification returns relating to scheduled infectious diseases have now been available, throughout the greater part of the country, for more than ten years (in a few towns for a longer period), and the use which has been made, for example, of those of London by Shirley Murphy, has been already more than once referred to. There are, apart from the statistics of infectious diseases, certain records of friendly societies, which show, *inter alia*, the average number of days of sickness per annum in the case of members of various ages. This number is found to vary from some six or seven days at ages 20—30, up to some thirty to fifty days at ages 60—70. There are, further, sickness statistics available relating to the army, navy, police, etc. Moreover, since the passing of the Factory and Workshop Act, 1895, returns of particular kinds of sickness in certain industries have been made. Further development of the notification of sickness was advocated by Newsholme in a paper which appeared in the *Journal of the Statistical Society* for 1896. In recent annual reports of the Medical Officer of the Local Government Board the notification returns of large towns have been tabulated, and the quarterly returns of the Registrar-General now contain tables dealing with the same material, and in the weekly returns the London notification figures are placed upon record.

Evidence of the Health of Communities is afforded by applying various tests. The general death-rate, if it be based on sufficiently large figures and be corrected for institution deaths, and for age and sex distribution, is fairly reliable. The zymotic death-rate, to which importance is often attached, is apt to mislead. Some of the zymotic diseases, considered individually, stand in much closer relation to what are generally regarded as insanitary conditions than others; the tendency of most of them to occur in epidemics, makes a zymotic death-rate, unless the period of time under review is a long one, unreliable. Infantile mortality is largely influenced by epidemic enteritis, whooping-cough, and measles. The phthisis death-rate and the death-rate from respiratory diseases are sometimes appealed to. They are certainly more reliable than the zymotic death-rate. For precise purposes, however, a more exact guide to health conditions is needed, and, in connection particularly with life assurance, a method of measuring accurately the mean duration of life is required. This is furnished by the Life Table.

Life Tables.—If a million children be supposed to be all born at the same point of time, and to be followed through life, it is possible to predict the number of the survivors as successive ages are reached, assuming the children to be exposed to such risk of dying as obtains, from one age-period to another, in a particular community. As the ages of the children advance beyond a certain limit the chance of continued survival undergoes diminution; this probability of further survival can be determined for each age. Further, the total number of years of life to be lived by persons at a particular age x, and upwards, can be predicted, and if this total number be divided by the number of persons surviving at the age x, what is called the mean after-lifetime of these persons is obtained. This mean after-lifetime, or expectation of life, can be set out in the form of a table, together with other particulars already referred to, the figures being given for each age. Such a table is called a life table.

A typical life table contains the following columns:—

(i) A column indicating the ages dealt with. Usually, annual periods are taken; sometimes the first five years of life are separately set out, and for the later years only every fifth or tenth year of age is shown.

(ii) An m_x column (sometimes indicated as the D column or M_x column). This column gives the annual mortality per unit of population at the centre of each year, or, as it is sometimes termed, the central death-rate of the year. Thus, m_x is the central death-rate of the year beginning on the completion of x years of age, and m_{10} is the rate of mortality per unit of population at the centre of the year beginning on completion of 10 years of age, or, in the case of a million children, all born at the same time, the death-rate at $10\frac{1}{2}$ years of age.

(iii) A p_x column. This column gives the probability of living one year from the age x.

(iv) An l_x column, which shows the number of children who may be expected to survive at the precise age x.

(v) A P_x column, which shows the mean population in each year of age. Thus $P_x = \frac{l_x + l_{x+1}}{2}$*, and $P_{10} = \frac{l_{10} \cdot l_{11}}{2}$.

(vi) A Q_x column, which shows the years of life lived at age x and upwards. The number corresponding to any age in this column, is the sum of all the numbers in the P_x column of an extended table from that age to the end of the table.

(vii) An E_x (or e_x) column, which shows for each age the value of $\frac{Q_x}{l_x}$, *i.e.*, $\frac{\text{The total number of years lived at age } x \text{ and upwards.}}{\text{Number of survivors at age } x.}$
This value, E_x, represents the mean after-lifetime, or expectation of life, at each age x.

The number (Q_x, or ΣP_x) of years lived at age x and upwards, it should be noted, may be also calculated from the figures given in the l_x column; for the total number of years lived includes the sum of the complete years lived at each age $x + 1$, $x + 2$, etc., to the last age in the table (Σl_{x+1}), together with the sum of the portions of lifetime lived by each person in the year of his death. It may

* Another formula is usually employed to calculate P_0 owing to the large error introduced by the assumption of an equal distribution of the deaths occurring between ages 0 and 1, viz.:—

$P_0 = \frac{1}{6}$ deaths aged 0—1 + $\frac{5}{8}$ deaths aged 6—12 months + l_1.

be assumed that the duration of life in the year of death is, on an average, half a year. Hence to the expression $\frac{\Sigma l_{x+1}}{l_x}$ the "curtate expectation of life" it is necessary to add half a year, in order to obtain the "complete expectation of life." To distinguish these expressions $\frac{\Sigma l_{x+1}}{l_x}$ is sometimes written e_x, and the complete expectation of life $\frac{\Sigma l_{x+1}}{l_x} + \frac{1}{2}$, or $\frac{\Sigma P_x}{l_x}$ is written $\mathring{e}_x$.

In further illustration, the headings and entries for certain sample years (the intermediate years being omitted) in Farr's English Life Table No. 3 for males may be quoted:—

Age x.	Annual Mortality per Unit at age x. D or M_x.	Probability of Living one Year from each Age. p_x.	Number born and Living at each Age. l_x.	Mean Population in each Year of Age. P_x.	Years of Life Lived at Age x and upwards. Q_x.	Mean after-Life-time at each Age x. E_x
0	0·18326	0·83212	511,745	456,820	20,426,138	39·91
5	0·01369	0·98640	370,358	367,672	18,410,252	49·71
10	0·00563	0·99438	353,031	352,007	16,608,936	47·01
15	0·00519	0·99482	344,290	343,415	14,866,429	43·18
20	0·00832	0·99171	333,608	332,231	13,169,656	39·48
25	0·00920	0·99084	319,442	317,892	11,536,677	36·12
35	0·01105	0·98901	288,850	287,229	8,492,601	29·40
45	0·01554	0·98458	253,708	251,763	5,774,489	22·76
55	0·02485	0·97644	209,539	206,984	3,447,708	16·45
65	0·04698	0·95410	150,754	147,315	1,631,508	10·82
75	0·10391	0·90122	75,777	72,012	491,685	6·49
85	0·21966	0·80208	16,877	15,151	63,030	3·73
95	0·42035	0·65265	833	678	1,806	2·17
105	...	...	4	3	5	...

The construction of a complete life table for each year of age is a very laborious piece of work. It is, of course, impossible to observe a million children, and to follow them through life, though the Institute of Actuaries H^M (Healthy Males) Table is in part, it may be noted, based upon the principle of following the history of individual lives, in this case insured lives, from the date of their insurance until death. The plan usually adopted, however, is to calculate from census data the number of lives at risk, at each group of ages, and to apply to these the deaths recorded as having occurred at those ages. By this means the rate of mortality per unit of population, the central death-rate (m_x), can be determined for each age-period. By making use of these rates the life table can be constructed.

Thus, if the rate for any age be expressed per 1,000, and called D, and if the D deaths be assumed to be evenly distributed over the age-period, so that half occur in the first portion of the period, and half in the second portion, then clearly the ratio of the final to the initial population $= \frac{1,000 - \frac{1}{2}D}{1,000 + \frac{1}{2}D}$; for every 1,000 at the centre of the period, must represent $1,000 + \frac{1}{2}D$ at the commencement of the period, and must be reduced to $1,000 - \frac{1}{2}D$ at the end of the period.

$$\text{Thus } \frac{l_{x+1}}{l_x} = \frac{1,000 - \frac{1}{2}D}{1,000 + \frac{1}{2}D}$$

and $\frac{l_{x+1}}{l_x}$ = the probability of surviving one year $= p_x$.

Given the values of D (or m_x), then, for each age-period after the first (for the first year the infant mortality per 1,000 births is applied) the values of p_x, l_x, P_x, Q_x, and E_x can be worked out, and the columns of the life table filled in. For example, suppose the infant mortality to be 150 per 1,000 births, so that 1,000,000 children are reduced during the first year of life to 850,000. Suppose now the death-rate in the second year of life to be 50 per 1,000. Applying the formula, $\frac{l_2}{l_1} = \frac{1,000 - 25}{1,000 + 25}$, and it will be found that the 850,000 children are reduced at the end of the second year to 808,536.

Similarly the survivors at the end of the third, etc., years can be determined. After the first five years (if it be proposed to proceed further by quinquennial periods, adopting what is known as Farr's short method) the rate for the whole period is assumed to hold good for each of the five years.*

* This assumption, of course, involves a certain amount of error; thus, after the age fifteen the chance of survival is greater in the first year of the age-period, and less in the last year, than the mean value. After dealing with the age-periods 5—10, 10—15, 15—20, and 20—25 it is usual in the short method to proceed by decennial periods, 25—35, etc. At the late ages the error incidental to use of the short method may be considerable. The expectation of life at 85, for example, was found by Newsholme in the case of Brighton (males) to be 2·17 years in excess of the value obtained from the extended life table, while at 95 the expectation of life was 5 years on the short method, as against 1·68 years on the extended method, an excess of 3·32 years. By a modification of Farr's method Dr. Hayward, in constructing a life table for Haydock, Lancashire, was able to approach the true values of E_x with remarkable exactitude. (*See* Newsholme's "Elements of Vital Statistics." In this work methods of obtaining corrected populations for each of the first five years of life are given, the liability to error in census returns is specially great at ages 0—5, and for precise purposes this fact requires to be recognised and dealt with.)

If this death-rate be, say, 7 per 1,000,

$$\frac{l_{10}}{l_5} = \left(\frac{1,000 - \frac{7}{2}}{1,000 + \frac{7}{2}}\right)^5$$

for $\frac{l_6}{l_5}$, $\frac{l_7}{l_6}$, $\frac{l_8}{l_7}$, $\frac{l_9}{l_8}$, and $\frac{l_{10}}{l_9}$ are each $= \frac{1,000 - \frac{7}{2}}{1,000 + \frac{7}{2}}$, and their product

is therefore equal to $\left(\frac{1,000 - \frac{7}{2}}{1,000 + \frac{7}{2}}\right)^5$.

For the determination of the values of D (or m_x) Farr used, in his English Life Table No. 1, the census returns of 1841 and the deaths of the same year. To base a life table upon the deaths of a single year is, however, open to serious objection, and, in the English Life Table No. 2, Farr employed the census enumerations of 1831 and 1841 and the deaths of seven years (the three years preceding 1841, the year 1841, and the three years succeeding 1841). The English Life Table No. 3 was based on the census enumerations of 1841 and 1851, and upon the deaths registered in the seventeen years 1838–54. Ogle constructed an English Life Table on the basis of the figures of the decennium 1871–80, and Tatham utilised for the like purpose the figures of 1881–90.

Farr, moreover, constructed a Healthy Districts Life Table on the basis of the mortality (during 1849–53) in sixty-three selected districts, and Tatham has prepared a New Healthy Districts Life Table, based on a larger population and on the mortality returns of 1881–90.

In constructing an Extended Life Table the number of lives at risk during the years dealt with* for the age periods 0—5, 5—10, 10—

* If the mortality of a decennium be taken as the basis to work on, the several "populations at risk" for the decade must be calculated. The total population at risk may be taken as being the sum of the ten mid-year populations. $P + PR + \ldots\ldots + PR^9$, or $\frac{P(R^{10}-1)}{R-1}$, *i.e.*,

$$\frac{\text{Population at middle of later census year} - \text{Population at middle of earlier census year}}{\text{Annual increase per unit.}}$$

This formula involves calculation of the central populations of the two census years. The number of lives at risk at each age-period can be determined by applying the same method. The sum of the ten mid-year populations, however, is only an approximation to the true years of life. A more

15, 15—20, 20—25, 25—35, 35—45, 45—55, 55—65, 65—75, 75—85, 85—95, and 95 and upwards, and the number of deaths at the same age-periods having been ascertained, it is necessary to obtain the corresponding numbers for individual years of life. This is done by interpolating the figures for intervening years either by the method of "finite differences," or by the "graphic method," which was used by Newsholme in constructing the Brighton Life Table, and which is described by him in his "Elements of Vital Statistics."

The following table gives the expectation of life, at the end of each five years of life up to 75 and for a final period up to 85, and for each sex, in England and Wales, London, Manchester, Glasgow, and Brighton, based on the figures of 1881–90 :—

Ages.	Males.					Females.				
	England and Wales.	London.	Manchester.	Glasgow.	Brighton.	England and Wales.	London.	Manchester.	Glasgow.	Brighton.
0	43·66	40·66	34·71	35·18	43·59	47·18	44·91	38·44	37·70	49·00
5	52·75	50·77	45·59	46·97	52·87	54·92	54·42	48·06	48·27	56·92
10	49·00	47·22	42·75	44·32	49·12	51·10	50·95	45·43	45·44	53·15
15	44·47	42·88	38·78	40·51	44·67	46·55	46·65	41·50	41·59	49·07
20	40·27	38·70	34·62	36·90	40·55	42·42	42·45	37·33	38·00	44·76
25	36·28	34·70	30·69	33·29	36·51	38·50	38·34	33·38	34·60	40·43
30	32 52	31·80	27·08	29·60	32·67	34·76	34·95	29·73	29·88	36·39
35	28·91	27·39	23·76	26·06	29·02	31·16	30·69	26·30	28·06	32·48
40	25·42	25·22	20·68	22·44	25·60	27·60	26·80	22·99	23·45	28·71
45	22·06	21·00	17·80	19·54	22·36	24·05	23·80	19·79	21·61	25·07
50	18·82	18·75	15·06	16·35	19·33	20·56	20·65	16·74	17·50	21·79
55	15·74	15·31	12·49	13·99	16·48	17·23	17·34	13·91	15·60	18·43
60	12·88	13·00	10·16	11·40	13·67	14·10	14·50	11·35	12·88	15·26
65	10·31	10·59	8·15	9·38	10·96	11·26	11·78	9·11	10·69	12·19
70	8·04	8·30	6·48	7·50	8·69	8·77	9·00	7 25	8·00	9·32
75	6·10	7·20	5·11	6·25	6·64	6·68	7·79	5·76	6·45	6·97
85	3·29	5·50	3·16	3·30	3 33	3·71	5·70	3·76	3·62	3·72

accurate formula for the years of life at all ages, or at a particular age-group, is $\frac{P_1 (r-1)}{r^{\frac{1}{10}} \log_e r} \times 10$, where P_1 is the number at all ages, or in the age-group, enumerated at the earlier census, and r is the decennial rate of increase. A difficulty arises, inasmuch as "the number arrived at by applying a process of calculation to the whole population-numbers, differs from the sum of the numbers obtained by applying the same process to the numbers of the separate age and sex groups" (see a paper "On the Construction and Use of Life Tables," by T. E. Hayward, the *Journal of Hygiene*, vol. ii. No. 1). This difficulty has been met by Mr. A. C. Waters (*Journal of the Statistical Society*, vol. lxiv. part ii., June, 1901), by applying two multiplying factors, m and n, to the census populations. If Q_1 and Q_2 represent whole populations at the two censuses, $(mQ_1 + nQ_2)$ gives the mean population. The true years of life for a particular age-group are taken as $(mP_1 + nP_2) \times 10$, where P_1 and P_2 are the numbers enumerated at corresponding age-groups in the populations Q_1 and Q_2, and the sum of all the populations at particular age-groups must then clearly be $(mQ_1 + nQ_2) \times 10$.

On comparison of English Life Tables based on the mortality of earlier, with tables based on that of later years, it will be found that the expectation of life has notably increased at the earlier ages, but has not done so at later ages. The annexed table gives the survivors at each age based on the 1881-90 figures, and the expectation of life as obtained in three successive English Life Tables:—

Age.	Males. Survivors at each age out of 1,000,000 born.	Males. Expectation of life. 1881-90.	Males. Expectation of life. 1871-80.	Males. Expectation of life. 1838-54.	Females. Survivors at each age out of 1,000,000 born.	Females. Expectation of life. 1881-90.	Females. Expectation of life. 1871-80.	Females. Expectation of life. 1838-54.
0	1.000.000	43·7	41·4	39·9	1,000.000	47·2	44·6	41·9
1	838.964	51·0	48·1	46·7	868.874	53·2	50·1	47·3
2	790.891	53·0	50·1	48·8	823,072	55·2	52·2	49·4
3	772.046	53·3	50·9	49·6	804,142	55·5	53·0	50·2
4	760.167	53·2	51·0	49·8	791,973	55·3	53·2	50·4
5	751,494	52·8	50·9	49·7	783,244	54·9	53·1	50·3
10	733,477	49·0	47·6	47·1	766,151	51·1	49·8	47·7
15	726,194	44·5	43·4	43·2	759.062	46·6	45·6	43·9
20	712.555	40·3	39·4	39·5	744.321	42·4	41·7	40·3
25	693,809	36·3	35·7	36·1	724,788	38·5	38·0	37·0
30	669.279	32·5	32·1	32·8	700.049	34·8	34·4	33·8
35	639,645	28·9	28·6	29·4	670,992	31·2	30·9	30·6
40	604.923	25·4	25·3	26·1	638,912	27·6	27·5	27·3
45	564.437	22·1	22·1	22·8	604,007	24·1	24·1	24·1
50	517,639	18·8	18·9	19·5	564,299	20·6	20·7	20·8
55	462,981	15·7	16·0	16·5	516,375	17·2	17·3	17·4
60	398,400	12·9	13·1	13·5	457,682	14·1	14·2	14·3
65	322,482	10·3	10·6	10·8	385,503	11·3	11·4	11·5
70	238.632	8·0	8·3	8·5	299.220	8·8	9·0	9·0
75	153.890	6·1	6·3	6·5	204,208	6·7	6·9	6·9
80	80.023	4·5	4·8	4·9	114,536	5·0	5·2	5·3
85	29.866	3·3	3·6	3·7	48.133	3·7	3·9	4·0
90	6.786	2·4	2·7	2·8	13,418	2·8	2·9	3·0
95	752	1·7	2·0	2·2	2,124	2·1	2·2	2·3
100	30	1·2	1·6	1·7	157	1·5	1·6	1·3

It will be seen from the above that the expectations of life on the 1871-80 table, as compared with those on the earliest table, are, for males, increased at ages below 20 but diminished at later years, and for females they are increased at ages below 40 but, as a rule, diminished after 45. On comparing the expectations of life on the 1881-90 table with those on the 1871-80 table, it will be found that, for both males and females, they are increased up to 40 years of age, but somewhat diminished after that age. Again, as regards the number of survivors, it may be stated that in the case of males, after the end of the first year until age 79, the 1881-90 table shows a larger number of survivors than is shown by either the 1838–54 or the 1871–80 tables; from age 84 onwards the survivors are, however, fewer by the new table than by either of the others. As Tatham points out: "This change is probably due, in part at least, to more accurate statement of age in recent than in earlier years." As regards females, just as in the case of males, the number of survivors at extreme ages diminishes more rapidly by the new table than by either of the old ones.

It may be here noted that the death-rates recorded in 1871–80 as compared with those of 1861–70, speaking generally, fell for the earlier age-periods, while they rose for the later periods of life. This fact excited much comment when the rates were first published, and it was even suggested that, as there was but little evidence of decline of the death-rate at working ages, the gain to the community, on the whole, was but small. On the other hand, it may be urged that a larger proportion of those born survived under the new conditions to working ages. Various theories were advanced to explain the increased death-rates at the higher ages. Thus, they were said to be due to survival of weakly children, who had escaped being carried off, as they formerly would have been, by zymotic disease; or to survival of persons who in earlier periods would have died from tuberculosis in one or other of its forms; or, again, the raised rates were ascribed to the "increased strain and pressure of modern life." Newsholme discussed these explanations in connection with his Brighton Life Table in 1893, and he added a fourth consideration—the fact that the fruits of the improvements in sanitation had not yet been reaped. He said: "Men now 40 years of age were born in the pre-sanitary period; and the first 20 years of their life were spent under more unhygienic conditions than those now holding good." This fact would not, of course, explain an increased death-rate, though "it would go far towards explaining a stationary one at the higher ages." On the whole, Newsholme was inclined to think that the explanation of the increase would "probably be evident when, at the end of another twenty or thirty years, the improved conditions of life have endured sufficiently long to enable their full force and value to be determined."

This conclusion is confirmed, as he notes, on comparing the statistics of 1881–90 with those of 1871–80, inasmuch as the decline in the death-rates, which, when the eighth was compared with the seventh decade, stopped short at adult life, was found, on comparing the ninth with the eighth decade, to extend to nearly every period of life in both sexes, though it was but small in amount after the forty-fifth year. Newsholme points out, however, that while the death-rates at nearly every period in both sexes are lower in 1881–90 than in 1871–80, the expectations of life at the higher ages, on the 1881–90 table, are lower than those on the 1871–80 table. "The key to the anomaly," he says, "is found in the fact that the expectation of life, at any given age, takes into account the total number of survivors from all lower ages, and these were more numerous, out of a given number at birth, according to the experience of 1881–90 than according to that of 1871–80." There needs also to be borne in mind, in this connection, Tatham's caution with regard to extreme ages; there can be no doubt that, with increasing accuracy as regards statement of age, the new table records the facts as to survivors at the extreme ages much more precisely than did the older ones; the result of this increased precision, doubtless, materially influences the expectation of life at higher ages.

Life Capital.—The aggregate future lifetime of an existing population the numbers of which, in groups of ages, are known at a particular time, can be estimated by applying to it the life table figures. This aggregate future lifetime has been termed by Tatham the Life Capital of the community. The future lifetime of P_x persons living between the ages x and $x + 1$ is $Q_x - \frac{P_x}{2}$ (the mean expectation of life of each being $\frac{Q_x}{P_x} - \frac{1}{2}$), and the future lifetime of ΣP_x persons is $\Sigma Q_x - \frac{1}{2} \Sigma P_x$. The improvement brought about in health conditions in a community, as testified by lessened death-rates, and by improved expectation of life, may be also expressed in terms of gain of Life Capital. It is clear, moreover, that—

$$\frac{\text{Life Capital}}{\text{Population}} = \text{the average life capital, or future lifetime, of each member of the population,}$$

and that—

$$\text{Proportion per cent. of life capital expended in a year} = \frac{\text{Years of life expended in a year} \times 100}{\text{Life capital}} = \frac{\text{Mean population} \times 100}{\text{Life capital.}}$$

Tests of Longevity.—The distinction between certain terms often used in connection with the measurement of the duration of life needs to be borne in mind. The *mean after-lifetime*, or *expectation of life*, has already been defined. The "*mean duration of life at birth*" is identical with the mean after-lifetime, and with the expectation of life; the "mean duration of life" for any later age, if the term is used at all, would signify the age in question plus the mean after-lifetime at that age.

