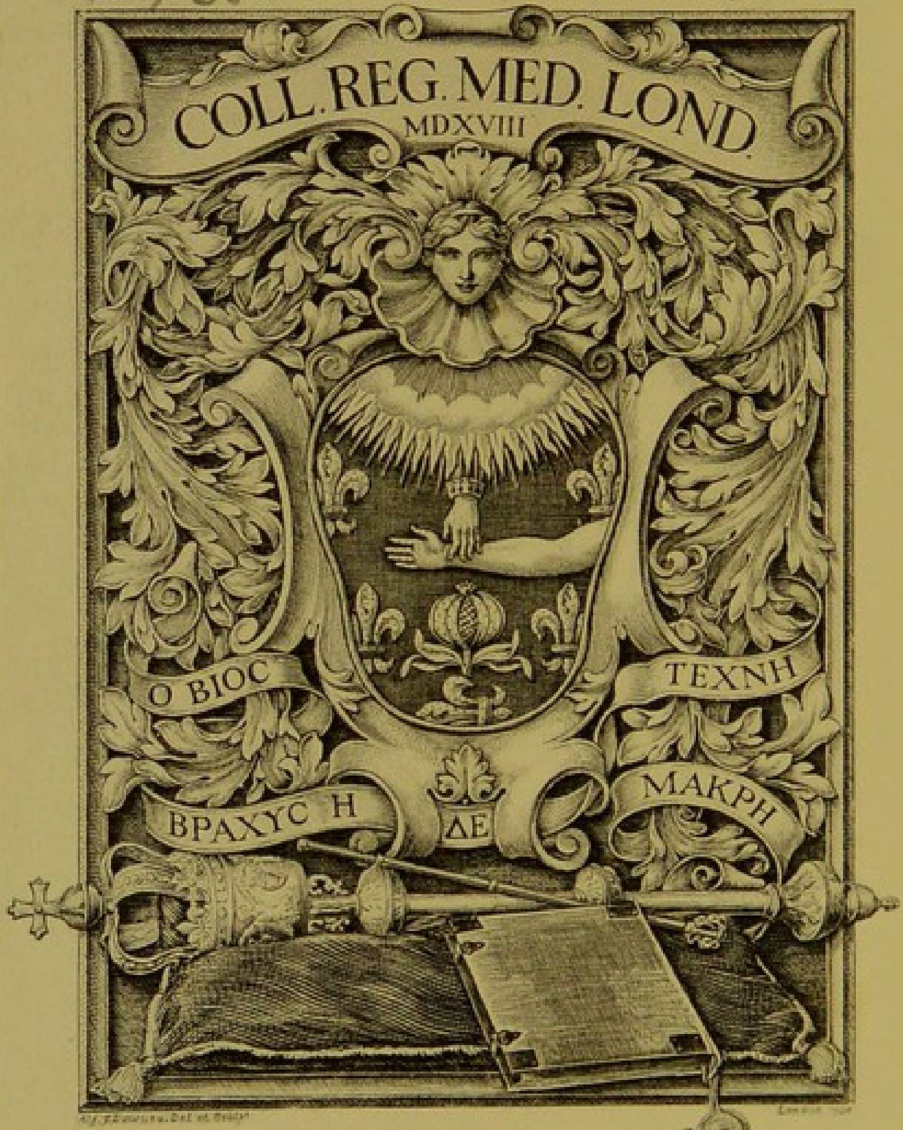
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The Milroy Lectures

ON

THE EARTH IN RELATION

TO

THE PRESERVATION AND DESTRUCTION OF CONTAGIA

DELIVERED AT

THE ROYAL COLLEGE OF PHYSICIANS OF LONDON
On February 23rd and 28th and March 2nd, 1899

BY

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The Milroy Lectures

ON

THE EARTH IN RELATION TO THE PRESERVATION AND DESTRUCTION OF CONTAGIA.

LECTURE I.[1]

EARTH.

MR. PRESIDENT AND GENTLEMEN,—That which we commonly speak of as "earth" is largely composed of excreta and the dead remains of animals and vegetables which, as the result of fresh biological processes, are either returned to the bodies of living vegetable organisms or, after becoming mineralised and soluble, are washed downwards by the rain and ultimately find an exit in the sea. It is obvious that not only does "earth" vary in composition with the varying conditions of subsoil, climate, flora and fauna, but that "earth" must undergo seasonal variations necessitated by the vigorous upgrowth in the spring or the decay of the fall—the heat and drought of summer or the flood and frost of winter. The interstices between the particles of "earth" are filled at one time with air, at another time with water, and the line of demarcation between earth and air on the one hand and earth and water on the other is often not very definite. Again, the dust which is suspended in the air and which settles on everything is liable to contain infective particles, harmless to breathe but dangerous if they fall upon a wound. It is obvious that such particles may be regarded as belonging to the earth or the air. Some of them doubtless emanate from the earth, having been raised as dust; but we must admit that there may be organisms which grow in the air, live in the air, and die in the air without ever touching earth or water and which elude all attempts at identification or

[1] Delivered on February 23rd, 1899.

artificial cultivation. While there are organisms which may live indifferently in air or water others are probably more exclusive in their obligatory conditions. The mutual interaction of earth, air, and water must never be lost sight of. It is the life in the earth, both vegetable and animal, which helps by its influence on vegetation to maintain the quality of the atmosphere. Again, it is the earth which gives the quality to spring and river water. Pure water is a body of definite chemical composition and pure air is a tolerably definite mixture of gases, and it is not difficult to approximately measure the degree of pollution of either. The chemical composition of earth, on the other hand, is complex and constantly changing and it is not possible for the chemist to fix any standard of quality. The practical agriculturist by the aid of touch, smell, and vision will say at once whether any given sample of earth is foul or pure, sour or sweet, rich or poor, fertile or sterile, and we must perforce content ourselves with the terms used by the practical man. The word "earth" in the ensuing lectures will usually be regarded as meaning humus in a healthy condition.

Pathogenic Saprophytes.

There are certain pathogenic organisms which are constantly found in the earth and which appear to be ubiquitous. They adhere to our skins and clothing, get under the nails, and lodge in the hair. They produce various diseases of wounds and wounded persons and we now recognise that in the absence of those precautions which we call "antiseptic" it is never safe to inflict even the smallest wound. The modern surgeon not only renders his hands and instruments aseptic but he operates in spotless garments and endeavours to have an operating-room as clean and free from dust as possible. The organisms which produce the various wound infections are saprophytes which flourish external to the body. They are ubiquitous and (probably) necessary and so long as we have a whole skin and uninjured mucous membrane they do us no harm. As all organic matter is constantly circulating, passing through death to other forms of life and necessarily undergoing humification as it does so, it follows that the agents of these changes, the microbes which are to this end hatched in the soil, vary with the circumstances. Houston[2] gives the estimated number of microbes per gramme found in 21 samples of soil. These vary from 8326 in a virgin sand and 475,282 in a virgin peat to 115,014,492 in the soil from the trench of a sewage farm. Broadly speaking, the microbes bear a proportion to the amount of dung. Warington estimated that a gramme of dung from a cow fed on hay contained 165,000,000. They all, presumably, have their optimum condi-

[2] Local Government Board Report, 1897-98.

tions—chemical and physical qualities of the nutritive medium, access of air or other gases, lightness or darkness and temperature—and when the optimum conditions concur growth and multiplication go forward at a pace which we can hardly appreciate. The fact that for the growth of some the access of air is necessary while others obtain their oxygen from the medium in which they grow and others again are able to take in oxygen from either source has formed the basis of a classification which has assisted our understanding. Saprophytes, including those which produce wound infection, are presumably of service in bringing about the decomposition of complex organic bodies. Whether we are able to check the growth and multiplication of these facultative parasites outside the body is doubtful and whether or no we should be gainers or losers by so doing is still more doubtful. Bacteriologists have experienced no little difficulty in discovering the exact conditions which are necessary for the growth and development of many of the micro-organisms which have been studied. Some are more exacting than others and those which are best able to accommodate themselves to varying circumstances naturally obtain the mastery when several are attempting to grow simultaneously in the same medium. Some of the larger saprophytes, such, for instance, as the common mushroom, require no little skill for their artificial production. Their cultivation requires far more attention to exact details than is necessary with ordinary green-leaved garden plants. We know that for a few weeks in the autumn they may appear in great numbers in dry pastures where horses have been fed, provided the conditions of the air as to temperature, light, and moisture be favourable, and we also know that directly the necessary conditions fail the mushroom harvest is at an end. We also know how strange is the predilection of certain fungi for the dung of particular animals and I would allude to a list furnished to me by Mr. George Murray, F.R.S., which shows that the optimum conditions for the growth and development of these short-lived and delicate organisms must be marvellously subtle and probably quite beyond the ken of the chemist.

I will now proceed to deal seriatim with some of the contagia which are best understood and will begin with

Tetanus.