The "*probable duration of life*" is the age at which, as ascertained from a life table, exactly half any given number of children born will have died. The table on p. 493 shows that the probable duration of life for males (on 1881 90 figures) is 51—52, and for females 56—57 years. The mean duration of life differs from the probable duration of life, as Whitelegge points out, "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 age at death*" is obtained by dividing the sum of the ages at death by the number of deaths; it is a very rough test of length of life, and its use is a fruitful source of misconception. It depends largely upon age-distribution, and is much affected by the birth-rate. Thus, in comparing one nation with another, the mean age at death is a very unsafe test of relative healthiness. The fallacies attendant upon the use of the mean age at death are most apparent when particular groups of population, such as those following certain professions, etc., are dealt with. Thus, as Farr remarked: "It has been somewhere stated that the mean age at death of dressmakers is exceedingly low, and this has been adduced as a proof of the destructive nature of their employment. If the inquiries had been extended to boarding-schools, or to the boys at Christ's Hospital, the mean age at death would have been found still lower."

Again, in the same connection, Farr wrote: "If it were found, upon an inquiry into the health of the officers of the Army on full pay, that the mean age at death of cornets, ensigns, and second lieutenants was 22 years; of lieutenants, 29 years; of captains, 37 years; of majors, 44 years; of lieutenant-colonels, 48 years; of general officers, ages still further advanced; and that the ages of curates, rectors, and bishops; of barristers of seven years' standing, leading counsel, and venerable judges differed to an equal or greater extent, a strong case may no doubt be made out on behalf of those young but early dying cornets, curates, and juvenile barristers whose mean age at death was under 30. It would be almost necessary to make them generals, bishops, and judges—for the sake of their health."

The *number living out of which one dies annually* is sometimes referred to in connection with tests of longevity. In a stationary population, unaffected by migration, and in which the births counter-balance the deaths, the number living out of which one dies annually is equal to the mean age at death, and to the expectation of life at birth. Thus Farr, writing in the Fifth Annual Report, says: "The duration of life in England is 41 years; if the population were *stationary*, the mean age of those who died would be 41 years; and 1 in 41 would die every year. The population has, however, increased 1·41 per cent. annually during the last 40 years, and we find that the mean age of the persons who died in the year 1841, instead of being 41, is 29 years; while 1 in 46 of the population died."

A life table represents a stationary population maintained by l_0 births annually, in which at every age, as deaths occur, and the survivors pass on to the next year of life, the vacant places may be assumed to be taken by a number equal to that of the previous occupants of the same age.

In such a life-table population it will be found that the number out of which one dies annually, and the expectation of life, are identical at birth or any subsequent age. For the number living at all ages above x is $P_x + P_{x+1} + P_{x+2} + \ldots\ldots$, *i.e.*, Q_x; and the deaths occurring in one year in this population are $l_x - l_{x+1}$ for the group P_x, $l_{x+1} - l_{x+2}$ for the group P_{x+1}, and so on, and hence the total deaths in the year, by addition, amount to l_x, as all the other terms cancel one another. If, then, Q_x, which represents the entire population living above the age x, be divided by l_x, the number of deaths occurring in that population in one year, the number out of which one dies annually is obtained; but the expression $\frac{Q_x}{l_x}$ also gives the expectation of life. Thus, the number out of which one dies annually and the expectation of life are identical for age x—*i.e.*, for any age.

It can be similarly shown that in such a population as that just considered, the mean age at death is identical with the mean expectation of life. Thus, total ages of those dying in each year of life = number of those dying in each year multiplied by their average age

$= \Sigma\,(l_x - l_{x+1})\,(x + \frac{1}{2})$, x having all values from 0, onwards.
And total number of deaths

$= \Sigma\,(l_x - l_{x+1})$, x having all values from 0, onwards. Hence mean age at death

$$= \frac{\text{total ages of the dying in each year of life}}{\text{total number of deaths}} = \frac{\Sigma\,(l_x - l_{x+1})\,(x + \frac{1}{2})}{\Sigma\,(l_x - l_{x+1})}$$

$$= \frac{(l_0 - l_1)\,\frac{1}{2} + (l_1 - l_2)\,\frac{3}{2} + (l_2 - l_3)\,\frac{5}{2} + \ldots\ldots}{l_0} = \frac{l_0 \cdot \frac{1}{2} + l_1 + l_2 + \ldots}{l_0}$$

$$= \frac{l_1 + l_2 + l_3 + \ldots\ldots}{l_0} + \frac{1}{2}$$

= expectation of life at birth.

Newsholme expresses the relationship existing between certain of the terms above used by saying that "in a stationary or life-table population the following represent identical quantities :—

Mean age at death of persons at all ages

$$= \frac{\text{Sum of ages at death}}{\text{Total number of deaths}}$$

$$= \frac{\text{Number of population}}{\text{Number of deaths in one year}}$$

= Mean duration of life
or Mean expectation of life } at birth."
or Mean after-lifetime

Bristowe obtained a formula, which is usually known by his name, by studying the hypothetical case—in which the births exceed the deaths (the ratio of both births and deaths remaining, however, uniform from year to year), in which no emigration or immigration is supposed to occur, and in which every individual born is supposed to die on attaining the mean age.

If b be the birth-rate, d the death-rate, and r the annual increase per unit of population, $r = b - d$. The unit of population becomes in the n^{th} year $(1 + r)^{n-1}$, and in that year the births are $b\ (1 + r)^{n-1}$, and the deaths $d\ (1 + r)^{n-1}$. Hence, by hypothesis, if the value of $n - 1$ be found, which makes $d\ (1 + r)^{n-1} = b$, that value of $n - 1$ will be the mean age at death,

i.e., $(n - 1) \log (1 + r) = \log b - \log d$,

$$\text{and mean age at death} = \frac{\log b - \log d}{\log (1 + r)}.$$

The formula is based on a purely hypothetical case, but it is of interest as throwing light on the extent to which the birth-rate as well as the death-rate influences the mean age at death in a population which is not stationary.

Yet another test of longevity has been proposed, *the mean age of the living*, obtained by dividing the sum of the ages of the population at the census by the number of the population. This test is found, however, to be a very unsafe one. In insanitary towns the mortality may, as Newsholme says, "spend itself chiefly among young children"; moreover, immigration is a complicating circumstance which especially disturbs the mean age of the living. On the whole, Newsholme considers that "the mean age of the living as a test of the duration of life is as untrustworthy as is the mean age of the dying."

A rough formula which gives approximate results for ages between 25 and 75 is that of Willich, which puts the expectation of life, at age x, at $\frac{2}{3}$ $(80 - x)$. Farr's rough approximation to the expectation of life is arrived at by adding $\frac{2}{3}$rds of the reciprocal of the death-rate per unit of population to $\frac{1}{3}$rd of the reciprocal of the birth-rate per unit of population.

Means and Averages—Value of a Mean Result.—Means are of various kinds. If four quantities (a, b, c, d) be considered,

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 a series are equal the means of various kinds are all equal; otherwise the quadratic mean is highest, then the arithmetic, the geometric, and the harmonic means follow in the order named. The arithmetic mean is that usually employed; the use of the geometric mean has already been illustrated in connection with the estimation of populations.*

In *Buchan and Mitchell's Method* (referred to in Chapter IX., in connection with seasonal fluctuations of disease) each term is expressed as a percentage of the arithmetic mean of the series, and a line is plotted out representing percentage excess above and deficiency below the mean. The method is convenient, as it secures uniformity of scale in comparing curves representing widely divergent or unlike quantities. It will be found that the best way of forming precise ideas as regards the utility of the method, is to undertake the labour of marking out a series of figures to scale on ruled paper, first on the ordinary system, and then on Buchan and Mitchell's method, and then make careful comparison of the charts thus obtained.

Bloxam's Method is sometimes employed when a curve has to be constructed from scanty data, and it is desirable to avoid great irregularity. For each term the mean of three adjoining terms is substituted. Thus, instead of a series a, b, c, d, etc., the terms $\frac{a+b+c}{3}$, $\frac{b+c+d}{3}$, etc., are graphically represented.

* An interesting discussion "On the importance and value of arithmetical means" in relation to medical statistics will be found in papers by Radicke and Vierordt in vol. xi. *New Sydenham Society's Transactions.*

Question may arise as to the extent to which reliance can be placed upon a mean result, and the general law of error can be applied in such cases. The *probable error* giving "the limits within which it is as likely as not that the truth will fall" is obtained as follows (Jevons):—

1. Draw the mean of all the observed results.
2. Find the excess or defect, that is, the error of each result from the mean.
3. Square each of these reputed errors.
4. Add together all these squares of the errors.
5. Take the square root of this sum.
6. Divide the square root by the number of results.
7. Multiply the quotient by ·67449 (or approximately ·674 or even ·67), a natural constant number derived from the law of error in a manner which is described in mathematical works upon the subject.

Thus, to quote an example given by Ransome, taking four weekly death-rates (32, 29, 20, and 18), and applying the above rules, the "probable error" works out at about 2·01. Thus, as he says, "the probability is one-half, or the odds are equal, that the true death-rate (the mean being 25) lies between 23 and 27. In actual working, as he says, "many more observations than four would be necessary to make such a calculation of any 'probable error'; but the above example may serve to show the untrustworthiness of weekly death-rates as a test of sanitary condition." To obtain more and more precise results the number of observations should be further and further extended. The mathematical rule may be expressed by saying that the error diminishes as the square root of the number of observations; hence, if 1,000 observations have been collected, in order to obtain a result twice as accurate, four times the number of facts must be brought together.

What is known as *Poisson's formula* is sometimes used to determine the sufficiency of a particular set of statistical data to bear having rates calculated upon them. Thus, if there are μ observations, of which m fall in one category, and n in others (*e.g.*, out of 100 cases of enteric fever, 15 deaths and 85 recoveries occur), Poisson's rule is to the effect that the true proportion of the m category to the total μ lies between

$$\frac{m}{\mu} + 2\sqrt{\frac{2mn}{\mu^3}} \quad \text{and} \quad \frac{m}{\mu} - 2\sqrt{\frac{2mn}{\mu^3}};$$

or, that the possible error of excess or defect amounts to $2\sqrt{\frac{2mn}{\mu^3}}$

In the case of the 15 per cent. case-mortality from enteric fever, therefore, the possible error of excess or defect $= 2\sqrt{\frac{2 \times 15 \times 85}{100^3}}$ = 10 per cent. nearly.

The range of possible values is, therefore, from 5 per cent. up to 25 per cent. case-mortality.

Correlation.—Mr. Francis Galton in his *Natural Inheritance* showed that the law of Frequency of Error could be applied with great advantage to the elucidation of certain problems suggested by the study of hereditary processes. His methods have recently been extended and developed by Karl Pearson and others who have applied the theory of correlation to the investigation of questions arising in connection with the theory of evolution. Like organs of the same individual resemble one another more closely than they resemble similar organs in another individual of the same race. Thus, to quote examples given by Professor Pearson, "capsules on the same poppy plant are more alike to each other than they are to the capsules of a second plant, or the leaves of one beech tree to each other than to those of a second beech tree." This resemblance is a particular case of correlation, and the numerical theory of correlation affords a means of measuring quantitatively the degree of resemblance. Professor Pearson has demonstrated the importance of looking upon "an organism or form of life as quantitatively described by the numerical values of the types and variabilities of its several organs, and by their inter-relationships as expressed by the coefficients of correlation." When the correlation is very high the correlation coefficient is nearly unity; if there be no correlation at all, the coefficient becomes zero. The correlation coefficients in man, of right and left femur (·96), first joints of right-hand index and little fingers (·82), etc., etc., have been determined (*See* table, p. 402, "The Grammar of Science."

In the questions of interest in preventive medicine the characters dealt with do not, as a rule, admit of quantitative measurement; thus, in vaccination, the presence or absence of a cicatrix is noted, but the data necessary for classification of cicatrices, after the manner adopted in dealing, for example, with lengths of bones, may not be available. Mr. G. Udny Yule, in a paper entitled "On the Association of Attributes in Statistics" (*Phil. Trans.*, Vol. 194, pp. 257–319), has referred to the "need of a *coefficient of association* to take the place of the *coefficient of correlation* for continuous variables, and be a measure of the approach of association towards complete independence on the one hand and complete association on the other." Having selected a form of coefficient which satisfies certain necessary conditions, he illustrates its use by investigating the association between non-vaccination and attack in infected households. He employs the table given on p. 65 of the Final Report of the Vaccination Commission, which gives particulars as to vaccination and attack, in children under 10 and persons over 10, in outbreaks of small-pox in five towns, and finds that—"The association between non-vaccination and attack is very high indeed for young children, ·8 to ·9, but drops sharply to ·5 (owing, presumably, to the waning protection of the vaccination made in infancy) in the older age group."

In a paper "On the Correlation of Characters not Quantitatively Measurable" (*Phil. Trans.*, Vol. 195, pp. 1—47), Professor Pearson has referred to "the correlation between strength to resist small-pox and the degree of effective vaccination." Dealing with the statistics of the Metropolitan Asylums Board for the epidemic of 1893, he obtains the coefficient ·5954 (with probable error ·0272), and hence concludes that there is "quite a large correlation between recovery and the presence of the cicatrix." He adds that, "while the correlation is very substantial," it is "perhaps smaller than some over-ardent supporters of vaccination would have led us to believe." He also applies his method to the question of the effectiveness of the anti-toxine treatment, and obtains coefficients which are "sensible as compared with their probable errors," but "the relationship is by no means so great as in the case of vaccination."

CHAPTER XII.

SANITARY ADMINISTRATION AND SANITARY LAW.

Local Authorities.—England and Wales are divided under the Local Government Act, 1894, into *administrative counties* and *county boroughs;* the former (with the exception of the County of London) are further divided into *county districts, urban* and *rural.* Further, under Section 287 of the Public Health Act, 1875, the Local Government Board may, by order, constitute any sanitary authority or combination of authorities, whose district or districts abut upon a port, a *Port Sanitary Authority.*

The authority in the area of an administrative county is the county council, first brought into existence by the Local Government Act, 1888. The county council may make by-laws for certain purposes, may appoint one or more medical officers of health, and may make complaint to the Local Government Board, under Section 229 of the Act of 1875, in cases in which any sanitary authority within the county is not doing its duty. Copies of periodical and special reports must be sent by medical officers of health of districts within the county to the county council. The county council has also powers under the Rivers Pollution Act, and the Isolation Hospitals Acts, and it is an "appeal authority" under the Local Government Act, 1894.

In county boroughs the town council, in other boroughs the municipal council, and in urban districts the urban district council, act as Sanitary Authorities and enforce any local sanitary Acts or the general code of legislation to be presently referred to. In rural districts the rural district council is the Sanitary Authority; its powers differ to some extent from those of an urban authority. Thus, urban authorities have somewhat wider powers than rural authorities, though, with the approval of the Local Government Board, most of these "urban powers" may be also exercised by rural authorities. Thus the power to make by-laws as to nuisances, new buildings, offensive trades and slaughter-houses, and authority to adopt the Public Health Acts Amendment Act, 1890, are frequently sought and obtained. Again, Part I. of the Housing of the Working Classes Act does not apply to rural districts. On the other hand, the Public Health Water Act, 1878, applies to rural and not to urban districts.

To the urban and rural district councils were allotted, in 1894, the functions previously performed by the urban and rural sanitary authorities, created in 1875. The Local Government Act, 1894, however, further created new authorities, called parish councils, in every rural parish with a population exceeding 300; and, in the event of certain preliminaries being complied with, in smaller parishes also. A few sanitary powers devolve upon parish councils, *e.g.*, power to utilise wells and springs, to deal with ponds, pools, ditches, drains, etc.; they may, moreover, hire lands for allotments, and they may make complaint, to the county council, of default on the part of the rural district council, and to the medical officer of health of the district council, concerning unhealthy dwellings. The question of the desirability of putting in force in the parish certain "Adoptive Acts" (Baths and Washhouses Acts, etc.) must be decided by the parish meeting. The powers of expenditure of the parish council, apart from expenditure in connection with "Adoptive Acts,' are limited by the condition that not more than a threepenny, or, with the consent of the parish meeting, a sixpenny rate may be incurred. The parish council may raise money on loan, but only with the consent of the parish meeting, the county council and the Local Government Board.

The rural district council remains, however, the Sanitary Authority in the rural parishes within its area, but it may appoint parochial committees, selected from the members of, or composed of, the entire parish council. The Local Government Board has prescribed the duties which may properly be delegated to a parochial committee as being those, of periodical inspection as to need of works of construction or of abatement of nuisances, of superintendence of works of construction, of examination and certification of accounts, and of reporting to the district council upon matters requiring attention and upon the performance of the duties of the officers of the council.

In London the council of the administrative county has, in addition to the ordinary powers of other county councils, other functions in connection with health administration. Such are the special powers exercised under the Housing of the Working Classes Act, 1890, the Public Health (London) Act, 1891, and the Common Lodging Houses Acts; there are also licensing and by-law-making powers inherited from the Metropolitan Board of Works. The London Government Act, 1898, constituted Borough Councils, in replacement of the vestries and district boards, which were, up to that time, the local sanitary authorities in London. Under the same Act considerable alterations of the boundaries of the local areas, with amalgamation of some of them into larger areas, were made, and certain powers of enforcing by-laws, regulations, etc., were transferred from the county council to the borough councils. In London the hospital-providing authority is the Metropolitan Asylums Board, a body distinct from the county and borough councils.

Medical Officers of Health.—It has been seen that Liverpool appointed a Medical Officer of Health in 1847, under the Towns Improvement Clauses Act of that year, and the Corporation of the City of London, under a special Act, made a like appointment in the following year. Other towns gradually followed the example of Liverpool and the City of London.

Qualifications, Tenure of Office, etc.—The Public Health Act, 1848, empowered local boards of health to appoint a legally qualified medical practitioner as medical officer of health, and the Public Health Act of 1872 imposed upon sanitary authorities generally throughout the country the duty of appointing such officers. Section 18 of the Local Government Act, 1888, requires that a medical officer of health appointed after the 1st January, 1892, to a district having at the last census 50,000 inhabitants or more, shall be the registered holder of a diploma in public health, or have been, during three consecutive years prior to 1892, a medical officer of a district with a population, at the last census, of not less than 20,000, or have been for not less than three years a medical officer or inspector of the Local Government Board.

In cases in which a portion of the salary of the medical officer of health was paid out of Imperial funds the Local Government Board, under the Act of 1872, were given the same powers as those they possessed in the case of district medical officers of health of unions with regard to appointment, duties, salary, and tenure of office. Regulations with regard to these matters were first issued by the Board in 1872. These regulations have from time to time been amended, and the Local Government Act of 1888 transferred to the county and borough councils the liability, to repayment of salary from Imperial revenue, if claimed by the local authority.

The duties of a medical officer of health are identical whether a contribution is made to his salary or not, save that in the latter case he must report his appointment to the Local Government Board within seven days. There is, however, no compulsion as regards sending copies of annual and special reports in the case of officers appointed before March, 1880, if no repayment is claimed. County councils may refuse to pay any contribution in the event of their not receiving copies of reports, required to be sent to the Local Government Board, to which they are entitled. When no part payment is made the authority may fix the salary at any sum they please, and may remove the medical officer from office at their pleasure. If, on the other hand, part payment is made, the local authority may suspend the officer, but the Local Government Board have power to remove the suspension.

The Duties of Medical Officers of Health were prescribed in an order issued on March 23rd, 1891, by the Local Government Board. In somewhat modified form, these instructions apply also to port medical officers, "ships" being substituted for houses, and other necessary corrections of a like character being made, and reference to offensive trades and to food inspection being omitted in the case of port medical officers.

"(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 by-laws and regulations as they may have power to make, and as to the adoption by the Sanitary Authority of the Infectious Disease (Prevention) Act, 1890, or of any section or sections of such Act.

(6) On receiving information of the outbreak of any contagious, infectious, or epidemic disease of a dangerous character within the district, he shall visit, without delay, the spot where the outbreak has occurred, and inquire into the causes and circumstances of such

outbreak, and, in case he is not satisfied that all due precautions are being taken, he shall advise the persons competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and take such measures for the prevention of disease as he is legally authorised to take under any Statute in force in the district, or by any resolution of the Sanitary Authority.

(7) Subject to the instructions of the Sanitary Authority, he shall direct or superintend the work of the inspector of nuisances in the way, and to the extent, that the Sanitary Authority shall approve, and on receiving information from the inspector of nuisances that his intervention is required, in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall, as early as practicable, take such steps as he is legally authorised to take under any Statute in force in the district, or by any resolution of the Sanitary Authority, as the circumstances of the case may justify and require.

(8) In any case in which it may appear to him to be necessary or advisable, or in which he shall be so directed by the Sanitary Authority, he shall himself inspect and examine any animal, 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 by-laws and regulations of the Sanitary Authority, duly confirmed where confirmation is legally required, in respect of any matter affecting the public health, and touching which they are authorised to frame by-laws and regulations.

(10) He shall inquire into any offensive process of trade carried on within the district, and report on the appropriate means for the prevention of any nuisance or injury to health therefrom.

(11) He shall attend at the office of the Sanitary Authority, or at some other appointed place, at such stated times as they may direct.

(12) He shall from time to time report, in writing, to the Sanitary Authority his proceedings, and the measures which may require to

be adopted for the improvement or protection of the public health in the district. He shall in like manner report with respect to the sickness and mortality within the district, so far as he has been enabled to ascertain the same.

(13) He shall keep a book, or books, to be provided by the Sanitary Authority, in which he shall make an entry of his visits, and notes of his observations and instructions thereon, and also the date and nature of applications made to him, the date and result of the action taken thereon, and of any action taken on previous reports; and shall produce such book, or books, whenever required, to the Sanitary Authority.

(14) He shall also prepare an annual report, to be made to the end of December in each year, comprising a summary of the action taken during the year for preventing the spread of disease, and an account of the sanitary state of his district generally at the end of the year. The report shall also contain an account of the inquiries which he has made as to conditions injurious to health existing in his district, and of the proceedings in which he has taken part, or advised, under 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. The report shall also record the action taken by him, or on his advice, during the year in regard to offensive trades, to dairies, cowsheds, and milk-shops, 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 medical officer of health shall cease to hold office before the thirty-first day of December 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, and of any special, report. He shall make a special report to the Local Government Board as to any advice he may give to the Sanitary Authority, with a view to their requiring 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) When giving information to the Local Government Board of the outbreak of infectious disease, or transmitting to them a copy of his annual report, or of any special report, he must give the like information, or transmit a copy of such report, to the county council or county councils of the county, or counties, within which his district may be situated.

(17) In matters not specifically provided for in this Order, he shall observe and execute the instructions of the Local Government Board on the duties of medical officers of health, and the lawful orders and directions of the Sanitary Authority applicable to his office.

(18) Whenever the Local Government Board shall make regulations for all or any of the purposes specified in Section 134 of the Public Health Act, 1875, relating to the prevention of infectious diseases, and shall declare the regulations so made to be in force within any area comprising the whole or any part of the district, he shall observe such regulations as far as the same relate to or concern his office."

The medical officer of health should keep a careful record of all his proceedings; he should endeavour to obtain early information concerning any unusual outbreak of illness in his district. He should see that the necessary steps are taken for securing the weekly returns of registered deaths, which, under Section 28 of the Births and Deaths Registration Act, 1874, a Sanitary Authority may, on payment, procure from the district registrar, and for obtaining returns of registered births and of deaths in outlying institutions. He should arrange that immediate notice should be given him "of all deaths from infectious diseases in fresh localities, and all groups of deaths from such disease, or from diarrhœa in any localities." By an Order of February 12th, 1879, of the Local Government Board, district and workhouse medical officers (and, by a later Order, medical officers of district schools) are required to furnish the medical officer of health with returns of pauper sickness and deaths, and to notify to him the outbreak of any dangerous infectious disease. If any such disease occur on canal boats, in common lodging-houses, or (if special by-laws have been made by the authority), in tenement houses or in tents or vans, the fact must be notified to the medical officer of health.

The extension of compulsory notification of infectious diseases to the general population of the whole country, by the Act of 1899, has placed valuable and much-needed information in the hands of medical officers of health, but the other sources of information specified are likely still to prove of use, and early knowledge of outbreaks of infectious illness is especially necessary for the undertaking of prompt preventive measures. Valuable aid may be afforded, for example, in this connection, where the co-operation of school authorities is secured.

Certain useful census data, over and above the published particulars, can be obtained with the consent of the Registrar-General. The population, for example, of "enumeration" districts is ascertained at the time of the census, but in the census tables these enumeration districts do not appear, the smallest areas dealt with being the "registration sub-districts," each of which may include a number of enumeration districts. When questions arise concerning local prevalences of disease, or the rate of mortality observed in specially unhealthy areas, knowledge of the population of individual enumeration districts may be of great value, and it is desirable, therefore, to have this information ready to hand.

Annual Reports.—The Local Government Board has from time to time issued Memoranda (with appended explanatory tabular forms) concerning the preparation of annual reports. It has been pointed out by the Board that the report should, in order to secure uniformity, be in all instances for the year ending December 31, and that it should be completed, if possible, within six weeks, and at latest within three months, of the end of the year to which the report relates. The following paragraphs may be quoted from the Memorandum of 1901:—

"The report should be chiefly concerned with the conditions affecting health in the district and with the means for improving those conditions. It should contain an account, brought up to the end of the year under review, of the sanitary circumstances of the district, and of any improvement or deterioration which may have occurred during the year in these circumstances."

As subjects concerning which the Board desire to obtain information the following deserve to be borne in mind:—

"Physical features and general character of the district.

House accommodation, especially for the working-classes: its adequacy and fitness for habitation. Sufficiency of open space about houses and cleanliness of surroundings. Supervision over erection of new houses.

Sewerage and drainage: its sufficiency in all parts of the district. Condition of sewers and house drains. Method or methods of disposal of sewage. Localities where improvements are needed.

Excrement disposal: system in vogue; defects, if any.

Removal and disposal of house refuse—whether by public scavenger or occupiers: frequency and method.

Water supply of the district or its several parts: its source (from public service or otherwise), nature (river water, well water, upland water, etc.), sufficiency, wholesomeness and freedom (by special treatment or otherwise) from risks of pollution.

Places over which the Council have supervision, *e.g.*, lodging-houses, slaughter-houses, bakehouses, dairies, cowsheds and milkshops, factories and workshops,* and offensive trades.

Nuisances: proceedings for their abatement—any remaining unabated.

Methods of dealing with infectious diseases: notification; isolation hospital accommodation and its sufficiency; disinfection."

"The medical officer of health, in reporting his proceedings and advice, should put on record whether he has made systematic inspections of his district. By 'systematic inspections' are meant inspections independent of such inquiries as the medical officer of health may have 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 such inspections will include the house-to-house inspections which may be necessary in particular localities."

"In making such systematic inspections as in much of his other action, the medical officer of health will usually have required the assistance of the inspector of nuisances, and the medical officer should 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.

"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 Board and the Councils concerned to an appreciation of the lines of action needful in the future."

"In Table I. should be stated for the whole district the number and rates of births, and of deaths under one year and at all ages, and the data on which the net death-rate is based. Spaces are given for the insertion of the corresponding figures for the ten previous years.—In Table II. the births and the deaths, corrected by

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* Sec. 132 of the Factory and Workshop Act, 1901, requires that a copy of the Annual Report dealing with workshops and workplaces shall be sent to the Secretary of State.

the exclusion of those of non-residents occurring in public institutions within the district and the inclusion of those residents dying in public institutions elsewhere, are to be distributed among the localities to which they belong, space being given in this table also for the insertion of the corresponding figures in previous years. As regards the classification by localities, it is to be observed that the district under the superintendence of a medical officer of health may contain several parts evidently differing in their circumstances, or having very different rates of mortality, either from all causes, or from some particular disease or class of diseases. The observation of these differences can scarcely fail to lead to valuable information, especially when the returns for several years can be compared together, and it is in view of such differences that the tabular statements are required, in Section 14 (of Article 18 of the Order of March, 1891), to be classified according to "*localities*," and that provision for such a classification is made on the forms supplied for returns of deaths. In the absence of any ascertained differences of the above sort, it will still be desirable, where the district is of any considerable size, and has recognised sub-divisions, 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 wards, parishes or groups of parishes, or registration sub-districts) may be taken as representing "*localities*" for the purposes of the Order. . . . Table III. provides for the number of notified cases of infectious disease during the year, classified according to ages of patients, and localities, and also the number of cases removed to hospital from each locality. . . . Table IV. provides for the classification of the deaths during the year according to causes, ages, and localities."

"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, but as indicating the sort of information required by the Board's Order. Many medical officers of health will doubtless, with great advantage to the administration of their district, furnish much more detailed information and statistics respecting particular questions to which they have been led by the circumstances of the 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."

Sanitary Inspectors.—These officers are still sometimes spoken of as inspectors of nuisances, in accordance with the original phraseology of earlier public health Acts. In London, sanitary inspectors appointed after January 1st, 1895, must be certificated, a saving proviso being made for existing inspectors. In Scotland, no medical officer *or sanitary inspector* . . . . can be removed from office without the sanction of the Scottish Local Government Board.

The duties of sanitary inspectors are prescribed by the Local Government Board, in an Order of March, 1891, as follows:—

"(1) He shall perform, either under the special directions of the Sanitary Authority or (so far as authorised by the Sanitary Authority) under the directions of the medical officer of health, or, in cases where no such directions are required, without such directions, all the duties specially imposed upon an inspector of nuisances by the Public Health Act, 1875, or by any other Statute or Statutes, or by the Orders of the Local Government Board, so far as the same apply to his office.

(2) He shall attend all meetings of the Sanitary Authority when so required.

(3) He shall, by inspection of the district, both systematically at certain periods and at intervals as occasion may require, keep himself informed in respect to 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 by-laws or regulations made by the Sanitary Authority for the suppression of nuisances, he shall, as early as practicable, visit the spot, and inquire into such alleged nuisance or breach of by-laws or regulations.

(5) He shall report to the Sanitary Authority any noxious or offensive businesses, trades, or manufactories established within the district, and the breach or non-observance of any by-laws or regulations made in respect of the same.

(6) He shall report to the Sanitary Authority any damage done to any works of water supply, or other works belonging to them, and also any case of wilful or negligent waste of water supplied by them, or any fouling by gas, filth, or otherwise of water used for domestic purposes.

(7) He shall from time to time, and forthwith upon complaint, visit and inspect the shops and places kept or used for the preparation or sale of butchers' meat, poultry, fish, fruit, vegetables, corn, bread, flour, milk, or any other article to which the provisions of the Public Health Act, 1875, in this behalf shall apply, and examine any animal, 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 medical officer of health, with the view of obtaining his advice thereon.

(8) He shall, when and as directed by the Sanitary Authority, procure and submit samples of food, drink, or drugs suspected to be adulterated, to be analysed by the analyst appointed under "The Sale of Food and Drugs Act, 1875," and upon receiving a certificate stating that the articles of food, drink, or drugs are adulterated, cause a complaint to be made, and take the other proceedings prescribed by that Act.

(9) He shall give immediate notice to the medical officer of health of the occurrence within the district of any contagious, infectious, or epidemic disease, and whenever it appears to him that the intervention of such officer is necessary in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall forthwith inform the medical officer of health thereof.

(10) He shall, subject to the directions of the Sanitary Authority, attend to the instructions of the medical officer of health with respect to any measures which can be lawfully taken by an inspector of nuisances under the Public Health Act, 1875, or under any Statute or Statutes, for preventing the spread of contagious, infectious, or epidemic disease of a dangerous character.

(11) He shall enter from day to day, in a book provided by the Sanitary Authority, particulars of his inspections, and of the action taken by him in the execution of his duties. He shall also keep a book or books, to be provided by the Sanitary Authority, so arranged as to form, as far as possible, a continuous record of the sanitary condition of each of the premises in respect of which any action has been taken under the Public Health Act, 1875, or under any other Statute or Statutes, and shall keep any other systematic records that the Sanitary Authority may require.

(12) He shall, at all reasonable times, when applied to by the medical officer of health, produce to him his books, or any of them, and render to him such information as he may be able to furnish with respect to any matter to which the duties of inspector of nuisances relate.

(13) He shall, if directed by the Sanitary Authority to do so, superintend and see to the due execution of all works which may be

undertaken under their direction for the suppression or removal of nuisances within the district.

(14) He shall, if directed by the Sanitary Authority to do so, act as officer of the said authority as local authority under the Contagious Diseases (Animals) Act, 1886, and any orders or regulations made thereunder.

(15) In matters not specially provided for in this Order he shall observe and execute all the lawful Orders and directions of the Sanitary Authority, and the Orders of the Local Government Board which may be hereafter issued, applicable to his office."

Sanitary Law.

In succeeding paragraphs the Public Health Act, 1875 (38 & 39 Vict., c. 55), will be cited as the Act of 1875. The Public Health Acts Amendment Act of 1890, and the Infectious Diseases (Prevention) Act of 1890 (*See* p. 539), will be incidentally referred to.

Sewerage and Drainage.—Section 13 of the Act of 1875 provides that all existing and future sewers, with the exception of certain private sewers, shall be vested in the local authority, who may, moreover, purchase sewers (Section 14), and shall (Section 15) maintain all sewers belonging to them; further, they must make such new sewers as may be necessary for effectually draining their district, and construct, cover, ventilate, and keep them so as not to be a nuisance or injurious to health, and cause them to be properly cleansed and emptied. Section 23 empowers the local authority to enforce drainage of undrained houses, and the drain must communicate with the local authorities' sewer, if there be one within one hundred feet from the site of the house, or else with such covered cesspool, or other place, not being under any house, as the local authority direct. The drain, or drains, may be required to be of such materials and size, and to be laid at such level and with such a fall as, on the report of their surveyor, may appear to the local authority to be necessary. In default the local authority may carry out the work and recover their expenses.

Difficulty has arisen in deciding, in certain instances, as to whether a particular channel is a drain or a sewer, and whether, therefore, the private owner or the local authority is responsible for its maintenance, etc. This question has especially forced itself upon attention in connection with "combined drains." Section 4 of the Act of 1875 defines a "drain" to be "any drain of, and used for the drainage of, one building only or premises within the same curtilage, and made merely for the purpose of communicating therefrom with a cesspool, or other like receptacle for drainage, or with the sewer, into which the drainage of two or more buildings or premises occupied by different persons is conveyed." "Sewer" includes "sewers and drains of every description, except drains to which the word drain as aforesaid applies, and except drains vested in, or under the control of, any authority having the management of roads, and not being a local authority under the Act of 1875."

The Public Health Acts Amendment Act, 1890, alters the position somewhat, as it throws upon the private owner the cost of executing any necessary works "where two or more houses belonging to different owners are connected with the public sewer by a single private drain." Thus the conduit used for the drainage of more than one building is styled, if the buildings drained by it are in different ownerships, a private drain; if the buildings are in one ownership, it is by implication a sewer.

In London the confusion is, perhaps, even greater, as "drain" is defined (Metropolis Local Management Act, 1855) as including "any drain for draining any group or block of houses by a combined operation under the order of any vestry or district board"; the amending Act of 1862 further extends the definition to combined drains, laid before vestries and district boards became sewer authorities, if made with the sanction or approval of the Metropolitan Commissioners of Sewers. If, however, the combined drain was laid without sanction or approval at all, it is a sewer, and therefore repairable by the local authority. A heavy responsibility is thus thrown upon local authorities in connection with the repair of combined drains.

Disposal of Sewage.—Section 27 of the Act of 1875 gives local authorities powers for disposing of sewage; they may construct works, purchase buildings, materials, etc., and contract to supply any person with sewage, provided that no nuisance is created in the exercise of any of these powers.

The extent to which watercourses became polluted by the sewage works of local authorities led to the passing of the **Rivers Pollution Prevention Act, 1876.** This Act deals not only with solid or liquid sewage matter, but also with solid refuse likely to interfere with the flow of, or to pollute, any stream with poisonous, noxious, or polluting liquid from any factory, or manufacturing process, and with solid matter from mines, likely to prejudicially affect the flow of any stream, and poisonous, noxious, or polluting solid or liquid matter, other than water in the same condition in which it has been raised or drained from the mine.

In the case of both sewage matters and trade effluents there are saving clauses relating to conditions existing at the time of the passing of the Act, no offence being deemed to have been committed if it is shown, in such cases, that the best practicable and available means of rendering the effluent harmless are being used.

With regard to solid matters and sewage, proceedings can be taken by any private person or local authority aggrieved; with regard to trade and mining effluents, only the local authority can act, and it must obtain the approval, before doing so, of the Local Government Board. Procedure under the Act has been beset with obstacles, and improvement has only gradually been effected. So far as sewage was concerned, local authorities, being themselves in many instances offenders, experienced difficulty in acting as prosecuting authorities. The 14th Section of the Local Government Act considerably advanced matters by giving county councils powers under the Act, and by providing for the constitution by the Local Government Board of joint committees, representing the several counties through which a river, or part of a river, passes, and having the powers of local authorities.

The Public Health Acts Amendment Act, 1890, makes it unlawful to pass into any drain or sewer any substance which may injure it or impede the flow of its contents, or any chemical refuse or waste steam, or water or other liquid heated over 110° F., which alone, or in combination with sewage, may cause nuisance or be dangerous to health.

Privies, Water-closets, etc.—Sections 35 and 36 of the Act of 1875 give the local authority power to enforce the provision, in connection with any house, of a sufficient water-closet, earth-closet, or privy, and an ashpit with proper doors and coverings. The authority may require separate accommodation for the two sexes in factories, etc., and the Act of 1890 makes such provision compulsory in all factories and workshops. Urban authorities may provide public sanitary conveniences (Section 39), and every authority is required to see that drains, closets, etc., are properly kept (Section 40). Section 41 deals with the examination of drains, etc., on complaint of nuisance, and with remedy of the faulty conditions found, if there be any.

Scavenging and Cleansing.—The local authority may, and, if required by the Local Government Board, shall, undertake or contract for the removal of house refuse, the cleansing of earth-closets, privies, ashpits, and cesspools, and the proper cleansing of streets (Section 42). Any person obstructing the removal of the matters above referred to is liable to penalty, and the local authority, if they undertake the work, are made liable to penalty for any delay exceeding seven days in removing refuse, etc., after written notice from the occupier of a house (Section 43). Where the local authority do not themselves undertake such work they may make by-laws imposing the duty of cleansing and removal upon the occupier. Section 46 provides for the purification of a house, in such a filthy or unwholesome condition as to endanger health, on the certificate of a medical officer of health or of two medical practitioners. Section 47 makes it unlawful to keep swine in any urban district so as to be a nuisance, and deals with waste water in cellars and overflows from water-closets, cesspools, etc.

Sections 48, 49, and 50 provide for the cleansing of offensive ditches, etc., the removal of filth on the certificate of the inspector of nuisances, and the periodical removal of manure from mews, etc.

Water Supply.—General powers of supplying water are given to the local authority under Section 51, but they may not construct waterworks within the limits of supply of any company empowered, by Act of Parliament, or any Order confirmed by Parliament, to supply water, so long as the company are able or willing to provide a proper and sufficient supply themselves (Section 52). Section 62 empowers the local authority to require that houses without a proper supply, when such supply can be furnished at a cost not exceeding the rate authorised by any local Act, or twopence a week, or such other cost as the Local Government Board may determine, shall be furnished with such supply. Sections 68 and 69 contain provisions for the protection of water. Section 70 prescribes the procedure to be adopted for the purpose of closing polluted wells, etc.

The Public Health (Water) Act, 1878, makes further provision for the needs of rural districts, and of such urban districts as the Local Government Board may order the Act to be extended to. If a house is without a proper water supply, and the authority find that such supply can be provided for a reasonable capital outlay (the interest on which, at 5 per cent., must not exceed 2d. a week, or, if the Local Government Board deem it desirable, 3d. a week), the owner may be required to provide such supply, and in his default the local authority may carry out the necessary works at the owner's expense. When, however, danger arises from the insufficiency or unwholesomeness of an existing supply, and a general scheme of supply is required, and can be carried out at a reasonable cost, it is the duty of the local authority to themselves carry out such scheme. Further, no house in future erected or rebuilt is to be occupied under the terms of the Act without a certificate from the local authority that it has a sufficient supply of wholesome water.

Cellar Dwellings.—No cellar, vault, or underground room built or rebuilt since 1848 can be occupied separately as a dwelling (Section 71), and no cellar whatsoever can be so occupied unless it complies with the following requirements (Section 72):—

"(i.) It must in every part be seven feet high, and at least three feet of its height must be above the surface of the street or the ground adjoining or nearest to it.

(ii.) An open area at least two feet six inches wide must extend, from six inches below floor level, along the whole frontage of the cellar. This area may be crossed by steps, provided they are not opposite the cellar window.

(iii.) There must be an efficient drain, the uppermost part of which is at least a foot below the level of the floor.

(iv.) There must be appurtenant to the cellar a proper closet and ashpit.

(v.) There must be a fireplace and a proper flue, and a window at least nine square feet in area, made to open. In the case of a back cellar, let or occupied with a front cellar, the window need only be four square feet in area."

Section 74 provides that any cellar in which any person passes the night shall be deemed to be occupied as a dwelling within the meaning of this Act. It must be noted, however, that it is only suffering the cellar to be occupied *separately* as a dwelling that is prohibited, and if the cellar is let with other rooms there is nothing to prevent its being used as a sleeping-room. Section 75 provides that, when two convictions regarding separate occupation of a cellar have taken place within three months, a court of summary jurisdiction may order the cellar to be closed for such a time as it deems fit, or may empower the local authority to permanently close the same.

Common Lodging-Houses are dealt with in Sections 76–89 of the 1875 Act. The Amendment Act of 1890 contains, moreover, a section (32) rendering a keeper liable to penalty who fails to give notice of any case of infectious disease as required by Section 84 of the Act of 1875. In London the original Common Lodging-Houses Acts of 1851 and 1853 are still in force. These Acts were administered by the Police Commissioners until 1894, when the duty was transferred to the London County Council. The Acts contain many of the provisions which are operative throughout the country generally, though in some respects London is placed at a disadvantage owing to the fact that the old Statutes have not been amended. In the Public Health (Scotland) Act, 1897, certain important provisions relating to common lodging-houses were for the first time introduced—notably, such houses were made subject to annual licence: again, a common lodging-house was defined (Section 3) as "a house or part thereof where lodgers are housed at an amount not exceeding fourpence per night for each person"; with the approval of the Local Government Board, the limit fixed may be diminished or raised, but not so as to exceed sixpence.

The English Acts contain no definition of a common lodging-house. The law officers of the Crown, in 1853, advised that the term applied "to that class of lodging-houses in which persons of the poorer class are received for short periods, and, though strangers to one another, are allowed to inhabit one common room," but not to "hotels, inns, public-houses, or lodgings let to the upper and middle classes." In a later opinion it was explained that the phrase "strangers to one another" was meant to distinguish "lodgers promiscuously brought together from members of one family or household"; and, further, question having been raised as to whether letting for a week or longer period would exclude houses otherwise within the definition, the law officers stated that they regarded the "period of letting" as "unimportant in determining whether a lodging-house comes under the Act now in question."

Several important decisions have in recent years been given as regards the interpretation of the term "common lodging-house." In Langdon *versus* Broadbent, in 1878, the principle was laid down that, in deciding whether a particular house was a common lodging-house, regard should in each case be given to the consideration whether the circumstances of occupation were such that supervision by the local authority was necessary in order to secure cleanliness, ventilation, good-ordering, etc.

In Booth *versus* Ferrett, 1890, it was held that a Salvation Army shelter, not carried on for profit, was not a common lodging-house. In 1899 the London County Council, however, raised question with regard to the use of certain premises, among which was included "The Harbour," Stanhope-street, Strand, a Salvation Army shelter. A summons was dismissed on the ground that the Harbour was a charitable institution, and that the facts were not distinguishable from those in Booth *versus* Ferrett. The decision in this case (Logsdon *versus* Booth) was appealed against, and judgment was given in favour of the Council by the Lord Chief Justice in 1899.

The Lord Chief Justice pointed out that "the learned judges in Booth *versus* Ferrett came to the conclusion (but with hesitation) that a similar house —— —— was not a common lodging-house on two grounds. First, that it was not carried on as a business for the sake of profit, but as a humane or charitable enterprise; and second, that it was not open to all comers, as, it was stated, a common lodging-house was. With regard to the first contention, it was noteworthy "that the Acts of 1851 and 1853 are sanitary Acts," and that their object is to secure, by inspection and control, for the poor in these houses "conditions safeguarding health and preventing the spread of disease, which people better off are supposed to be able to secure for themselves." Again, the question was not "with what object or with what motive the house is carried on, but whether the house is such, or is so carried on as a lodging-house, as to be within the provisions of the Act, as it is clearly within the mischief aimed at by the Act." "We fail," Lord Russell said, "to see the relevance in this connection of the motive actuating the keeper of such a house whether it be philanthropic or mercenary." Coming now to the second contention, the need of distinguishing, between receiving all comers without discrimination, and saying that the keeper is under an obligation to receive all comers, was pointed out; in fact, it was found in the case of the Harbour that practically all comers were admitted. The conclusion was therefore arrived at that Booth *versus* Ferrett was wrongly decided.

A further test case, Logsdon *versus* Trotter, was also decided in favour of the Council in 1900. Here a point was raised (in connection with a dormitory divided up by partitions) with regard to the words, "allowed to inhabit one common room." The decision given was that the house was a common lodging-house, inasmuch as the inmates were "allowed so to associate with one another as to make the danger of insanitary conditions likely to arise and likely to spread."

Section 76 of the Act of 1875 requires every urban and rural authority to keep a register of common lodging-houses, and Section 77 prohibits lodgers being received in unregistered houses. Section 78 empowers the authority to require a certificate of character from the keeper, and provides that before a house is registered it must be "inspected and approved for the purpose by some officer of the Sanitary Authority." For the principles which should guide the "approving officer" *see* p. 281. Section 79 requires a notice of registration to be affixed to the common lodging-house if the

Sanitary Authority demand it. Section 81 deals with the provision of proper water supply, and Section 82 with periodical lime-washing. Section 83 gives power to order reports from keepers of houses in which vagrants are received. Section 84 requires the keeper to give notice of fever and infectious disease occurring in the house. Section 88 provides that, where the keeper is convicted of a third offence under the Act, the court may, if it thinks fit, prohibit him, for a period not exceeding five years, from keeping a common lodging-house without a licence from the Sanitary Authority. Under Section 80 the duty is imposed upon the authority of making by-laws for the purpose of supplementing the provisions of the Act (*See* p. 566).

Houses let in Lodgings.—By-laws under Section 90 of the Act of 1875 were only operative in districts in which they had been declared, by the Local Government Board, to be in force. Section 8 of the Housing of the Working Classes Act, 1885, made the preliminary declaration unnecessary (*See* p. 570).

Nuisances.—"Whatsoever unlawfully annoys or does damage to another is a nuisance," says Blackstone, and he instances stopping "ancient light" as a private nuisance, and placing a gate across a public highway as a common or public nuisance. In addition to such "nuisances at common law," there are the special "statutory nuisances," which either cause, or are likely to cause, injury to health, and which come within the scope of the Public Health Acts. Certain kinds of nuisance are referred to in special sections of the Act of 1875 (*e.g.*, Sections 18, 19, 27, 40, 41, 49, and 50, relating to sewers, drains, etc.; Section 44, dealing with snow, dust, etc.; Section 47, regulating the keeping of animals; and Sections 112—114, which are concerned with offensive trades); there is, further, the general nuisance section (Section 91), which defines a number of other conditions likely to injure health as being "nuisances," which can be dealt with summarily under the Act. These conditions are :—

(1) Any premises in such a state as to be a nuisance or injurious to health.

(2) Any pool, 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 already under the operation of any general Act for the regulation of factories or bakehouses) 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 while work is carried on 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 mill, factory, dyehouse, brewery, bakehouse or gaswork, or in any manufacturing or trade process whatsoever; and any chimney (not being the chimney of a private dwelling-house) sending forth black smoke in such a quantity as to be a nuisance, shall be deemed to be nuisances liable to be dealt with summarily in the manner provided by this Act.

Two saving clauses must be specially noted in connection with the above. First, there is no liability to penalty under the heading (4) if it is shown that the accumulation or deposit is necessary for, and "has not been kept longer than is necessary for the purposes of the business or manufacture, and that the best available means have been taken for preventing injury thereby to the public health." Secondly, as regards (7), the complaint shall be dismissed if it is proved that the fireplace or furnace is "constructed in such manner as to consume as far as practicable, having regard to the nature of the manufacture or trade, all smoke arising therefrom, and that such fireplace or furnace has been carefully attended to by the person having the charge thereof." There is a further saving clause contained in Section 334, which relates to mines, the smelting of ores and minerals, and the calcining, puddling, etc., of iron.

Later Acts have extended the definition of the term "nuisances." Thus, filthy and overcrowded tents and vans are included under the Housing of the Working Classes Act, 1885; unfenced quarries by the Quarry Fencing Act of 1887; and abandoned coal mines by the Coal Mines Regulation Act of the same year. Section 2 of the Public Health (London) Act, 1891, substitutes, it should be noted, for the words "a nuisance or injurious to health" the words "a nuisance or injurious or dangerous to health."

Section 16 of the Public Health (Scotland) Act, 1897, also includes as "nuisances" any premises, *or part thereof of such a* *construction*, or in such a state, as to be a nuisance; any well or water supply; any deposit of offensive matter (other than farmyard manure or spent hops from breweries) within 50 yards of any public road, or standing at any railway station, siding, or in canal boats; any schoolhouse or any factory not subject to the Factory and Workshops Acts, 1878-1895, in respect of cleanliness, ventilation, and overcrowding; and any churchyard or cemetery so situated or so crowded, or otherwise so conducted as to be offensive or injurious or dangerous to health.

Section 92 of the Public Health Act, 1875, makes it the duty of the local authority to cause their district to be inspected for the detection of nuisances. Sections 189 and 190 require that every urban authority must appoint one, and every rural authority one or more inspectors of nuisances. Section 93 provides that information of any nuisance may be laid by any person aggrieved thereby, by any two inhabitant householders, or by any officer of the authority, the relieving officer, or a police-officer in the district. Section 94 deals with the service of notice, to abate the nuisance within a time specified, upon the person "by whose act, default, or sufferance the nuisance arises or continues, or, if such person cannot be found, on the owner or occupier of the premises on which the nuisance arises." If the nuisance result from some structural defect the notice must be served on the owner, and where the person causing the nuisance cannot be found, and the nuisance does not arise or continue by the act, default, or sufferance of the owner or occupier of the premises, the local authority may themselves abate the same without further order. Section 255 relates to nuisance caused by the act or default of two or more persons.

Section 96 provides that the court adjudicating upon the alleged nuisance, in the event of non-compliance with the notice of the authority, may make an abatement order or an order prohibiting the recurrence of the nuisance, non-compliance with which involves liability to penalty; the order may direct the execution of works, and must then specify what works are necessary. In cases where the nuisance renders a dwelling unfit for human habitation a closing order may be made, this order may be determined when the dwelling has been rendered habitable: there is an appeal to quarter sessions against the order of the court. Section 102 gives power of entry to the local authority or its officers for the purposes of examining as to the existence of any nuisance. In case of refusal, complaint must be made to a justice, who may make an order for admission.

Section 107 relates to cases in which the local authority elect to institute proceedings for the abatement of nuisance in the High Court of Justice, under circumstances in which it is thought summary proceedings will not afford an adequate remedy. Section 108 gives power to proceed where the cause of nuisance arises without the district; Section 110 contains a special provision as to ships or vessels within the district of the local authority, which are made subject to the same jurisdiction as if they were houses within such district.

In the event of the local authority failing to take proceedings there are three courses open to any aggrieved individual. Under Section 299 complaint may be made to the Local Government Board that the local authority has made default, and the Board, if satisfied that the complaint is well founded, may make an order, enforceable by mandamus, requiring the authority to perform the duty within a specified time. This method of proceeding is cumbersome, and the authority when required to take action under compulsion is not likely to take pains to demonstrate that its previous neglect to do so was unjustifiable. A second course of action is that provided for under Section 106, which empowers the Local Government Board to authorise any officer of police acting within the district of the defaulting authority to institute the proceedings and to recover the expenses from the authority. Here, again, the procedure is cumbersome, and the police-officer, although not directly interested in the failure of the proceedings, has no interest in their success. The third course is that contemplated by Section 105, which enables any person aggrieved, or any inhabitant of the district, or any owner of premises within the district, to institute proceedings. The section provides that the court may adjourn the case, if necessary, for examination of the premises to be made, and may authorise the entry of any constable or other person for the purposes of such examination. Such constable or person may further execute any order made by the court, and recover expenses from the person on whom the order is made. In London and in county districts there is, it should be noted, provision for making complaint to the county council in case of default on the part of the local authority.

Offensive Trades.—Section 112 of the Act of 1875 defines offensive trades as being those of "blood boiler, bone boiler, fell-monger, soap boiler, tallow melter, or tripe boiler, or any other noxious or offensive trade, business, or manufacture." It is illegal to establish any such trade within an urban sanitary district without the consent in writing of the local authority. Section 19 of the

Public Health (London) Act, 1891, makes it illegal (*a*) to establish anew "the business of a blood boiler, bone boiler, manure manufacturer, soap boiler, tallow melter, or knacker"; and (*b*) to establish anew, without the sanction of the county council, "the business of fellmonger, tripe boiler, slaughterer of cattle or horses, or any other business which the county council may declare by order, confirmed by the Local Government Board, and published in the *London Gazette*, to be an offensive business." The subject of offensive businesses has already been referred to (p. 71). Section 113 of the Act of 1875 empowers sanitary authorities to make by-laws with respect to offensive trades, and Section 19 of the London Act confers a like power on the London County Council.

Section 114 of the Act of 1875 (and the corresponding section [21] of the London Act) give power to local authorities to deal with any of the following premises, from which effluvia are evolved, which are certified by the medical officer of health, or two legally qualified medical practitioners, or ten inhabitants of a district, to be a nuisance or injurious to health. The premises referred to are: "Any candle house, melting house, melting place, or soap house, or any slaughter house, or any building or place for boiling offal or blood, or for boiling, burning, or crushing bones, or any manufactory, building, or place used for any trade, business, process or manufacture, causing effluvia." On such certification being made, it is the duty of the local authority to take proceedings, and the offender is liable to a penalty not exceeding £5, unless he can show that he has used the best practicable means for abating the nuisance, or preventing or counteracting the effluvia. (In London the fine must not exceed £50.) Section 115 of the Act of 1875 (Section 21 of the London Act) gives power to authorities to take action in cases in which nuisance is caused in their districts by offensive trades carried on in premises situated beyond the limits of the district.

Unsound Meat, etc.—Section 116 provides that—"Any medical officer of health, or inspector of nuisances, may at all reasonable times inspect and examine any animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour or milk exposed for sale, or deposited in any place for the purpose of sale, or of preparation for sale, and intended for the food of man, the proof that the same was not exposed or deposited for any such purpose, or was not intended for the food of man, resting with the party charged; and if any such animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk, appears to such medical officer or inspector to be diseased, or unsound, or unwholesome, or unfit for the food of man, he may seize and carry away the same himself or by an assistant, in order to have the same dealt with by a justice."

Among the articles specified above, eggs, butter, and cheese are not included; further, no proceedings can be taken if the articles have been already sold. The Public Health Acts Amendment Act, 1890, extends the power to take proceedings to all articles intended for the food of man sold or exposed for sale; it also provides for the condemnation of any article by a justice without previous seizure.

Section 118 of the Act of 1875 imposes a penalty for obstruction, and Section 117 provides for condemnation by a justice, and destruction of any article seized, and for the imposition of a penalty not exceeding £20, or of imprisonment for a term of not more than three months. Section 15 of the Markets and Fairs Clauses Act, 1847, which is incorporated with the Act of 1875, deals with the sale of unwholesome meat or provisions in a market or fair regulated by the local authority; Section 42 contains provision for making by-laws for preventing the sale of unwholesome provisions in a market or fair.

The need for regulating the use of horseflesh as human food became apparent when it was found not only that horseflesh was occasionally sold as ordinary butcher's meat, but also that there was reason to believe it was sometimes used for making potted meat, sausages, etc., under conditions in which the origin of the material could not be recognised by the consumer. *The Sale of Horseflesh, etc., Regulation Act*, 1889, prohibits "the sale of horseflesh for human food elsewhere than in a shop, stall, or place, over or upon which there shall be at all times painted, posted, or placed in legible characters, of not less than four inches in length, and in a conspicuous position, and so as to be visible throughout the whole time, whether by night or day, during which such horseflesh is being offered or exposed for sale, words indicating that horseflesh is sold there." Section 2 prohibits the sale of horseflesh for human food to any person who has asked to be supplied with some meat other than horseflesh, or with some compound article of food other than horseflesh.

Infectious Diseases.—Sections 120 to 130 relate to disinfection, etc., and they are supplemented and amended in certain important particulars by the Infectious Diseases (Prevention) Act, 1890. Section 120 makes it the duty of the local authority to cause premises to be cleansed and disinfected. The procedure detailed is cumbersome, and Section 5 of the Act of 1890 substitutes other provisions which are more effectual. On a certificate of the medical officer of health, or other registered practitioner, the clerk to the authority gives written notice that the premises will be cleansed and disinfected by the authority, at the cost of the occupier or owner, unless the said occupier or owner, within twenty-four hours, replies stating that he will do the work himself to the satisfaction of the medical officer of health. Where the owner or occupier is unable to effectually cleanse or disinfect the house, this may be done without notice by the officers, and at the cost, of the local authority. Penalties are provided in cases of exposure of infected persons and things, for failing to disinfect public conveyances, for letting houses in which infected persons have been lodging, and in the event of persons making false statements (in connection with such letting) as to infectious disease. Moreover, persons, who cease to occupy houses in which there has been infectious disease within a period of six weeks, without previous disinfection or first giving notice to the owner, or who make false answers, with regard to the matter, are also liable to penalty.

The local authority may destroy infected bedding, etc., and give compensation; they may provide a disinfecting apparatus* and disinfect free of charge, they may provide an ambulance, and, in cases where a person is suffering from any dangerous infectious disease, and is without proper lodging or accommodation, or lodged in a room with more than one family, or is on board any ship or vessel, a justice may make an order (on the certificate of a medical practitioner) for the compulsory removal of such person to a hospital within a convenient distance. A person lodged in a common lodging-house may be similarly removed at the instance of the local authority.

Section 130 empowers the Local Government Board to make regulations, as to the treatment of persons affected with cholera or other epidemic disease and for preventing the spread of the same, and to declare by what authority or authorities such regulations may be enforced. Section 134 empowers the Board

* In London the provision of "proper premises with all necessary attendance for the destruction and for the disinfection, and carriages or vessels for the removal," of infected articles is made obligatory upon the Sanitary Authority. The authority must, moreover, provide temporary shelter or house accommodation for persons compelled to leave their dwellings while the process of disinfection is in progress. Such provision is only required, outside London, in places where the Infectious Diseases (Prevention) Act, 1890, is in force.

to make regulations whenever any part of England appears to be threatened with, or is affected by, any formidable epidemic, endemic, or infectious disease for the following purposes:—

(1) For the speedy interment of the dead.

(2) For house-to-house visitation.

(3) For the provision of medical aid and accommodation; for the promotion of cleansing, ventilation, and disinfection; and for guarding against the spread of disease.

The Public Health Act, 1896, repealed the old Quarantine Act of 1825, and extended the powers of the Local Government Board as regards making Orders under Sections 130 and 134. Moreover, the *Public Health Ports Act*, 1896, authorised the Local Government Board to apply the Infectious Diseases (Prevention) Act, 1890, to any port sanitary district.

The earlier Orders issued by the Board contained provisions to be exercised by the officers of Customs (with the consent of the Commissioners of Customs),* as well as by the officers of port sanitary authorities. On the repeal of the old Quarantine Act the Board issued in 1896 the Order now in force, which contains *Regulations as to Cholera, Yellow Fever, and Plague*, of which the following summary may be given:—

Every Port Sanitary Authority must provide a place for mooring, at which persons can be landed from ships "coming foreign" which are infected, and must provide for the reception of actual or suspected cases of cholera, yellow fever, or plague. An "infected" ship is one on which there has been, while in the port of departure or on the voyage, a case of one of the above-named diseases, and any such ship must fly a black and yellow flag when within three miles of the coast of England or Wales. The Customs officer must ascertain whether each ship arriving is infected, and if there is reason to believe it is, or if it has come from an infected port, he must obtain a written statement from the surgeon, if there be one, or from the master of the vessel. If he finds the ship infected he must order it to be anchored, and give notice to the port authority.

The medical officer of health must visit any ship concerning which he receives information, and may visit any ship from an infected port. If he finds the ship infected he must cause it to moor in the appointed place, and examine every person on board. Persons suffering from one of the diseases named must be removed to hospital, and suspects may be detained either on the ship, or in

* Before the Public Health Act, 1896, came into force the Privy Council, aided by officials of the Board of Trade, was the Quarantine Authority.

some place provided by the authority, for not more than two days. Other persons are permitted to land on satisfying the medical officer of health as to their place of destination, and their names and addresses are transmitted to the Sanitary Authority of the district in which such destination is situate.

The medical officer of health must give directions as to any steps necessary for preventing the spread of infection, as to the disinfection or destruction of clothes, etc., and he may order bilge water to be pumped out before the ship enters dock, and may cause water-ballast tanks to be sealed, and tanks containing drinking water to be emptied or cleansed. In the event of a fatal case occurring on board, the master must bury the body at sea or deliver it to the port authorities for interment. If a vessel, though not infected, has passengers on board who are in a filthy or otherwise unwholesome condition, such persons shall not be allowed to land until they have satisfied the medical officer of health as to their place of destination. The Sanitary Authority of the place in which such place of destination is situate is then communicated with, as aforesaid.

Orders have been from time to time issued by the Local Government Board prohibiting the importation of rags from infected ports. In 1900 an Order was made declaring plague a notifiable disease; again, in 1901, an Order was issued on the subject of rats, in connection with vessels coming from ports infected with plague. In 1893, when there was a threatened prevalence of cholera, epidemic regulations were made under Section 134 by the Board. Two Orders—the Grimsby and Cleethorpes' Orders of September 1 and 6, 1893—were issued; they provided, *inter alia*, for daily meetings of the local authorities or their committees, the appointment of medical visitors, etc., the opening of dispensaries, the speedy interment of the dead, and the furnishing of daily returns to the Local Government Board.

Prohibition of the Supply of Infected Milk.—In places in which the Infectious Diseases (Prevention) Act, 1890, is in force powers for this purpose can be exercised. Section 4 of the Act provides that where the medical officer of health has reason for believing that infectious disease in his district is attributable to milk from any dairy, whether within or without the district, he may, if authorised by a justice having jurisdiction in the place where the dairy is situate, inspect the dairy, and, if accompanied by a veterinary surgeon, the animals therein. If on such inspection he concludes that the infectious disease is caused by the milk he must report to his authority, who may then summon the dairyman to appear to show cause why the supply of milk in their district should not be prohibited. If he fail to show such cause the authority may order accordingly, and non-compliance then renders the dairyman liable to a penalty not exceeding £5, and if the offence is repeated to a further penalty not exceeding forty shillings a day so long as the offence continues.

The London Act contains provisions similar to these, and somewhat more comprehensive powers are given in the Scotch Act. The procedure detailed above will be seen to entail much delay, and the penalty for non-compliance with an order, if made, is a small one; moreover, there is no requirement that a milk vendor shall furnish information with regard to his sources of supply, or that he shall provide the medical officer of health with lists of his customers. The section much needs amendment. In practice the dairyman, in order to safeguard his own interests, is usually prepared to stop the supply of infected milk, without waiting for the above-mentioned formalities to be complied with. In the event, however, of the dairyman not being willing to take action on the advice of the medical officer of health, an infected supply can, in the existing state of the law, be distributed with impunity for a number of days, pending the necessary technicalities detailed above being observed, with a view to the order being issued.

The special clauses obtained by certain towns with respect to the milk of cows affected with tubercular disease of the udder, and the powers of control over dairies, cowsheds, etc., conferred upon Sanitary Authorities under the Contagious Diseases (Animals) Acts, will be later referred to (*See* Dairies and Cowsheds' Orders, p. 577).

Cleansing of Persons Act, 1897.—This Act may be mentioned here, although it does not relate to the infectious diseases which have been the subject of consideration in the preceding paragraphs, but with the question of the destruction of vermin. The Act empowers a local authority to expend money in providing buildings, appliances, and attendants with the object of cleansing the bodies, and disinfecting the clothing, of verminous persons who may make application to have this service performed. It was urged when the Bill was before Parliament that little use would be likely to be made of the facilities afforded, inasmuch as those in need of cleansing would be unwilling to acknowledge that they were verminous persons. In the borough of Marylebone, however, the Act has been put in force for some years, the appliances provided have been extensively used, and great benefit has resulted from the exercise of the powers conferred on the authority.

Baths and Washhouses.—The Act of 1846 first facilitated the provision of public baths and washhouses, subject to the approval of the Secretary of State. In 1871 the Local Government Board was made the approving authority in regard to such matters. Section 10 of the Act of 1875 enables urban authorities to act, under the various Statutes, to the exclusion of other authorities. The London Government Act, 1898, places the control of baths and washhouses in the hands of borough councils.

Hospitals.—Sections 131 to 133 of the Act of 1875 relate to hospital provision. Any local authority may build, or contract for the use of, hospitals, and authorities may combine for the purpose; further, the expenses of maintenance may be recovered from a patient who is not a pauper.

The Isolation Hospitals Acts, 1893 *and* 1901. The object of the Act of 1893, Lord Thring's Act, was the promotion of the establishment of isolation hospitals. It does not apply to London, to county boroughs, to any borough with a population of 10,000 without the consent of the borough council, or to any borough with a smaller population without the like consent, or unless the Local Government Board direct that the Act shall apply to such borough. Certain limited powers are given by the Act to county councils enabling them to provide hospitals, or to cause them to be provided. The county council may cause local inquiries to be held for the purpose of constituting "hospital districts," comprising one or more local areas. If any local authority object to being included in a hospital district there is a right of appeal to the Local Government Board. For the management of the hospital a committee is constituted by the county council, and if the cost of the hospital is in part paid from the county fund the committee may consist wholly, or in part, of county councillors. Otherwise it will be composed entirely of local representatives. The committee may undertake the training of nurses, and may charge for their attendance outside the hospital. An ambulance or ambulances must be provided, and, if practicable, the hospital must be "in connection with the system of telegraphs." The amending Act of 1901 removed certain difficulties experienced by hospital committees under the original Act.

Mortuaries.—Sections 141 to 143 of the Act of 1875 relate to mortuaries. The local authority may, and, if required by the Local Government Board, must, provide a mortuary, and may make by-laws for its management (*See* p. 573). Section 142 provides that where the dead body, of one who has died of any infectious disease is retained in a room in which persons live or sleep, or where any dead body which is in such a state as to endanger the health of the inmates of the same house or room, is retained in such house or room, any justice may, on a certificate signed by a legally qualified medical practitioner, order the body to be removed at the cost of the local authority to any mortuary provided by such authority, and direct the same to be buried within a time to be limited by such order. If the friends fail to bury the body the relieving officer must do so at the expense of the poor rate, and he may recover the cost from any person legally liable to pay the expense. Section 143 empowers a local authority to provide a place for post-mortem examinations, otherwise than at a workhouse or at a mortuary (*See* p. 574). In places in which the Infectious Diseases (Prevention) Act, 1890, is in force it is further provided that the body of a person who has died of any infectious disease shall not, without a certificate from the medical officer of health, or a registered medical practitioner, be retained for more than forty-eight hours, save in a mortuary or in a room which is not being used at the time as a dwelling-place, sleeping-place, or workroom. Further, no such body must be conveyed in any public conveyance (other than a hearse) without due warning being given to the owner or driver, who must forthwith provide for disinfection.

The "sanitary provisions" of the Act of 1875 are for the most part contained in Part III. of that Act: the sections relating to default of local authorities will be found in Part IX., which has concern with the functions of the Local Government Board: Part VIII. of the Act contains provisions as to combination of Sanitary Authorities for the appointment of a medical officer of health, and as to the union of districts for certain sanitary purposes; there are also sections dealing with Port Authorities.

Part IV. contains a number of "local government provisions" of sanitary importance. These, in so far as they relate to new streets and buildings, have been already referred to (Chap. VII.). Certain sections of the Towns Improvements Clauses Act, incorporated in Section 160 of the Act of 1875, give the surveyor of an urban authority powers of control over dangerous structures.

Slaughter-houses, etc., are referred to in sections 166 to 170 of Part IV. Section 166 empowers an urban authority to provide markets, and Section 169 enables such an authority to construct abattoirs or slaughter-houses, and if they do so they must make by-laws with respect to management and charges. They may, moreover, *license* slaughter-houses and knackers' yards not used at the time of the passing of the Act, and they must *register* all establishments of the kind in question. The owner or occupier of any slaughter-house must exhibit a notice in a conspicuous part of his premises indicating that the place is used as a "licensed slaughter-house or registered slaughter-house," as the case may be. Licences, it should be observed, are not, under this Act, annually renewable, but are granted once for all. The duty of making by-laws with respect to slaughter-houses and knackers' yards is imposed on all urban authorities. Any person convicted of killing or dressing any cattle contrary to the provisions of the Public Health Act, or convicted under any by-law, is liable to have his licence suspended, by the court convicting him, for two months or less, and in the case of a second offence the licence may be entirely revoked.

In places where the Public Health Acts Amendment Act, 1890, is in force it is further provided that licences granted after the adoption of that Act shall remain in force only for such period, not being less than a year, as the authority shall specify; moreover, change of occupancy of a licensed slaughter-house must be notified; and, further, a court may revoke the licence of any occupier of a licensed slaughter-house who is convicted of any offence under Sections 116 to 119 of the Act of 1875, which relate to unsound meat.

Parks, Open Spaces, and Commons.—Section 164 of the Act of 1875 empowers urban authorities to provide, and to make by-laws regulating, public parks and pleasure grounds. Under the Amendment Act of 1890 their powers in regard to this matter are further extended. Section 8 of the Local Government Act, 1894, confers the powers given under Section 164, with regard to village greens, etc., on parish councils. The Open Spaces Act, 1887, enables authorities, with the consent of the Local Government Board, to acquire, maintain, and regulate open spaces, including disused burial grounds. In London the Metropolitan Open Spaces Acts of 1877, 1881, and 1887 confer special powers on the London County Council, the City Corporation, and local authorities (*See* p. 272).

Notification of Infectious Disease.—The steady growth of appreciation of the value of the results obtained by the system of notification of infectious diseases has been a remarkable feature in the history of the development of preventive medicine during the last twenty years. Information concerning the occurrence of such disease, first became available in connection with the administration of the poor law, as has been already noted (*See* p. 509); after a time, such illness if developed in common lodging-houses, canal boats, registered tenement houses, etc., was made notifiable to the local authority. Certain enterprising towns, by obtaining special powers under local Acts, made it evident that it was practicable to extend notification requirements to the general population, and at length the *Infectious Disease (Notification) Act*, 1889, was passed. This Act was, as a tentative step, made an "adoptive Act" (notification was, however, made compulsory in London). The operation of the Act of 1889 was gradually extended during "the nineties" in various parts of the country in which local Acts were not already in force, and at length, in 1899, notification was brought into operation throughout the whole of England and Wales.

The Act of 1889 scheduled certain diseases—small-pox, cholera, diphtheria, and membranous croup, erysipelas, scarlet fever, typhus fever, enteric fever, continued fever, relapsing fever, and puerperal fever—the local authority, with the consent of the Local Government Board, being empowered to add to the number of notifiable diseases. The duty of notifying was imposed on "every medical practitioner attending on, or called in to visit, the patient," the notification was to be made to the medical officer of health of the district, and a fee of half-a-crown was to be paid for each certificate relating to a private patient, and a fee of one shilling for cases attended in the course of public practice. A similar duty was imposed on the head of the family, or in his default on the nearest relatives of the patient present, or in their default on any person in charge of or in attendance on the patient, and in default of such person on the occupier of the building. Under this "dual system" it was thought to make sure of receiving notification from one or the other source; only the medical practitioner, however, was to receive a fee. In practice it has been found unnecessary to insist upon notification being made by the head of the family or the other persons placed under the obligation of notifying in his default.

At first it was supposed that difficulties might arise in connection with notification as between medical men and their patients, that the employment of unqualified practitioners would be encouraged, that the fear of publicity would lead to concealment of cases, and so on. In the early years of notification strange attempts were made to discredit its usefulness; it was even contended that where notification was adopted there was actual increase in the general death-rate or in the death-rate from notifiable diseases. Despite these contentions, notification made steady progress. It appears (Twenty-eighth Annual Report of the Local Government Board for 1898–99) that, taking into account the adoption by local authorities of the Infectious Diseases (Notification) Act, 1889, the provisions having the same effect in several local Acts, and the provisions of the Public Health (London) Act, 1891, the system of compulsory notification of cases of infectious disease had on March 31, 1899, been applied in districts having an aggregate population of 28,118,619, out of a total population in England and Wales (1891) of 29,002,525. In addition the Act was also in force in forty-one port sanitary districts, the population of which could not be stated.

The Infectious Diseases (Notification) Extension Act, 1899, came into force on January 1, 1900, and from that date the system of notification became operative in every urban, rural, and port sanitary district in England and Wales. From the annual report of the Local Government Board for 1898–99 it appears that at that time 132 authorities had from time to time availed themselves of the power given them to require the notification of diseases other than those specified in the Act. In 110 cases the Act had been extended to measles; in 7 to rötheln or German measles; in 26 to whooping-cough; in 8 to chicken-pox; and in 1 each to mumps, hydrophobia, yellow fever, and plague.* But in 38 of the above cases the addition of measles had subsequently been revoked; in 7 the addition of whooping-cough, in 4 the addition of chicken-pox, and in one the addition of hydrophobia had also been revoked. In one case, moreover, the Act had been only extended to measles for a limited period, which period had expired.

It may be noted that in London the county council (as well as the local authorities) is empowered to extend compulsory notification to diseases other than those scheduled, and if such extension is made by the county council, the disease added becomes, of course, notifiable throughout the county; chicken-pox was thus made notifiable in London during 1902. Further, in London the notification certificate differs from that required in the country generally, inasmuch as the age and sex of the patient are required to be specified. In London, "dangerous infectious diseases" are defined as including those only which are compulsorily notifiable, and hence penalties for failure to take precautions against spread of infection, etc., do not apply to diseases other than the notifiable diseases. Thus, unless measles and other non-notifiable diseases are specially declared to be dangerous infectious diseases for the purposes in question, they do not in London come within the purview of the sections which require precautions to be taken.

The inclusion of erysipelas among notifiable diseases has been the subject of much criticism; the relationship of this disease to

* On September 19, 1900, the Local Government Board made epidemic regulations declaring plague an infectious disease, notifiable under the Act throughout England and Wales.

puerperal fever, however, makes it specially desirable that careful record should be kept of its occurrence; moreover, the possibility that erysipelas may occur in connection with vaccination has been urged as a reason for making erysipelas notifiable. Puerperal fever notifications specially need to be carefully inquired into. The high case-mortality of puerperal fever, as deduced from applying deaths from, to notifications of, the disease, suggests that only some of the cases of puerperal fever are notified. The Royal College of Physicians, on being appealed to by the London County Council, defined puerperal fever as including "septicæmia, pyæmia, septic peritonitis, septic metritis, and other septic inflammations in the pelvis occurring as the direct result of childbirth." It may, perhaps, be anticipated that now that this definition has been formulated there will be greater precision as regards notification of cases of the disease.

There has been much controversy as to the desirability of extending the notification requirements to other diseases, particularly to measles and phthisis. With regard to measles, it has been pointed out, on the one hand, that in many instances medical men are not called in to attend at any stage of the illness, and that therefore there is likely to be special difficulty in securing notification of a considerable number of the cases; further, that measles is specially infectious early in the course of the disease and before the rash appears, and thus, ere the malady has yet declared itself, and before therefore preventive measures can be thought of, much mischief has been done; again, to isolate measles in a comprehensive way would require extensive hospital provision, and, as most of the sufferers are young infants, there might be difficulty in securing their removal to hospital; further, the cost of a system of measles notification has been held by some to be altogether prohibitive. On the other hand, the fact that the mortality from measles remains high, while that from certain other diseases specially affecting children has been materially reduced within recent years, has been urged as a reason for making the attempt to control the spread of the malady. It has been pointed out that small-pox, like measles, is infectious in its early stages; that small-pox was once especially prevalent among young children, and that preventive measures have been found particularly useful as a means of controlling the spread of the malady. Moreover, as Newsholme remarks, the difficulty as regards the early infectivity of measles "is not a sufficient reason for refraining from an attempt to control the disease during its subsequent course, during which it probably still remains infectious, though to a less extent."

Newsholme estimates the cost of notification at some £50,000 per annum, on an average, for the whole country, but, as he says, this is on the assumption "that the present machinery of notification is incapable of modification," whereas nothing would be easier than to arrange, for example, that only the first notification in each house should be paid for. In addition to notification fees, the increased work entailed in connection with utilisation of the knowledge gained would, however, have also to be considered. The explosive character of measles outbreaks tends, of course, to throw the additional work upon the staff of a sanitary authority all at one time.

The question of the control of measles was the subject of a report by Theodore Thomson, which appears in the twenty-fourth Annual Report of the Medical Officer of the Local Government Board. The measures, which it is practicable to adopt, were considered in this report under the following heads:—(1) Sources whence information may be derived by sanitary authorities as regards occurrences of measles in their districts; (2) measures whereby extension of measles within the invaded dwelling may be limited; and (3) measures whereby extension of measles throughout the invaded district may be checked. The general conclusion arrived at is that in no single district in which inquiry had been made had all the practicable measures of precaution for the prevention of measles been systematically adopted. Sir Richard Thorne, in summarising Dr. Thomson's report, observed: "Where compulsory notification of measles is utilised, by prompt and systematic visitation, as a clue to the existence of unreported cases; where knowledge thus acquired is supplemented by information derived from school authorities and properly utilised; where, in inter-epidemic periods or during stages before epidemics have passed beyond control, measures are adopted with a view to isolation and disinfection; and where judicious restrictions are imposed on attendances at elementary and other schools, much more is to be looked for in the control of measles than has heretofore been attained; but it cannot be too clearly understood that good result is not to be expected from the adoption of any one of these several measures; and that if any approach to complete success be aimed at, each one of the several measures indicated must be regarded as necessary and supplementary to the others."

As regards the notification of phthisis, certain special difficulties have been emphasised, such as the chronic nature of the malady and the extent to which bacilli have been expectorated before the disease comes under notice, the likelihood of particular cases being again and again notified, and the probability that objection would be raised on the ground of interference with business and other relationships, this difficulty being specially likely, of course, to occur in a malady, mainly affecting adults, and which should therefore be distinguished from those notifiable diseases which usually attack children. Again, it has been said that to require notification with a view to destroying tubercle bacilli is altogether to mistake the nature of the problem to be dealt with, for the tubercle bacillus is practically omnipresent; the fact that a large proportion of persons are immune to the bacillus should, it is urged, serve as the guide to prevention, which should aim at fortifying the resistance of the patient. In New York an attempt has been made to deal with phthisis by notification, and Newsholme, at Brighton, Niven, at Manchester, and others in this country, have shown that, in the absence of a requirement that phthisis shall be compulsorily notifiable, a good deal of useful work can be done by encouraging voluntary notification, by applying methods of disinfection in cases reported from hospitals and public institutions, and by also adopting such methods in houses in which deaths occur.

The two "Adoptive Acts" of 1890 have been already referred to from time to time; their main provisions may be here conveniently summarised.

The Public Health Acts Amendment Act, 1890, Part III., deals with the discharge of injurious substances into sewers; with nuisances arising from the common use of sanitary conveniences, and with the provision of suitable conveniences with separate accommodation for each sex in workshops and factories; it empowers by-laws to be made for certain purposes (*See* p. 575); it prohibits new buildings being erected on polluted sites; it provides for the cleansing of common passages; it deals with the pollution of streams by solid refuse; it extends the scope of Sections 116-119 of the Act of 1875 relating to unsound meat (*See* p. 527); finally it gives certain additional powers with regard to slaughter-houses and common lodging-houses.

The Infectious Diseases (Prevention) Act, 1890, contains important provisions relating to milk supplies (*See* p. 530); it simplifies the procedure with regard to disinfection (*See* p. 528); it gives additional powers for securing the prompt interment of dead bodies (*See* p. 533); it empowers a justice to order a person suffering from any infectious disease, who is an inmate of an infectious diseases hospital, to be detained for any specified period; it makes it the duty of a local authority to provide temporary shelter, with any necessary attendance, for persons who are compelled to leave their dwellings while disinfection is in progress; finally it prohibits infectious rubbish being thrown into any receptacle for refuse without previous disinfection.

The Sale of Food and Drugs Acts, 1875 1899.—The principal Act, that of 1875, originally defined food as "every article used for food or drink by man, other than drugs or water." Question arose as to whether flavouring matters and articles, such, for example, as baking powder, which were used in the preparation of food, were included, and in Section 26 of the Act of 1899 the point was made clear by addition of the words "and any article which ordinarily enters into, or is used in the composition or preparation of, human food; and shall also include flavouring matters and condiments." Drug is defined as including "medicine for internal or external use." In the case of articles such as sulphur, carbolic acid, and sulphuric acid, which have a commercial as well as a medicinal use, difficulty as to interpreting the definition might arise, and it would be for the magistrate to determine whether the particular sale in question was a sale for medicinal purposes.

Sections 3 and 4 of the Food and Drugs Act of 1875 are concerned with a particular class of offences, the adulteration of food and drugs respectively, with substances injurious to health. They provide that no person shall mix, colour, stain, or powder, with any ingredient or material, any article of food, so as to render it injurious to health, or any drug so as to affect injuriously the quality or potency of the drug, or shall sell such food or drug, under a penalty not exceeding £50 for a first offence; every offence, after a conviction for a first offence, to be a misdemeanour, for which the person on conviction shall be imprisoned for a period not exceeding six months with hard labour. Convictions under these sections are comparatively rare; to obtain them it is necessary to prove that the adulteration is dangerous to health (or in the case of a drug that its quality or potency has been injuriously affected), and that the person charged with the adulteration has guilty knowledge of the same. The penalty is much more severe than in the cases, to be now considered, of adulteration with harmless substances.

The second class of offences under the Act are those referred to in Sections 6, 7, and 9. Section 6 prohibits the sale "to the prejudice of the purchaser, of any article of food, or any drug, which is not of the nature, substance, or quality of the article demanded." Section 7 prohibits the sale of any compound article of food, or compounded drug, which is not composed of ingredients in accordance with the demand of the purchaser. Section 9 prohibits the abstraction from any article of food, of any part of it, so as to affect injuriously its quality, substance, or nature, or the sale of any article so altered without making disclosure of the alteration. In the case of these offences a smaller penalty (one not exceeding £20) is prescribed. The majority of the prosecutions under the Act are instituted under these sections, and more particularly under Section 6. For securing a conviction there is no necessity to prove guilty knowledge, as is the case in offences under Sections 3 and 4.

There are certain limitations to the operation of Section 6, which contains a proviso that no offence shall be deemed to have been committed under the 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, as in this Act mentioned.

(4) Where the food or drug is unavoidably mixed with some extraneous matter in the process of collection or preparation.

It rests with the defendant to prove that his particular case comes within any of these exceptions (Section 24). Section 8 enables the seller to safeguard himself "in respect of the sale of an article of food or a drug mixed with any matter or ingredient not injurious to health, and not intended fraudulently to increase its bulk, weight, or measure, or to conceal its inferior quality," by supplying to the purchaser a notice, by a label, to the effect that the same is mixed. Again, Section 25 provides that the defendant shall be discharged if he prove that he bought the article "as the same in nature, substance, and quality as that demanded of him by the prosecutor, and with a written warranty to that effect, that he had no reason to believe at the time when he sold it that the article was otherwise, and that he sold it in the same state as when he purchased it."

Under Section 10 of the Act of 1875 local authorities were empowered, subject to the approval of the Local Government Board, to appoint public analysts; Section 3 (1) of the Act of 1899 casts the duty of making such appointments upon local authorities,* and in default enables the Local Government Board or the Board of Agriculture to enforce the Act.

Under Section 12 of the Act of 1875 a public analyst is bound, on payment of his fee, to make an analysis of any article of food or drug purchased by any person. The sample is usually obtained, however, by an official purchaser—the medical officer of health, inspector, or other officer appointed for the purpose by the local authority. In connection with the purchase, Section 14 provides that the seller or his agent must be "notified of the intention to analyse the same, and the person purchasing must offer to divide the article into three parts, to be then and there separated, and each part to be marked, and sealed, or fastened up, in such manner as its nature will permit, and shall, if required to do so, deliver one of the parts to the seller or his agent. He shall afterwards retain one of the said parts for future comparison, and submit the third part, if he deems it right to have the article analysed, to the analyst." The official purchaser may, moreover, procure at the place of delivery a sample in the course of delivery (Section 3, Act of 1879, and Section 14, Act of 1899). Again, under Section 10 of the Margarine Act of 1887 he may take, without purchase, a sample of butter. The Commissioners of Customs have power to take samples of imported articles (Section 1, Act of 1899).

The public analyst's certificate must be in a prescribed form, and is sufficient evidence of the facts therein stated, unless the other party requires the analyst to be called. The court may, if it thinks fit, and must, at the request of either party, send a sample to the Government Laboratory for further analysis. Amendments first introduced in the Act of 1879 settled some disputed points. Thus, it was to be no defence to say the purchaser was not prejudiced because he merely purchased for analysis, or to allege that the substance, though defective in nature, or substance, or quality, was not defective in all three respects. Moreover, provision for sampling milk in course of delivery was made by the Act.

The Margarine Act, 1887, provides that margarine—*i.e.*, "all substances, whether compounds or otherwise, prepared in imitation

* In London, the borough councils, in the rest of the country, county councils or (in county boroughs and some quarter sessions boroughs) town councils, are local authorities.

of butter, and whether mixed with butter or not," shall not be lawfully sold except under certain conditions. The premises upon which margarine is manufactured must be registered with the local authority (Section 9). Section 7 (4) of the Act of 1899 extends this requirement to any premises upon which the business of a wholesale dealer in margarine is carried on. All imported margarine, and all margarine forwarded by any public conveyance, must be consigned as such (Section 8). Packages containing margarine must be so marked in letters of a specified minimum size, and where the margarine is exposed for sale by retail a label must also be used, and each package must be delivered in a specially marked paper wrapper (Section 6). There are saving clauses framed on the model of Section 25 of the Food and Drugs Act, 1875, already referred to.

The Food and Drugs Act, 1899, amends the definition of "food" and defines "cheese" and "margarine-cheese," the latter being "any substance, whether compound or otherwise, which is prepared in imitation of cheese, and which contains fat not derived from milk." It provides (in Sections 2 and 3) for action on the part of the Local Government Board or the Board of Agriculture, with a view to ascertaining whether local authorities are doing their duty and if necessary enforcing its performance. The Commissioners of Customs are empowered to take samples of imported articles, and provision is made for the marking, in a conspicuous manner, of certain adulterated and impoverished articles of food (Section 1). The Board of Agriculture is authorised to make regulations as to the analysis of milk, cream, butter, or cheese, specifying what deficiency of any of the normal constituents shall raise a presumption until the contrary is proved that the article is not genuine or is injurious to health (Section 4). Section 5 extends provisions relating to margarine to margarine-cheese, and Section 8 prohibits the manufacture, sale, or importation of margarine containing more than 10 per cent. of butter-fat. Section 14 extends the power of sampling, in course of delivery, to other articles besides milk, but only on a request from, or with the consent of, the consignee; moreover, a portion of any sample taken in course of delivery must be sent to the consignor. Vendors of milk and cream must exhibit their name and address on the vehicle or receptacle from which the milk is sold. Section 11 provides that condensed, separated, or skimmed milk shall not be sold or exposed for sale except in receptacles labelled so that the words are clearly visible to the purchaser. Section 16 imposes a heavy penalty for obstructing, or attempting to bribe, an inspector;

and Section 17 increases the maximum penalty in the case of second and subsequent convictions for offences against the Act.

The Housing of the Working Classes Acts, 1890 and 1900.—The Act of 1890 consolidates and amends three groups of enactments—The Labouring Classes Lodging Houses Acts, 1851 to 1867, known as Lord Shaftesbury's Acts; The Artisans' and Labourers' Dwellings Acts, 1868 to 1882, known as Torrens's Acts; and the Artisans' and Labourers' Dwellings Improvement Acts, 1875 to 1882, known as Cross's Acts. The Act also consolidates the greater part of the Housing of the Working Classes Act of 1885.

Lord Shaftesbury's Acts, if adopted in any district, enabled the authority to provide lodging-houses, at the cost of the rates, for letting to the labouring classes; they remained, however, practically a dead letter. Lord Shaftesbury, in giving evidence before the Royal Commission on the Housing of the Working Classes in 1884, stated that these Acts had been totally forgotten, and that until that year he did not believe there was any man living, besides himself, who knew that they existed. Part III. of the Act of 1890, which consolidates and amends Lord Shaftesbury's Acts, has of late years, been somewhat extensively put in operation.

Torrens's Acts were designed to deal with insanitary dwellings, but they provided for putting such dwellings in repair rather than for effecting any radical improvement, and were found almost unworkable by reason of the opportunities afforded to owners for hampering their operation by again and again appealing against decisions of the local authorities. Useful amendments have, however, from time to time been introduced, and are now embodied in Part II. of the Act of 1890, which consolidates and amends Torrens's Acts.

Cross's Acts (now embodied in Part I. of the Act of 1890) were put in operation in London and some of the large towns, but at considerable cost. The Act of 1890 was intended *inter alia* to bring about more equitable assessment of compensation, to prevent excessive awards being given to owners of insanitary premises and to diminish the cost incidental to arbitration proceedings. In London, up to the year 1900, a sum of £2,930,000 had been expended in connection with improvement schemes under the Housing Acts, £1,200,000 being attributable to the work of clearing away unhealthy areas. The total number of persons for whom dwellings had then been, or were then being, erected amounted to nearly 32,000.

Part I. of the Act of 1890, Section 4, makes provision for action to be taken by a "local authority"* upon an "official representation" (by a medical officer of health as defined in Section 5) to the effect that within a certain area in the district of such authority either—

(*a*) Any houses, courts, or alleys are unfit for human habitation; or,

(*b*) The narrowness, closeness, and bad arrangement, or the bad condition of the streets and houses or groups of houses within such area, or the want of light, air, ventilation, or proper conveniences, or any other sanitary defects, or one or more of such causes, are dangerous or injurious to the health of the inhabitants either of the buildings in the said area, or of the neighbouring buildings; †

and that the evils connected with such houses, courts, or alleys, and the sanitary defects in such area, cannot be effectually remedied otherwise than by an improvement scheme for the re-arrangement and reconstruction of the streets and houses within such area, or of some of such streets and houses.

A medical officer of health must make such an "official representation" whenever he sees cause, and he must inspect and report upon any area to which his attention is directed by two justices of the peace, or twelve or more ratepayers. If he fail to inspect or report, or decide that the area is not an unhealthy area, there is an appeal (Section 16) to the confirming authority, the Local Government Board (in London, the Home Secretary). Again, if the local authority fail or decline to take action upon the "official representation," they must state their reasons for not acting to the confirming authority, which may direct an inquiry to be made into the circumstances of the case. If, however, the local authority be satisfied of the truth of the representation, and of the sufficiency of their resources, they may pass a resolution declaring the area an unhealthy area, and may prepare a "scheme" for its improvement.

* The first schedule of the Act specifies the local authority in each particular case. The urban authorities in urban districts (and the Corporation in the City of London) are local authorities throughout the Act. For the purposes of Parts I. and III. the County Council is the local authority in the county of London; for the purposes of Part II., in London, the vestries and district boards (now borough councils), and for the purposes of Parts II. and III., in rural districts the rural authorities (rural district councils) are the local authorities.

† Under the earlier Act of 1875 the representation was to state "that diseases indicating a generally low condition of health amongst the population have been from time to time prevalent, and that such prevalence was attributable, etc. etc."

Schemes under Part I.—The scheme must be accompanied by maps, particulars, and estimates; it may include any number of areas, but must not deal with an area comprising less than ten houses (Section 72, Part IV.). It need not relate to all the property represented, and may include any "neighbouring lands" necessary for making the scheme efficient for sanitary purposes. The scheme may provide for the improvement being effected with the co-operation of the freeholders, under the control of the local authority.

Section 11 relates to the question of "re-housing accommodation." In London such provision must be made for as many "persons of the working classes"* as may be displaced, the accommodation, in the absence of special reasons to the contrary, to be within the limits of the area dealt with, or in the vicinity thereof. The Secretary of State may, however, permit the accommodation to be provided elsewhere, and may dispense with the obligation, in so far as he may deem expedient, but not in any case to an extent exceeding one-half the number of the persons displaced.

Outside London the Act leaves it entirely to the Local Government Board to determine to what extent, whether for all or any of the number displaced, re-housing accommodation shall be provided. The local authority may not itself undertake the erection of dwellings, save with the consent of the confirming authority, and must sell or dispose of all such dwellings within ten years of their completion, unless the confirming authority otherwise determine. When a scheme has been prepared, and approved by the local authority, advertisement of the fact must be made for three consecutive weeks in September or October or November, and notices of the scheme must be served upon persons whose interests it is proposed to compulsorily acquire. Application is then made to the confirming authority; a local inquiry is held by a commissioner, and upon his report a "Provisional Order" may be made sanctioning the scheme, with any modifications which are deemed necessary; it is usual for the Secretary of State to require that all plans of dwellings shall be approved by him. The Provisional Order must be subsequently confirmed by Act of Parliament and compulsory powers for the acquirement of property must be exercised within three years of the passing of the Act confirming the scheme.

* The expression "labouring class" is defined by Standing Orders of both Houses to include "mechanics, artisans, labourers, and others working for wages, hawkers, costermongers, persons not working for wages but working at some trade or handicraft without employing others, except members of their own family, and persons other than domestic servants whose income does not exceed an average of thirty shillings a week, and the families of any such persons who may be residing with them."

In assessing the compensation to be given no additional allowance is made for compulsory purchase in regard to any unhealthy portion of the area (portions coloured red), but 10 per cent. above the market value is, as a rule, given in the case of the remaining portions, if any, of the area (parts coloured blue). If no agreement is arrived at by the parties the case is adjudicated upon by an arbitrator appointed by the confirming authority. The special provision which guides the arbitrator's decision is contained in Section 21, which prescribes that no additional allowance shall be made in the case of property which the arbitrator deems to form a part of the unhealthy area, and that no addition shall be made for improvements to property made after the date of advertisement of the scheme, unless such improvements were necessary for the maintenance of the property in a proper state of repair.

Section 21, sub-section (2), further states that evidence may be tendered to the arbitrators to prove—

(1) That the rental of the house or premises was enhanced by reason of the same being used for illegal purposes, or being so over-crowded as to be dangerous or injurious to the health of the inmates; or,

(2) That the house or premises are in such a condition as to be a nuisance within the meaning of the Acts relating to nuisances, or are in a state of defective sanitation, or are not in reasonably good repair; or,

(3) That the house or premises are unfit, and not reasonably capable of being made fit, for human habitation;

and if the arbitrator is satisfied by such evidence, then the compensation—

(*a*) Shall, in the first case, so far as it is based on rental, be based on the rental which would have been obtained if the house or premises were occupied for legal purposes, and only by the number of persons whom the house or premises were, under all the circumstances of the case, fitted to accommodate, without such overcrowding as is dangerous or injurious to the health of the inmates; and

(*b*) Shall, in the second case, be the amount estimated as the value of the house or premises if the nuisance had been abated, or if they had been put into a sanitary condition or into reasonably good repair, after deducting the estimated expense of abating the nuisance or putting them into such condition or repair, as the case may be; and

(*c*) Shall, in the third case, be the value of the land and of the materials of the buildings thereon.

Provision is made for appeal against the arbitrator's award when the amount of compensation exceeds £1,000. The arbitrator's costs are payable by the local authority, and the arbitrator may himself order the local authority to pay the costs of arbitration of the other party, where the award is for a greater sum than was offered by the local authority in respect of the claim before the appointment of the arbitrator.

Part II. of the Act of 1890 applies to rural as well as urban districts; it relates to unhealthy dwellings, to obstructive dwellings, and to the carrying out of small improvement schemes. The confirming authority, as regards schemes under this part of the Act, is the Local Government Board. In London, if the county council consider an area too small to be dealt with under Part I., and suitable for improvement under Part II., or if, on the other hand, it is urged by the district authority that a scheme is of importance to the metropolis as a whole, and should be dealt with under Part I. rather than under Part II., the Secretary of State is empowered to hold a local inquiry and decide the question. The county council may prepare schemes under Part II., and apply to the Secretary of State to require a contribution to be made towards the cost by the district authority, and similarly the latter may apply for a contribution from the county council.

Schemes under Part II.—The procedure under this part of the Act is somewhat simpler than under Part I. The Local Government Board, after local inquiry, issue a Provisional Order, upon which, if no person interested petitions against the scheme within two months, follows a Confirming Order; should such a petition, however, be presented, and not withdrawn, a special Act of Parliament is necessary, as in the case of schemes under Part I. The Local Government Board may require such amount of re-housing provision to be made as they deem necessary in the circumstances of the case, and before sanctioning the scheme the Board requires to be satisfied as to the plans of the dwellings it is proposed to construct. Under Part II. "neighbouring lands" cannot be taken: the compensation provisions are similar to those in Part I., but the arbitrator may take into account any benefit which may accrue by the execution of the scheme to other dwelling-houses of the same owner, and the arbitrator's award is final and binding on all parties.

As regards *Buildings unfit for human habitation*, the Act provides (Section 30) that "it shall be the duty of the medical officer of health of every district to represent to the local authority of that district any dwelling-house which appears to him to be a state so dangerous or injurious to health as to be unfit for human habitation."

Local authorities are also required to cause inspection of their districts to be made with a view to ascertaining whether any such dwelling-houses exist, and they may, if satisfied that any dwelling is unfit for habitation, take proceedings against the owner for closing such dwelling, under the enactments set out in the third schedule of the Act. It should be noted that the term "owner" under this Act does not include landlords holding the premises for a term of which less than twenty-one years are unexpired. When a "Closing Order" has been made, and has not been determined by a further Order, the local authority may, after hearing the objections (if any) of the owner, and if they are of opinion that the "continuance of any building, being part of the dwelling-house, is dangerous or injurious to the health of the public or of the inhabitants of the neighbouring dwelling-houses" make a "Demolition Order." There is an appeal against such an Order to Quarter Sessions.

On written complaint from four or more householders the medical officer of health must inspect and report upon any particular house, and if within three months after receiving such report the local authority takes no proceedings, the householders (save in London or in rural districts where the county council can act in default of the local authority) may petition the Local Government Board for an inquiry.

Obstructive Buildings.—Under Section 38 power is given to a local authority to proceed on the report, of the medical officer of health or four or more householders, to the effect that a building, although not in itself unfit for human habitation, is so situate that by reason of its proximity to or contact with any other buildings, it either (*a*) stops ventilation or otherwise conduces to make them unfit for habitation, or (*b*) prevents proper measures being carried into effect for remedying any nuisance injurious to health or other evils complained of in respect of such other buildings. This section was designed to enable the local authority to purchase houses for opening up alleys, etc. If the authority decide to proceed they can make an Order for demolition, subject to appeal to Quarter Sessions. The compensation to be paid is settled by arbitration in case of difference, and where, in the opinion of the arbitrator, the demolition of an obstructive building adds to the value of other buildings, he may apportion a part of the cost of the demolition amongst such other buildings respectively, the said expenses being defrayed by improvement rates levied on the occupiers. This obstructive building section has been hitherto allowed to remain practically a dead letter.

Part III. of the Act may be adopted by local authorities; in the case of a rural authority the consent of the county council to such adoption is necessary. The authority can then compulsorily acquire land within its district for the purpose of erecting lodging-houses for the working classes. The Amending Act of 1900 extends the powers of compulsory acquirement to land outside the area in which the local authority has jurisdiction. Section 62 of the Act of 1890 provides that the "local authority may make by-laws for the management, use, and regulation of the lodging-houses."

Part IV. of the Act of 1890 contains certain supplemental provisions, notably Section 75, which provides that "in any contract made after the fourteenth day of August, 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."

Canal Boats Acts, 1877 and 1884.—Under the Act of 1877 a canal boat used as a dwelling must be registered by a local authority, and can only be so used by persons of the ages and sexes for which it is registered. The registering authority must be the authority of a district abutting on the canal upon which the boat plies, and the boat is to be allocated as belonging to a place within a particular school district. The boat must have painted on it the word "registered," its registered number, and the place to which it belongs. If infectious disease occur on the boat, the sick person may be removed to hospital, and the boat may be detained, to be cleansed and disinfected.

The Local Government Board is empowered (Section 2) to make regulations concerning questions arising in connection with canal boats, and regulations were accordingly issued in 1878. They prescribe that there shall be at least one dry, clean, weatherproof cabin (an after-cabin intended for use as a dwelling must be of at least 180, and a fore-cabin of at least 80 cubic feet capacity); such cabin must have means of ventilation apart from the door, and must provide adequate sleeping accommodation. One cabin is to contain a stove and chimney. There must be provided storage for three gallons of water, and, if the boat carries foul cargoes, the hold must be separated from any inhabited cabin by a double bulk-head with an interspace of four inches; further, the bulkhead next the cargo must be water-tight. Sixty cubic feet of space are to be allowed for each person over twelve, and 40 cubic feet for each person under twelve. In boats worked by shifts a cabin designed for two persons must contain at least 180 cubic feet. No boy of more than fourteen, and no girl of more than twelve years of age, may sleep in a cabin occupied by a married couple, and males over fourteen and females over twelve must not sleep in the same cabin; reservation is made for married couples and also (under certain conditions) in respect of boats constructed before the regulations were issued. The interior of a cabin must be kept clean, and repainted every three years. Bilge water must be pumped out daily. The master of the boat must notify any case of infectious disease, and the boat may be detained for purposes of cleansing and disinfection.

The Act of 1884 places the duty of enforcing the Acts and regulations, and of reporting annually to the Local Government Board, upon local authorities through whose districts a canal passes. The Board is, moreover, to appoint inspectors, to inquire as to the working of the Acts and to report annually to Parliament.

Factory and Workshop Act, 1901.—This Act consolidates, with amendments, all previous Acts* relating to factories and workshops.

Definitions.—"Factories" include (1) all places in which mechanical power is used in aid of the manufacturing processes; and (2) all places, whether mechanical power is used or not, in which certain industries specified in Part I. of Schedule VI. of the Act are carried on. "Workshops" include (1) certain places specified in Part II. of Schedule VI., if they are not factories by reason of the fact that mechanical power is used; (2) any other premises (not being factories) in which manual labour is exercised by way of trade or for purposes of gain in or incidental to the making, altering, repairing, ornamenting, finishing, or adapting for sale of any article, and to or over which the employer of the persons working there has the right of access or control; and (3) any workplace (termed in the Act "tenement workshop") in which, "with the permission of, or under agreement with, the owner or occupier, two or more persons carry on any work which would constitute the workplace a workshop if the persons working therein were in the employment of the owner or occupier. This third group is included for the first time under the Act of 1901.

Laundries do not come within the definitions of factory and workshop; there is a section (103) of the Act which specially relates to them (subject to certain exemptions, as regards laundries in which the persons employed are inmates of prisons, reformatories,

* In recent years important Acts were passed in 1878, 1883, 1891, and 1895.

etc., or inmates of an institution conducted for religious or charitable purposes, or members of the same family dwelling there, or in which not more than two persons dwelling elsewhere are employed). So far as sanitation and means of escape from fire are concerned, laundries to which the Act applies are to be treated as factories or workshops, according as mechanical power is, or is not, used.

"Workplace" is not defined in the Act; in a case under Section 38 of the Public Health (London) Act, 1891, Bennett *versus* Harding, it was held that "workplace" includes any "place where work is done permanently, and where people assemble together to do work permanently of some kind or other." A stable and stable-yard where men were employed as cab-cleaners and horsekeepers was therefore held to be a workplace. The term has thus wider signification than the term workshop. The kitchens of restaurants, for example, though not workshops, come within the meaning of the term workplace.

The Act of 1901 is divided into ten parts. Part I. deals with Health and Safety; Part II. with Hours of Employment, Overtime, etc.; Part III. with the Education of Children; Part IV. with Dangerous and Unhealthy Industries; Part V. with Tenement Factories, Cotton Cloth, and other Humid Factories, Bakehouses, Laundries, Docks, etc.; Part VI. with Home Work; and the other parts with Administration, Legal Proceedings, etc. Part I. is the most important part of the Act from a public health point of view.

Factories—Under Section 1 every factory, except a domestic factory, must be kept in a cleanly state; must be kept free from effluvia arising from any drain, water-closet, earth-closet, privy, urinal, or other nuisance; must not be so overcrowded while work is carried on as to be dangerous or injurious to the health of the persons employed therein; and must be ventilated in such a manner as to render harmless, as far as practicable, all gases, vapours, dust, or other impurities generated in the course of the manufacturing process or handicraft carried on, that may be injurious to health. Sub-section (3) of Section 1 provides, subject to certain powers of exemption (as regards particular classes of factories) given to the Secretary of State, that "all the inside walls of the rooms of a factory, and all the ceilings or tops of those rooms, and all the passages and staircases, if they have not been painted with oil or varnished once at least within seven years, shall be limewashed once at least within every fourteen months, and if they have been so painted or varnished they shall be washed with hot water and soap once at least within every fourteen months."

The administration of these provisions is in the hands of the factory inspector of the district. The duties of district councils in respect to factories are those which relate to means of escape in case of fire, special duties as regards domestic factories and underground bakehouses (similar to those applying in the case of workshops), and, in places where Part III. of the Public Health Acts Amendment Act of 1890 is in force, the enforcement of the requirement, in Section 22 of that Act, as to the provision of suitable and sufficient sanitary conveniences. (*See* p. 539.)

Workshops.—Under Section 2 the provisions of Section 91 of the Public Health Act, 1875, as to cleanliness, overcrowding, and ventilation are to apply to "every factory, workshop, and workplace, except any factory to which the last preceding section (Section 1 of the Act of 1901) applies." These provisions are supplemented (sub-sections (2) and (3) of Section 2) by others which relate to freedom from effluvia, and to limewashing and cleansing of workshops on the certificate of a medical officer of health or inspector of nuisances. These requirements and others (Sections 3, 7, and 8), to be presently referred to, are to be enforced by district councils. The provisions of Sections 6 and 9 are not, however, brought under the law relating to public health, and will therefore be enforced by the factory inspectors.

Section 3 defines "overcrowding" in a factory or workshop; 250 feet, or during overtime 400 cubic feet, per person, being the limits prescribed. The Secretary of State, by special order, may modify this proportion for any period during which artificial light, other than electric light, is employed for illuminating purposes. Similarly the proportion may be modified where a workshop or workplace, not being a domestic workshop, is occupied by day as a workshop and by night as a sleeping place. Notices specifying the number of persons who may be employed in each room must be affixed in every factory and workshop.

Section 4 empowers the Secretary of State to act in default of the local authority in the event of his being satisfied that the authority have failed to carry out "the provisions of this Act or of the law relating to public health in so far as it affects factories, workshops, and workplaces." Any expense incurred may be recovered from the local authority.

Section 5 empowers an inspector to give notice concerning sanitary defects, remediable under the law relating to public health, to the local authority, who must then take action thereon, and inform the inspector of the proceedings taken; if proceedings are not taken within one month the inspector may himself take proceedings, and may recover his expenses.

Section 6 requires that in every factory and workshop "adequate measures must be taken for securing and maintaining a reasonable temperature in each room in which any person is employed. The Secretary of State may, by special order, direct, with respect to any class of factories or workshops, that thermometers be provided in specified positions.

Section 7 stipulates that sufficient means of ventilation shall be provided, and that sufficient ventilation shall be maintained, in every room in any factory or workshop. The Secretary of State may, by special order, prescribe a standard of sufficient ventilation for any class of factories or workshops. There is, moreover, a sub-section (4) dealing with apportionment of the cost of providing means of ventilation between owners and occupiers. Workshops where men only are employed are exempted from the operation of this section. (Such workshops are also excluded from the operation of the sections relating to temperature, thermometers, and some other matters, Section 157.)

Section 8 prescribes that in cases where any process is carried on which renders the floor liable to be wet, adequate means of drainage shall be provided.

Section 9 requires sufficient and suitable accommodation in the way of sanitary conveniences to be provided, with proper separate accommodation for persons of each sex. The Secretary of State shall, by special order, determine what is sufficient and suitable accommodation. The section does not apply to London, or to any place where Section 22 of the Public Health Acts Amendment Act, 1890, is in force.

Safety from Fire.—Section 14 makes it the duty of a district council (in London, of the London County Council) to see that factories and workshops are provided with sufficient means of escape in case of fire. Every factory of which the construction was commenced after January 1st, 1892, and every workshop of which the construction was commenced on or after January 1st, 1896, must, if more than forty persons are employed, be furnished with a certificate from the district council, to the effect that it is provided with such means of escape as can reasonably be required in the circumstances of the case. The district council must from time to time ascertain, as regards all other factories and workshops, in which more than forty persons are employed, whether they are provided with such means of escape from fire as can reasonably be required, and, if they are not, must serve on the owner a notice specifying what should be done. If the owner disagrees the dispute is to be determined by arbitration in the manner prescribed in the Act. Section

15 newly empowers district councils to make by-laws providing for means of escape from fire in the case of any factory or workshop.

Parts II. and III. of the Act need not be here further referred to. Some of the provisions of Part IV. relating to *Dangerous and Unhealthy Industries*, require to be specially mentioned. Thus, Section 73 provides that every medical practitioner attending on, or called in to visit, a patient whom he believes to be suffering from lead, phosphorus, arsenical or mercurial poisoning or anthrax, contracted in any factory or workshop, shall notify the fact to H.M. Chief Inspector of Factories. The Secretary of State may, by special order, apply the provisions of the section to any other disease occurring in a factory or workshop. Sections 74—78 relate to the provision of ventilation, by means of a fan, in particular factories and workshops, with the provision of lavatories, with arrangements as to meals in certain dangerous industries, and with other restrictions imposed in the case of particular trades. Sections 79—86 relate to regulations for dangerous trades, the procedure to be adopted in such cases, inquiries as to draft regulations, etc. "Special rules" have been applied in the past to white lead and other kinds of lead works, to lucifer-match works, and to works in which earthenware and china, explosives, bichromate, etc., are manufactured.

Part V. contains important provisions as to cotton cloth, and other humid factories (Sections 90—96), bakehouses (Sections 97—102), laundries (Section 103), docks (Section 104), etc. As regards *Humid Factories*, the Cotton Cloth Factories Act, 1889, already regulated humidity and temperature in such places, and an amending Act of 1897 contained the provision that the air in humified cotton cloth factories must not contain more than ·9 part of CO_2 per 1,000 parts of air. These provisions are re-enacted in the Factory and Workshop Act, 1901. It is prescribed that the amount of moisture in the atmosphere must not exceed an amount shown in a table (appended in the fourth schedule to the Act) which gives maximum limits of humidity at different temperatures.

Bakehouses are subject to the general provisions of the Act. They are either factories or workshops, according as mechanical power is or is not used. A general power (Section 98) is given, in the case of premises in such a state as to be on sanitary grounds unfit for occupation as a bakehouse, to bring the case before a court of summary jurisdiction, which may impose a fine and order means to be adopted for removing the ground of complaint. In addition there are other special sections relating to bakehouses, the provisions of which may be summarised as follows:—

Section 97.—A bakehouse must not contain or communicate directly with a water-closet, earth-closet, privy, or ashpit; a cistern supplying water to a bakehouse must be separate from any cistern supplying water to a water-closet; again a sewage pipe or drain must not have any opening in a bakehouse.

Section 99.—All inside walls and ceilings of rooms, and all passages and staircases must be limewashed every six months, or coated with three coats of paint, or varnish, every seven years, and washed with hot water and soap every six months; if not, the bakehouse will be deemed not to be kept in conformity with the Act.

Section 100.—Places on the same level with a bakehouse, and forming part of the same building, must not be used as sleeping places unless effectually separated from the bakehouse by a partition from floor to ceiling, and provided with an external glazed window at least 9 square feet in area, of which $4\frac{1}{2}$ feet must be made to open for ventilation. For a first offence a penalty of £1, and for a second or subsequent offence a penalty of £5 may be imposed, both on the person occupying and on the person letting or knowingly suffering the place to be occupied.

Section 101 provides that "an underground bakehouse shall not be used as a bakehouse unless it was so used at the passing of the Act"; further, that after January 1, 1904, "an underground bakehouse shall not be used unless certified by the district council to be suitable for that purpose." An underground bakehouse is defined as being one "any baking room of which is so situate that the surface of the floor is more than three feet below the surface of the footway of the adjoining street or of the ground adjoining or nearest to the room." These regulations are to be enforced (Section 102) in the case of "retail bakehouses" by the district council. In London they are enforced by the borough councils in all bakehouses, whether retail or not, which are workshops.

Part VI. relates to *Home Work*. Section 107 requires that lists of "outworkers," in such classes of work as may from time to time be specified by special order of the Secretary of State, shall be kept by occupiers of factories and workshops and contractors employed by them, and shall be forwarded twice yearly to the district council. The council shall furnish particulars as to outworkers employed outside their district to the council of the district in which the place of employment is situated. Section 108 empowers the district council to give notice to employers prohibiting work being done upon unwholesome premises. This power is limited to particular classes of home-work specified by special order of the Secretary of State. Section 109 prohibits the making, cleansing, or repairing, of wearing apparel in places where there is scarlet fever or small-pox, and Section 110 prohibits home-work (of certain kinds specified by special order) in a house any inmate of which is suffering from any infectious disease required by law to be notified to the local authority. Section 111 deals with the application of the Act to domestic factories and workshops.

Section 131 newly imposes on district councils the duty of keeping a register of workshops in their districts, and Section 132 requires the council's medical officer of health for the future, in his annual report to the council, to report specifically on the administration of the Act in workshops and workplaces (provisions as to sanitation, bakehouses, and home-work), and to forward a copy of his report on the subject to the Secretary of State. It is, moreover, under Section 133, the duty of the medical officer if he finds any woman, young person, or child employed in a workshop in which no abstract of the Act is posted up, to inform the District Inspector of Factories of the fact, in writing.

Alkali, etc., Works Regulation Acts, 1881 and 1892. (*See* p. 77.) The Amending Act of 1892 extended the operation of the principal Act to Venetian red works, arsenic works, and some other trades.

Cemeteries and Burial Grounds.—The evils resulting from intra-mural burials and from overcrowding of burial grounds attracted much attention towards the middle of the last century. In 1834 Sir Edwin Chadwick reported on the subject. The overcrowding of metropolitan churchyards gradually led, at about this time, to the formation of cemetery companies, and it was with a view to providing a code of rules, to be applied in cases in which private companies made application for the necessary powers, that the Cemeteries Clauses Act of 1847 was passed. In this Act, such obligations as the following were imposed:—

"The cemetery is not to be constructed nearer to any dwelling-house than two hundred yards, except with the consent of the owner and occupier."

"The cemetery must be enclosed by substantial walls or iron railings of the height of eight feet at least."

In 1850 a Royal Commission reported on the question of burial, and, as a result of their inquiries and recommendations, the General Board of Health was made the burial authority in the metropolis, and it was intended that it should assume control over existing private cemeteries and make any necessary additional provision. This scheme, however, proved an abortive one. The Public Health Act of 1848 had, it may be noted, forbidden throughout the country generally interments underneath, or within the walls of, any church built after that year.

The Burial Act, 1852.—This, the first of the Burial Acts, provided that no new burial ground or cemetery within two miles of the metropolis should be brought into use without the approval of the Secretary of State, and it authorised the making of Orders in Council for the discontinuance of burials in any part of the metropolis subject to certain exceptions; it also provided for the constitution of burial boards for parochial areas. The Act originally applied only to the metropolis, but in 1853 its operation was extended to the whole of England and Wales. In 1855 an amending Act provided for the appointment of burial boards for united parishes, and prohibited a burial ground being within 100 yards of a dwelling-house without consent. The Act of 1852 empowered the Secretary of State to make regulations as to burial grounds, for the protection of the public health and the maintenance of public decency, and from time to time such regulations have been made.

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 feet by 4 feet, and those for the burial of children under twelve years of age 6 feet by 3 feet, or, if preferred, half the measurement of the adult grave space—namely, $4\frac{1}{2}$ feet by 4 feet.

(4) A register of graves shall be kept, in which the name and date of burial in each shall be duly registered.

(5) No body shall be buried in any vault or walled grave unless the coffin be separately entombed in an air-tight manner—that is, by properly cemented stone or brickwork, which shall never be disturbed.

(6) One body only shall be buried in a grave at one time, unless the bodies are those of members of the same family.

(7) No unwalled grave shall be reopened within fourteen years after the burial of a person above twelve years of age, or within eight years after the burial of a child under twelve years of age, unless to bury another member of the same family, in which case a

layer of earth not less than a foot thick shall be left undisturbed above the previously buried coffin; but if on reopening any grave the soil is found to be offensive, such soil shall not be disturbed, and in no case shall human remains be removed from the grave.

(8) No coffin shall be buried in any unwalled grave within 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.

The Burial Act, 1855, provided that the Secretary of State should from time to time appoint and authorise any person to inspect any burial ground or cemetery to which the regulations applied, to ascertain whether they had been observed. The regulations do not, save in so far as they relate to common graves, apply to private cemeteries already in existence in 1852.

The Public Health Interments Act, 1879, extended the provisions of the Public Health Act, 1875, relating to mortuaries, to cemeteries, and empowered Sanitary Authorities to provide a cemetery, imposing upon them the obligation to do so if required by the Local Government Board. This Act incorporated the provisions of the Cemeteries Clauses Act of 1847. In a circular letter dated August 19, 1879, the Board referred to the following as being the circumstances under which Sanitary Authorities should take action:—

1. Where in any burial ground which remains in use there is not proper space for burial, and no other suitable burial ground has been provided.

2. Where the continuance in use of any burial ground (notwithstanding that there may be such space) is by reason of its situation in relation to the water supply of any 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 burial in a particular town, village, or place within certain limits.

Sanitary Authorities, by the application to cemeteries of Section 141 of the Act of 1875, were, moreover, empowered to make bylaws with regard to such places.

The Disused Burial Grounds Act, 1884, provided that no buildings should be erected on any disused burial ground to which the Act applied, except for the purpose of enlarging a place of worship, and the scope of this provision was extended by the Open Spaces Act of 1887, which amended the definitions of "disused burial ground" and "building." The last-named Act also gave facilities for the acquirement and maintenance as open spaces of disused burial grounds, extending to other parts of the country, powers already existing in London in virtue of the Metropolitan Open Spaces Acts of 1877 and 1881. (*See* p. 534).

In London existing places of interment consist in the main of burial grounds provided by local authorities under the Burial Acts and of private cemeteries provided under special Acts. In the country generally the question which arises, in any particular place in which the local authority decides that a place of interment shall be provided, is whether the provision should be made by the authority itself under the Public Health Interments Act, 1879, or by a burial board under the Burial Acts. The prescribed distance from houses, and the requirements as to enclosure and fencing, differ somewhat under these alternative methods of procedure, and a portion of a burial ground must be consecrated, whereas this is not a necessity in the case of a cemetery. Further, a burial board has no compulsory powers of purchase, and, most important consideration of all, there is the question whether the area for which the cemetery is required is entirely included within the area over which the Sanitary Authority has jurisdiction.

As a matter of fact, the outstanding loans of burial boards largely exceed in amount the sums borrowed by Sanitary Authorities under the Interments Act. This circumstance finds explanation in the consideration that prior to 1879 rural authorities had no power to provide burial grounds, and urban authorities could only do so when they acted as burial boards under the Burial Acts. Furthermore, the need of making provision for areas not necessarily coincident in boundary with sanitary areas, and the fact that the rural authority contains, as a rule, representatives of many parishes, while a burial board can be appointed from persons residing in a particular parish, or other limited area, still lead in many instances to the provision of burial grounds under the Burial Acts instead of under the Public Health Acts.

In a **Memorandum on the Sanitary Requirements of Cemeteries**, issued by the Local Government Board in 1888, it was pointed out that the dangers to the public health, to which places of burial may give rise, are of two kinds—there is risk of contamination (1) of air, by gaseous and volatile substances, and (2) of drinking water, by liquid products of decomposition. As regards the former, the risk must be obviated, according to the Memorandum, by limiting the number of decomposing bodies, causing a sufficient depth to intervene between the corpses and the surface, choosing suitable soils, and providing for their adequate drainage. Moreover, the place of burial should be "in an open situation and at a sufficient distance from dwellings." As regards the latter risk, suitability of soil and efficient means of drainage are of importance, and the burial ground should be "at a sufficient distance from subterranean sources of water supply."

The sanitary requirements for a cemetery are summed up under four heads:—

(1) *Suitable soil and a proper elevation of site.*—The soil should be of an open porous nature with numerous close interstices. It should be easily worked, and free from water or hard rock to a depth of at least 8 feet; if not naturally free from water, it should be adequately drained, and for that purpose should be sufficiently elevated above the drainage level of the locality. Loam and sand with a sufficient quantity of vegetable mould are the best, clay and loose stones the worst forms of soil.

(2) *Suitable position*, especially with respect to houses and sources of water supply. Public convenience requires that the cemetery shall not be too far distant from the population for which it is intended; a due regard to public health requires that it shall not be dangerously near. As already mentioned, a distance of 200 yards from the nearest dwelling-house, except with the consent of the owners and occupiers, is sometimes specified. It is clear that the drainage of a cemetery should not be allowed to enter a stream used for the supply of water for domestic purposes. The Memorandum points out that it does not appear "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 single year amount to several times the weight of his body."

(3) *Sufficiency of space.*—The size of grave spaces and the time deemed necessary for decomposition have been dealt with in the Home Office regulations already referred to. As regards population, an allowance of a quarter of an acre per thousand inhabitants is usually estimated as being the minimum for a period of fourteen years.

(4) *Proper regulation and management.*—This matter is made a subject of consideration in the model by-laws and in the regulations issued by the Home Secretary.

Within recent years a system of disposing of dead bodies has been advocated, which if adopted would involve considerable or entire reorganisation of existing methods of burial. "Surface burial" is usually understood to imply the employment of perishable coffins placed near the surface; by this means, more rapid dissolution may be anticipated than occurs when resistant coffins are used and when these are placed at some depth. Sir Seymour Haden, as the result of experiments which he made with the bodies of animals, found that a period of "something more than four years (depending mainly on the size of the animal buried) was necessary for complete dissolution; and, speaking roundly, that for every foot of depth below the surface a year or thereabouts was necessary; for a depth of 3 feet, three years; of 2 feet, two years; and of 1 foot, one year. In a word, that dissolution was rapid in proportion as the grave was shallow and the soil porous." He pointed out that, if the system of burial near the surface in perishable coffins were adopted, the land after the lapse of a few years would again be liberated for purposes of hygiene or of utility. He further referred to the experience of the Commission appointed by the Prussian Government to inquire into the condition of the dead in the battlefields of the Vosges. The Commission found that, after the lapse of nine months or thereabouts, "in cases in which as many as 800 dead bodies, in the hurry incident to rapid military movements, had been thrust into one shallow excavation," the bodies had already disappeared, their bones and accoutrements alone being left; but to this unexpected disappearance there was a remarkable exception—the bodies of officers buried in their mackintoshes (which thus represented more or less the condition of bodies buried in coffins) had not disappeared. Coffins made of paper pulp or millboard about one-eighth of an inch in thickness, on a framework of wood, have been recently introduced, but they have not hitherto been much used, and experience is wanting as to the applicability of surface burial on a large scale. (*See* Report by C. W. F. Young, Appendix III., Ann. Rep. Med. Off. County of London, 1899).

Cremation.—This method of dealing with dead bodies has been widely adopted at various times in the world's history. In recent years there has been a steady growth of opinion in favour of the practice among civilised nations. In 1883 a judgment was given by Sir James Stephen to the effect that cremation was a legal proceeding if no nuisance was caused, and in 1885 the Cremation Society, which had been established in 1874, carried out its first cremation at Woking. In 1898 the number of bodies cremated in a year at Woking had risen to 240, and in this country crematoria have also been established at Manchester, Glasgow, Liverpool, and Hull. During the ten years, ending 1898, 3,700 cremations are said to have been carried out in Paris, and up to that year 3,110 were effected in Germany, while 70 crematoria in all had been established in Europe and America, this number including 27 in Italy, 20 in the United States, 5 in Germany, 2 in Switzerland and Sweden, and 1 in Norway. There has, therefore, been a steady extension of the practice of cremation. In the modern crematorium an ordinary body is reduced to some 3 lbs. of ash in about two hours. The advantages of cremation from the point of view of the public health are obvious; in particular it has been urged that it at once destroys the germs of infectious disease.

Several objections have been raised to the practice. Sentiment has been opposed to it in the past, but the force of this class of opposition appears to be waning. The only hostile criticism which really demands serious notice is the contention that, inasmuch as it would be impossible to exhume for purposes of chemical examination, cases of poisoning would be less likely to be detected, and that this might lead to increase of crime. Under existing conditions exhumation is very rarely resorted to, but it is urged that the fact that it may be practised in a particular case acts as a deterring influence. An improved system of death certification, and the retention in particular instances of the stomach and of a portion of one of the viscera, have been suggested as being practical means of obviating all risk in this connection. It is quite clear that much more can be done, in the direction of preventing crime, by improving the certification system, than is effected by its being known that the body of a person who has been poisoned may at a later date be exhumed for the purposes of examination.

By-Laws and Regulations.

The Local Government Board first issued nine sets of model by-laws in July, 1877. In July, 1882, sixteen principal series had been issued, and two further sets have since been framed. The subjects to which these eighteen groups of model by-laws relate are as follows:—

I. Private Scavenging.
II. *Prevention of nuisances.*
III. Common Lodging-houses.
IV. *New Streets and Buildings.*
V. Markets.
VI. *Private Slaughter-houses.*
VII. Hackney carriages.
VIII. *Public bathing.*
IX. Public baths, washhouses, and open bathing places.
X. *Pleasure grounds.*
XI. *Horses, etc., standing for hire.*
XII. *Pleasure boats.*
XIII. Houses let in lodgings or occupied by members of more than one family.
XIV. Cemeteries.
XV. Mortuaries.
XVI. *Offensive trades.*
XVII. Hop-pickers and fruit-pickers.
XVIII. Tents and vans.

There are a few other subject-matters concerning which by-laws can be made, but with regard to which model by-laws have not been issued. Such are public slaughter-houses, public conveyances, public recreation grounds, streets and buildings (the by-law making powers given by Sec. 157 of the 1875 Act being extended by Section 23 of the Act of 1890), removal of offensive material through the streets, and removal of house refuse (powers to control these matters being also given under the Act of 1890). Local authorities are empowered to make certain regulations, notably under the dairies, cowsheds, and milk shops Orders, also with regard to public sanitary conveniences, cabmen's shelters, and allotments. There is further a power to make regulations (to be approved by the Local Government Board) for removing to hospital infected persons brought within a district by ships. Some by-laws (those indicated in italics in the list given above) can only be made by urban authorities. It may, moreover, be noted that by-laws as to common lodging-houses and slaughter-houses *must* be made by urban authorities; as regards the other matters, the powers are permissive, and no obligation is placed on the authority to make the by-laws.

Section 182 of the Public Health Act, 1875, contains the words :—"No by-law made under this Act by a local authority shall be of any effect if repugnant to the laws of England or to the provisions of this Act." In order not to be repugnant to the general law, a by-law must be reasonable and certain and determinate. The Local Government Board, in a circular letter of July, 1877, pointed out, as regards reasonableness, that "The exercise of the power which the Legislature has confided to Sanitary Authorities must frequently bring them into contact with important interests. Within certain limits they may regulate the conduct of persons employed in certain specified callings. They may impose restrictions upon the enjoyment of individual rights and privileges. Trade and property may, under certain conditions, be affected by their action. These considerations point to the necessity for prudence and deliberation in the choice of by-laws, so that the duties and restraints which they create may not interfere oppressively with individual freedom of action." Two instances of judgments given in the courts may be cited; thus a by-law prohibiting the keeping of swine within fifty feet of any dwelling-house, within a rural district, was held to be unreasonable; on the other hand, in an urban district a by-law prohibiting the keeping of swine within 100 feet of a dwelling-house has been held to be reasonable.

As regards the need for making by-laws certain and determinate, the Board, in the circular letter above referred to, point out that assumption by the Sanitary Authority of "power of suspending the operation of particular provisions in individual cases is open to much objection." Again, the Board disapproves of inserting, in place of "necessary details," "vague conditions which render compliance with the by-laws dependent upon the approval by the Sanitary Authority or their officers of the mode of proceeding in each case." The letter states that "The Board think that every person, who by neglect of the rules which a by-law is intended to prescribe may be rendered liable to a penalty, is entitled to demand from those who impose such rules a clear statement of the course of action which must be followed or avoided."

As regards the need for a by-law not being repugnant to the provisions of the Act under which it is made, the Board point out that "authorities cannot legally assume the power of making by-laws for carrying out the general objects of the Act. It follows, therefore, that every by-law must be strictly limited with reference to the terms of the specific enactment from which its force is derived. Any attempt by the strained construction of any such enactment to extend the range of a by-law should especially be avoided."

Section 182 of the Act of 1875 provides that by-laws shall be under the common seal of the local authority, and Section 185 requires that they shall be printed and exhibited and open to inspection. By-laws are of no validity until they have been confirmed by the confirming authority; in this respect, and also by reason of the fact that infringement of the provisions of a by-law entails liability, as a rule, to the imposition of a penalty, they differ from "regulations." Sometimes regulations, however, require confirmation, and in particular instances regulations contain a penalty clause, so that the distinctions mentioned are not of invariable application.

The following is a brief summary of the provisions contained in the model by-laws:—

I. **Private Scavenging.**—Under Section 44 of the Act of 1875 it is provided that "where the local authority do not themselves undertake or contract for

> "The cleansing of footways and pavements adjoining any premises;
>
> "The removal of house refuse from any premises;
>
> "The cleansing of earth-closets, privies, ashpits, and cesspools belonging to any premises;

"they may make by-laws imposing the duty of such cleansing or removal, at such intervals as they think fit, on the occupier of any such premises."

The by-laws are only applicable in districts in which the local authority do not themselves perform the work of scavenging. Under Section 42 of the Act a local authority may, and when required by order of the Local Government Board shall, undertake such duties.

Where this is not done it is usual for by-laws to impose upon occupiers of premises the duty of providing for the daily cleansing (Sundays excepted) of footways and pavements; for the weekly removal of house refuse; for the cleansing once at least in every three months of earth-closets with fixed receptacles, and once at least in every week of earth-closets with movable receptacles; for the cleansing at least once a week of privies, whether the receptacles are fixed or movable, and of ashpits, whether used in connection with privies or merely as receptacles for ashes, dust, and dry refuse; and for the cleansing once at least in every three months of cesspools.

II. **Prevention of Nuisances.**—By-laws under this head provide for the clearing away of snow on footways; for the use of suitable vessels or receptacles (with sufficient coverings) for the removal of filth; for the cleansing of privies, etc., during certain hours (those usually specified are between the hours of 6 and half-past 8 in the forenoon in the summer months, and the hours of 7 and half-past 9 in the forenoon in the winter months); for preventing night soil, manure, etc., being deposited for more than twenty-four hours within a specified distance (usually 100 yards) of any premises used for human habitation, or as a school, place of public worship or public assembly, or place of business; and for the prevention of nuisance from the unloading or depositing, or conveyance through the streets, of any kind of "filth emitting a stench." These by-laws also deal with the keeping of swine in proximity to dwellings, with the keeping of cattle, or the deposit of the dung of cattle in such a manner as to pollute any supply of water for domestic use, with the provision, construction and cleansing of dung receptacles, and with the cleansing of stables.

III. **Common Lodging-houses.** — These by-laws contain provisions—(1) "For fixing and from time to time varying the number of lodgers who may be received into a common lodging-house, and for the separation of the sexes therein." The practice generally adopted is to prescribe the maximum number of lodgers to be received in each room (300 cubic feet of space is often fixed as the minimum allowance in rooms used by night only). As a rule, no person over ten years of age is allowed to occupy any room used as a sleeping apartment by persons of the opposite sex; but the use of a common sleeping apartment by married couples has been hitherto generally permitted, provided each bed is effectually screened, by means of a partition of wood or other solid material extending upwards to a sufficient height, and downwards to a distance of not more than 6 inches above the level of the floor.

It is usual to provide that no bed in a room used as a sleeping apartment by persons of the male sex, above the age of ten years, shall be occupied at any one time by more than one such person.

(2) "For promoting cleanliness and ventilation in such houses." Under this head by-laws are usually made dealing with the sweeping of floors and staircases, the cleansing of windows and fixtures and of yards, the cleansing of beds and bedding, the keeping in good order of water-closets, earth-closets and ashpits, the provision of lavatory accommodation, the removal of filth and refuse from rooms, the opening of windows at stated times, and the keeping in order of the means of ventilation.

(3) "For the giving of notices, and the taking precautions in the case of any infectious disease." Immediate notice is required to be given of the occurrence of illness of an infectious character, prompt removal of any lodger affected with such illness is provided for, and requirements as to cleansing and disinfecting rooms, as to ceasing, if required by the medical officer of health, to receive lodgers in particular rooms, and as to complying with all instructions given by that officer with regard to the proper cleansing and disinfection of rooms and articles contained therein, are usually made.

(4) "Generally, for the well ordering of such houses." In addition to the requirements already specified, by-laws are often made requiring that kitchens shall not be used as sleeping-rooms, that there shall be an interval of at least eight hours between successive occupations of the same bed, that notices specifying the maximum number of lodgers authorised to be received in any particular room, and that copies of the by-laws, shall be, if required, fixed in suitable and conspicuous positions.

IV. **New Streets and Buildings.**—By-laws under this heading have concern with the level, width, construction and sewerage of new streets; the structure of walls, foundations, roofs and chimneys, for securing stability and the prevention of fires, and for purposes of health; the sufficiency of the space about buildings to secure free circulation of air, and the adequate ventilation of buildings; with the drainage of buildings, with water-closets, earth-closets, privies, ashpits, and cesspools in connection with buildings, and with the closing of buildings unfit for human habitation. This important series of by-laws has already been referred to in some detail in Chapter VII.

V. **Markets.**—The questions of public health interest mainly involved in connection with markets are those relating to prevention of nuisance arising from the keeping of animals, to inspection of slaughter-houses, and to prevention of the sale, or exposure for sale, of unwholesome provisions in the market-place.

VI. **Slaughter-Houses.**—By-laws under this heading prescribe the mode of application for licences and for registration. Slaughter-houses in existence prior to the time when the provisions in the Public Health Act relating to such premises were first applied to the district, and which have continued to be used as slaughter-houses ever since, do not require a licence, but they must be registered (*See* p. 533). The by-laws provide for access being afforded for purposes of inspection, for animals being supplied with water during confinement, for the use in the process of slaughtering of such instruments and appliances and the adoption of such methods as will prevent unnecessary suffering; for the maintenance of drainage, water-supply, and means of ventilation in efficient order; for keeping the slaughter-house in good repair; for lime-washing at stated periods; and for cleansing being carried out within a stated number of hours after slaughtering or dressing.

Further, provision may be made that no dog shall be kept in the slaughter-house, the object of this prohibition being the prevention of the spread of parasitic disease, and particularly of hydatid disease (*Tænia echinococcus* being of common occurrence in dogs). Again, it is usual to prohibit the keeping in any slaughter-house of an animal the flesh of which may be used for human food, unless the animal is so kept in preparation for slaughter upon the premises. Finally, the by-laws may provide for the removal of hides, offal, etc., within a stated time after the completion of slaughtering, for the collection and removal of blood in proper receptacles or vessels, and for the cleansing of such vessels.

These by-laws, it will be noted, do not refer to questions of structure, but the considerations to which regard may be paid, in the case of premises subject to the discretionary power of licensing on the part of the Sanitary Authority, have been summarised in a Local Government Board Memorandum, as follows:—

"(1) The premises to be erected, or to be used and occupied as a slaughter-house, 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 adjoining ground.

(4) The approach to the slaughter-house should not be on an incline of more than one in four, and should not be through any dwelling-house or shop.

(5) No room or loft should be constructed over the slaughter-house.

(6) The slaughter-house should be provided with an adequate tank, or other proper receptacle for water, so placed that the bottom shall not be less than 6 feet above the level of the floor of the slaughter-house.

(7) The slaughter-house should be provided with proper ventilation.

(8) The slaughter-house should be well paved with asphalt or concrete, and laid with a proper slope and channel towards a gully, 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 should also be made for the effectual drainage of the slaughter-house.

(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."

VII. **Houses Let in Lodgings or Occupied by Members of more than one Family.**—Under Section 90 of the Act of 1875 the Local Government Board could empower local authorities to make by-laws, for fixing the number of persons who may occupy a house or part of a house let in lodgings, for the separation of the sexes therein, for the registration and for the inspection of such houses, for enforcing drainage, etc., and cleanliness, for lime-washing, paving yards, etc., and for giving notice and taking precautions in case of any infectious disease in such houses. The need for the enactment being declared to be in force in any particular district, by the Board, was removed by Section 8 of the Housing of the Working Classes Act, 1885, so that local authorities were empowered, from that date, to make by-laws without any preliminary declaration.

In London the obligation of making such by-laws was placed upon Sanitary Authorities by the Public Health (London) Act, 1891. When the practice of letting houses for occupation by several families first became established in London it was seen to be fraught with an element of danger (*See* p. 6). It appears, however, that house-to-house visitation in poor neighbourhoods, undertaken at times of cholera prevalence, specially served to emphasise the importance of inspecting houses of the poorer sort occupied by more than one family. Already, in "the sixties," power had been obtained under a special Act for dealing with the matter in the City of London. The Sanitary Act of 1866 practically gave the right of making by-laws with regard to such houses to any authority choosing to make application for it. The Housing of the Working Classes Commissioners, in 1884, were greatly impressed with the usefulness of the by-laws, which had been enforced at that time in a few districts.

The early tenement-house regulations referred to a variety of matters which are now in many instances included within the scope of special by-laws relating to drainage, collection of refuse, yard paving, the keeping of animals, etc., and applying not only to tenement houses, but to houses generally. Moreover, the power given in 1866 to make by-laws as to giving notice of infectious disease, occurring in tenemented houses, has now by the general application of the system of notification been rendered practically unnecessary. Thus, many of the rights originally conferred on authorities, and in some instances exercised by them, with regard to houses let in lodgings are now applicable to houses of all kinds.

There still remain, however, certain powers which can, with advantage, be specially applied to this class of houses. The most important of these are those relating to enforcement of periodical cleansing, lime-whiting, etc., and to the control of overcrowding. Further, under special by-laws, rights of entry "at all times" can be obtained; this is a matter of great importance in connection with overcrowded tenemented houses. Proof of the existence of overcrowding can, as a rule, only be obtained by inspection at night time; such inspection should, of course, only be undertaken under exceptional circumstances, and with exercise of all due precautions. As a matter of fact, it has been found that when once it is understood that the power may be occasionally used overcrowding ceases to exist, and this in houses and localities in which the overcrowding difficulty has been previously found to be an insurmountable one. The reason no doubt is that under by-laws there is liability to penalty upon proof of the overcrowding being forthcoming, whereas, in the ordinary nuisance procedure, all that can be done is to obtain an order requiring its abatement. Under the latter system tenants have in practice been disturbed to little or no purpose; the rooms evacuated are again, as a rule, let in such a way as to reproduce the overcrowding, and the outgoing tenants often merely pass from one to another set of overcrowded rooms. The power of applying directly for penalty, taken in conjunction with that of obtaining proof of the existence of overcrowding, disposes of these difficulties at once; indeed, the mere moral effect of the knowledge that these powers are likely to be exercised has been found to produce a greater impression than the abatement notices of a long series of years had been able to effect.

In the model by-laws "landlord" is defined as "the person (whatever may be the nature or extent of his interest in the premises) by whom, or on whose behalf, the house or part of a house is let in lodgings, or for occupation by members of more than one family, or who for the time being receives, or is entitled to receive, the profits arising from such letting." The by-laws impose upon the landlord the responsibility for structural details; but in cases where a lodger has exclusive use of a particular appliance such lodger is made liable for its maintenance in a wholesome condition. As regards overcrowding, it is usual to prohibit both landlord and lodger from knowingly causing or suffering the condition to exist.

The model by-laws contain a clause to the effect that a lodging-house shall be exempt from the operation of the by-laws:—

(*a*) Where the rent or charge payable by each lodger, and exclusive of any charge for the use by such lodger of any furniture, is at the rate of —— per week or upwards.

(*b*) Where the rent or charge payable by each lodger, and inclusive of any charge for the use by such lodger of any furniture, is at the rate of —— per week or upwards.

The limits of rent prescribed are, of course, intended to be varied according to the circumstances of the particular locality. The Local Government Board pointed out in a Memorandum of July, 1899, that it is desirable to exempt from the operation of the by-laws "lodging-houses as to which it may reasonably be inferred that such supervision as elsewhere a local authority alone can efficiently exercise will, in fact, be exercised by the lodgers themselves." Difficulty has been experienced in some instances in connection with "exemption limits" by reason of the fact that the rentals fixed have been found to exclude houses which might with great advantage have been regulated.

The standards of air space laid down in the model by-laws are as follows:—

For rooms used by night only—

300 cubic feet for each person of an age exceeding 10 years.

150 cubic feet for each person of an age not exceeding 10 years.

For rooms not used exclusively at night—

400 cubic feet for each person of an age exceeding 10 years.

200 cubic feet for each person of an age not exceeding 10 years.

The Memorandum already referred to states that, if it should in future be found "practicable to enforce an increased allowance of free air space, the Board will gladly facilitate the confirmation of new by-laws for that purpose."

The Statute gives power for a by-law to be made as regards "separation of the sexes." The model series makes no mention of the subject, but a by-law has, in particular instances, been confirmed to the effect that "a lodger in a lodging-house shall not suffer any person above the age of 12 years to occupy as a sleeping apartment any room let to such lodger, if the room is occupied by more than one person above that age and of the opposite sex."

As regards periodical cleansing and limewashing, the model by-law prescribes that "in the first week of the month of —— in every year, ... the landlord shall cause every part of the premises to be cleansed," and further that "he shall cause the internal walls and ceilings to be washed with hot limewash," save in particular instances where the surface is covered with paint, or other material to which the application of limewash would be "unsuitable or inexpedient," and where such surface is thoroughly cleansed, and the paint or other covering, if necessary, renewed.

In addition to those already referred to, the model series contains requirements as to the landlord's furnishing particulars concerning the mode of occupation of the house; as to rights of entry and obstruction of officers; as to water-closets, etc., and their maintenance in a cleanly condition; as to the cleansing of yards, floors, windows, staircases, cisterns, etc., and the removal of filth and rubbish; as to the keeping of animals; as to ventilation; and as to precautions being taken with regard to infectious disease.

Working Class Lodging-Houses.—As already noted, Part III. of the Housing of the Working Classes Act empowers the local authority to make by-laws for the management, use, and regulation of lodging-houses which they have established or acquired under that part of the Act.

Seamen's Lodging-Houses.—Under the Merchant Shipping Act, 1894, a local authority whose district includes a seaport may, with the approval of the Board of Trade, make by-laws providing "for the licensing, inspection, and sanitary condition of seamen's lodging-houses, for the publication of the fact of a house being licensed, for the due execution of the by-laws, for preventing the obstruction of persons engaged in securing that execution, for the preventing of persons not duly licensed holding themselves out as keeping or purporting to keep licensed houses, and for the exclusion from licensed houses of persons of improper character." By-laws dealing with these matters are found useful in securing the sanitary condition of seamen's lodging-houses, and in protecting seamen against imposition. They have been made and enforced in a few seaport towns, and were brought into operation in London in 1901 at the instance of the London County Council.

VIII. **Cemeteries.**—Section 2 of the Public Health (Interments) Act extended to cemeteries, the provisions of the Act of 1875 relating to mortuaries, and hence made applicable to the former the powers given under Section 141 with respect to the latter. A model series of by-laws has been issued, which follows, in the main, the lines of the Home Office Regulations already referred to (*See* p. 558). The Board issued, in 1888, an important Memorandum on the sanitary requirements of cemeteries, reference to which has also already been made (*See* p. 560).

IX. **Mortuaries.**—Section 141 of the Act of 1875 enables by-laws to be made as to mortuaries. The model series which has been issued by the Local Government Board contains a by-law dealing with the period within which bodies shall be removed from the mortuary (it is usual to specify five days from the date of death in non-infectious and three days in infectious cases); there are also by-laws for preventing misbehaviour of persons "viewing," or depositing, or removing bodies, and there is one requiring undertakers to convey empty shells from the premises without delay.

In a *Memorandum as to the Site and Structure and the Administrative Arrangements of Mortuaries* dated 25th July, 1882, the Local Government Board offer the following suggestions:—Care should be taken to make the buildings, as far as practicable, "isolated and unobtrusive"; they should be substantially constructed, and "in their external appearance attention should be paid to such architectural features as may serve to carry the impression of due respect for the dead." The chamber intended for the reception of corpses should be on the ground or basement floor; there should be provided a waiting-room, a caretaker's dwelling-house, and a shed or out-house for the keeping of shells, etc. A plan showing a mode of arranging the premises is appended to the Memorandum. It is, moreover, pointed out that the mortuary chamber should be constructed so as to ensure "convenience, decency, cleanliness, and coolness." It should be lofty, with adequate floor space, and should have a ceiling, or, if open to the roof, there should be a double roof. Louvres, or air-gratings, under the eaves should be provided; the chamber should be lighted, if practicable from the north side; the floor should be paved evenly and closely, a uniform cement floor being preferable; water should be laid on and shelves and tables (preferably made of slate slabs) provided; the ceiling and internal walls should be whitewashed and the outside of the roof whitened; the entrance to the chamber should be direct, without the intervention of any passage. There should be two chambers at least, an "infectious" and a "non-infectious" chamber, and these should be placed as far apart as may be practicable.

Section 143 of the Act of 1875 empowers a local authority to provide a post-mortem room otherwise than at a workhouse or a mortuary. The introduction of this limitation was no doubt suggested by the consideration that the provision of a post-mortem room in connection with a mortuary might tend to discourage the use of the latter by poor persons. The Public Health (London) Act, 1891, permits the construction of a post-mortem room in connection with a mortuary, and such an arrangement is obviously a convenient one. Under Section 143 of the Act of 1875 regulations (which do not require to be confirmed) may be made as to the management of the post-mortem room.

X. **Offensive Trades.**—Model by-laws have been issued by the Local Government Board relating to certain trades. The questions needing consideration in this connection have already been referred to (*See* p. 75).

XI. **Tent and Van Dwellings; Housing of Hop-Pickers, Fruit-Pickers, etc.**—Section 9 of the Housing of the Working Classes Act of 1885 provides that "a Sanitary Authority may make by-laws for promoting cleanliness in, and the habitable condition of, tents, vans, sheds, and similar structures used for human habitation, and for preventing the spread of infectious disease by persons inhabiting the same, and generally for the prevention of nuisances in connection with the same." Tents, etc., used by military and naval forces are exempted from the operation of such by-laws.

The model series deals with the cleansing and ventilation of vans, etc.; provides that such structures shall be reasonably weather-proof, that the flooring or other covering of the ground shall be dry, that sufficient receptacles shall be provided for the storage of water, and that a sufficient supply of wholesome water shall be made available. It also provides for notification of infectious disease among inmates of vans, tents, sheds, etc.; it requires that any reasonable precautions ordered by the medical officer of health shall be complied with; it deals with the isolation of an infected person; and it provides for the medical officer of health exercising control over the movements of an infected van or tent, and for its cleansing and disinfection. The series also includes by-laws as to the disposal of refuse and filth; and for the protection of wells, springs, streams, etc., against pollution.

Section 314 of the Act of 1875 empowers the local authority to make by-laws "for securing the decent lodging and accommodation of persons engaged in hop-picking within the district of such authority," and Section 2 of the Public Health (Fruit-Pickers' Lodgings) Act, 1882, extends the operation of the above-named section to pickers of fruit and vegetables. The model series dealing with these matters follows, broadly speaking, the series relating to tents and vans. It may be noted, however, that it requires "sixteen square feet at the least of available floor space in respect of each adult person"; it makes provision for adequate privacy when adult persons of different sexes are accommodated; it contains requirements as to cooking places—a cooking-house is to be provided for every fifteen persons—and it makes reference to the need of furnishing a sufficient supply of clean, dry straw, or other clean, dry, and suitable bedding.

XII. **Public Slaughter-Houses.**—Section 169 of the Act of 1875 empowers an urban authority to make by-laws for the management, and charges for the use, of any slaughter-houses provided by them. No model series has been issued by the Board under this heading.

XIII. **By-laws under the Public Health Acts Amendment Act, 1890.**—Under Section 23 of this Act Section 157 of the Act of 1875 is extended so as to empower urban authorities to make by-laws with respect to—

The keeping of water-closets supplied with sufficient water for flushing;

The structure of floors, hearths and staircases, and the height of rooms intended to be used for human habitation;

The paving of yards and open spaces in connection with dwelling-houses; and

The provision, in connection with the laying out of new streets, of secondary means of access, where necessary, for the purpose of the removal of house refuse and other matters.

Further, by-laws under Section 157, as thus extended (with regard to drainage, water-closets, etc., and the flushing of water-closets), may be made to affect old buildings, and the provisions of the section, as amended (so far as they relate to the structure of walls and foundations of new buildings for purposes of health; to sufficiency of air space about buildings, and to the ventilation of buildings; to drainage, water-closets, etc., and the closing of buildings unfit for human habitation; to the structure of floors, the height of rooms, and the keeping of water-closets supplied with sufficient water for flushing) are extended so as to empower rural authorities to make by-laws in respect to the said matters. Moreover, by-laws may be made preventing buildings "erected in accordance with by-laws under the Public Health Acts, from being altered in such a way that if at first so constructed they would have contravened the by-laws."

Again, under Section 26 of the Act of 1890, an urban authority may make by-laws—

"(*a*) For prescribing the times for the removal or carriage through the streets of any fæcal or offensive or noxious matter or liquid, whether such matter shall be in course of removal or carriage from within or without or through the district.

(*b*) For providing that the vessel, receptacle, cart, or carriage used therefor shall be properly constructed, and covered so as to prevent the escape of any such matter or liquid.

(*c*) For compelling the cleansing of any place whereon such matter or liquid shall have been dropped or spilt in such removal or carriage."

No "models" have been issued, but by-laws relating to these subject-matters are in force in various places, and similar by-laws have been made under the Public Health (London) Act, 1891. The principle of insisting on the performance of scavenging operations during the hours of the early morning has usually been accepted (*See* p. 227); it may be further noted that stable manure has commonly been exempted from the operation of the by-laws.

Section 26 (2) of the Act of 1890 provides that, where the local authority themselves undertake or contract for the removal of house refuse, they may make by-laws imposing duties on the occupier so as to facilitate the work. Here, again, no model series has been issued, but by-laws have been confirmed requiring occupiers at specified times to deposit, in a place prescribed, movable receptacles of a capacity not exceeding (say) six cubic feet, containing the house refuse which may have accumulated.

Finally, the Act of 1890, Section 20, authorises the making of regulations concerning the management and use of public sanitary conveniences. Such regulations usually deal with questions of decent conduct, the payment of fees, writing or fixing bills, etc., on walls, damage to fittings, the duties of attendants, cleansing operations, and the like.

Dairies, Cowsheds, and Milk Shops Orders.—Section 34 of the Contagious Diseases (Animals) Act, 1878, empowered the Privy Council to make Orders for the registration of cowkeepers, dairymen, and purveyors of milk; for the inspection of cattle in dairies; for the lighting, ventilation, cleansing, drainage, and water supply of dairies and cowsheds; for securing the cleanliness of milk-stores, milk shops, and milk vessels; for prescribing precautions to be taken for protecting milk against infection or contamination; and for authorising a local authority to make regulations for the purposes aforesaid, or any of them. Section 9 of the amending Act of 1886 transferred the powers above specified from the Privy Council and the local authorities under the Contagious Diseases (Animals) Act, 1878, to the Local Government Board and the several urban and rural Sanitary Authorities. The Orders in force at the present time are that made by the Privy Council in 1885, in substitution for an earlier Order made in 1879, the amending Order, issued in 1886 by the Local Government Board, and the amending Order of 1899.

The main provisions relating to the matters in question are contained in the Order of 1885; the Order of 1886 is concerned with the above-mentioned substitution of authorities and contains a penalty clause. Under the 1885 Order it is declared unlawful to carry on the trade of a cowkeeper, dairyman, or purveyor of milk without previous registration, and the local authority is required to keep a register, and to give notice by advertisement that registration must be effected, etc.; a person who sells milk of his own cows in small quantities, to his workmen or neighbours for their accommodation, is not required to be registered. The Order assigns to the local authority powers of control as regards the lighting, the ventilation including air space, and the cleansing, drainage, and water supply of new dairies and cowsheds, and requires that one month's notice shall be given of the intention to occupy a new building as a dairy or cowshed. It also assigns more limited powers in regard to buildings already occupied as dairies or cowsheds. It prohibits any person suffering from dangerous infectious disease, or having been in contact with a person so suffering, from milking cows or assisting in the conduct of a milk business. The Order further deals with the question of possible contamination from communication of water-closets, etc., with milk stores and milk shops; with the use of the places last named as sleeping apartments; and with the keeping of swine in cowsheds or places used for keeping milk for sale. It authorises the making of regulations, and it prohibits the milk of a diseased cow being mixed with other milk sold or used for human food, or sold or used as food for animals, until it has been boiled.

The Report of the Royal Commission on Tuberculosis, 1898, draws attention to the need of requiring a proper amount of cubic space in cowsheds. The Commissioners suggested, however, that a distinction should be made between cowsheds situated in populous and those situated in non-populous places; they further pointed out that the term "disease," in the Order of 1885, was limited to diseases included under the Contagious Diseases (Animals) Act of 1878, of which tuberculosis is not one, and they recommended that the Order "should be made applicable to all diseases of the udder in cows of which the milk is offered for sale."

The Local Government Board issued an amending Order in 1899, extending the definition of disease so as to include "such disease of the udder as shall be certified by a veterinary surgeon to be tubercular," and the Board, in a circular letter to borough and urban and rural district councils, dated March, 1899, express the opinion that "it will be competent for the council to employ and pay a veterinary surgeon with a view to obtaining a certificate under the article as amended, or to appoint him as an officer for this purpose, if they think fit to do so." (*See also* p. 208.)

Manchester, in 1899, and numerous towns since that date, have obtained powers in private Bills relating to tuberculous milk. The "Manchester Milk Clauses" provide that the milk of a cow known to be suffering from tuberculosis of the udder must not be used for human food; they give power to inspect and to take samples of milk within the city, and outside it, on production of the order of a justice having jurisdiction in the place in which the farm is situated, and they impose on dairymen supplying milk within the city the duty of notifying cases of tubercular disease of the udder to the medical officer of health.

The *Model Regulations* issued in 1899 by the Local Government Board deal with the inspection of cattle in dairies, and with the lighting, ventilation, cleansing, drainage, and water supply of cowsheds and dairies. Distinction is made, as regards overcrowding, between cowsheds the cows from which are habitually grazed on grass land during the greater part of the year, and when not so grazed are habitually turned out during a portion of each day, and other cowsheds. As regards the latter, and for them only, it is prescribed that 800 feet of air space for each cow shall be provided, and that no space shall be reckoned which is more than 16 feet above the floor; if "the roof or ceiling is inclined, then the mean height of the same above the floor may be taken as the height thereof" for the purposes of the regulation. Further, the requirement is not to apply to old cowsheds until two years after the date when the regulations come into force.

There are, moreover, in the model series, regulations concerning cleanliness of milk stores, milk shops, and milk vessels, and there is, further, one requiring reasonable and proper precautions to be taken by purveyors of milk and persons selling milk by retail in connection with the storage and distribution of milk. This last-named regulation specifically prohibits milk intended for sale being deposited or kept—"(*a*) in any room or place where it would be liable to become infected or contaminated by impure air, or by any offensive, noxious, or deleterious gas or substance, or by any noxious or injurious emanation, exhalation, or effluvium; or (*b*) in any room used as a kitchen or living-room; or (*c*) in any room or building or part of a building communicating directly by door, window or otherwise with any room used as a sleeping-room, or in which there may be any person suffering from any infectious or contagious disease, or which may have been used by any person suffering from any such disease and may not have been properly disinfected; or (*d*) in any room or building or part of a building in which there may be any direct inlet to any drain." Milk must not be kept in any vessel which is not thoroughly clean and vessels must be cleansed with steam or clean boiling water after use. Finally, it is provided that no cow shall be milked for the purpose of obtaining milk for sale

"(*a*) unless at the time of milking the udder and teats of such cow are thoroughly clean; and

(*b*) unless the hands of the person milking such cow, also, are thoroughly clean and free from all infection and contamination."

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