Among the ubiquitous organisms which are habitually found in earth is the bacillus of tetanus. It is said to be present in almost all rich garden soils and that the presence of horse-dung favours its occurrence. It is strictly anaerobic and has been artificially cultivated by Kitasato in an atmosphere of hydrogen. It forms spores and grows best at a blood heat. Marchesi has found it at a depth of two metres but no lower. The pure cultivation of the bacillus which has a disagreeable aromatic odour is often not very virulent. It is fatal to animals as well as man and among animals the horse appears to be most liable to be attacked. Infection always takes place by inoculation through the wounded skin or mucous membrane—never, it is believed, through the healthy alimentary or respiratory tracts. Cases of "idiopathic" tetanus are reported, but it has fallen to the lot of few of us to see a case and professional opinion seems to lean to the idea that in such cases the inoculating wound has been overlooked. The toxin which the bacillus brews locally in the wound is toxic to the central nervous system and the antitoxin to be effectual must, it is said, be injected subdurally into the central nervous system. The exhaustion of the nervous system seems to increase its vulnerability which is, perhaps, the reason why tetanus has been relatively common in the domain of military surgery. There seems to be no doubt as to the ubiquity of the tetanus germ. Every child who falls on the ground and gets an abrasion of the skin, all tillers of the soil who get accidental wounds in the course of duty, and every horse which "breaks its knees" by falling in the London streets, runs, potentially, a risk of inoculation with tetanus. In the face of the ubiquity of the cause the rarity of the disease is remarkable. I have made inquiry of many practitioners in the Thames valley where market gardening is the chief industry and where countless tons of London horsedung are spread upon the land and learn from them that tetanus is in their experience the rarest of diseases. Seeing that the bacillus is so strictly anaerobic one is justified in supposing that the tillage of the soil which brings it in contact with air and sunshine must be unfavourable for its growth and virulence. The bacilli must die out under such conditions and the inoculation of the spores alone is said by Vailliard, Rouget, and Vincent to be incapable of setting up tetanus. If the bacillus or the spore be carried in dust, or if they be washed into the water and drunk we have no evidence that any harm results therefrom. In common with some other microbial diseases tetanus is more virulent in the tropics than in temperate climates. Friedberger and Frohner state that it is so common among horses in St. Domingo, especially after the operation of castration, that geldings are worth twice as much as stallions.

The statement made by Ledantec and H. M. Stanley that the natives of the New Hebrides and Central Africa are in the habit of poisoning their arrows by smearing them with mud (obtained in the New Hebrides from a mangrove swamp) gives emphasis to the importance of a tropical temperature and the absence of tillage as factors which make for increase of virulence of the tetanus bacillus and other organisms found in earth. Pus from the wound of an animal suffering from tetanus is capable of conveying the disease and perhaps it is due to this fact that certain stables and pastures have at times acquired an evil reputation in respect of tetanus. Captain Hayes, F.R.C.V.S., is of opinion that wounds in the hoof as the result of careless shoeing are a great cause of what may look like idiopathic tetanus in horses. In an article by Mr. Sidney Villar in the *Journal of Comparative Pathology and Therapeutics* for December, 1897, an observation by Mr. Joseph Woodger is quoted to the effect that tetanus is particularly common among horses used in dust-carts and Mr. Villar continues: "In my own practice in Middlesex there are two farms where the disease is specially prevalent. One of these at Alfreton is occupied by a farmer who habitually spreads on his fields large quantities of London refuse; at the second farm, five miles away, the bailiff brought two large loads of the sweepings of London roads in 1893 and dressed his home meadows with it. On these meadows his colts and young stock were pastured and for two and a half years tetanus was endemic on his farm; during this period six colts became affected and I believe only one entirely escaped the disease."

This experience of Mr. Villar seems to point to the danger of placing upon grazing land material which is probably mixed with broken glass or crockery. On clay lands such as are common in the north of London manurial matters placed on a pasture would be long in getting incorporated with the soil, and to allow horses to browse amongst the crude impurities of a great city cannot be without danger to the horses. Municipal authorities who wish to find a ready market for street refuse must clearly take care that it is not mixed with dangerous materials of no manurial value likely to wound the feet of animals. In connexion with Marchesi's observation that the tetanus organism has not been found at a greater depth than two metres I would allude to a fact to which I shall return later that this approaches the maximum depth to which the earthworm burrows. It is obvious that if a spore were carried downwards by a worm it would there meet with anaerobic conditions favourable for its preservation. A review of the main facts connected with tetanus cannot but rouse in us some surprise that in face of the ubiquity of the cause the disease in man should be so rare. This is probably in part due to the fact that we wear boots.

ANTHRAX.

Anthrax is a disease which undoubtedly is connected with the soil. The bacillus was discovered by Pollender in 1849, a discovery which is just 50 years old and which marks the dawn of pathological bacteriology. The identification of the bacillus in the laboratory and the diagnosis of the disease in animals from quarter-evil and septicæmia is not without difficulty. These difficulties are now understood but they are sufficient to throw a shade of doubt over some of the earlier observations. It may be well in the first place to give some of the facts collected by Pasteur without comment.

M. Chamberland, the able assistant of M. Pasteur, in his work[3] gives a *résumé* of what one may call the modern history of charbon. In 1842 a Government report showed that in France the disease raged among the flocks of half-bred merino sheep belonging to farmers in La Beauce. It especially attacked lambs and the losses in this district of La Beauce

[3] Le Charbon, Paris, 1883.

amounted to as much as 20 per cent. (out of a total of some 1,300,000 sheep) "et souvent dans les localités dont le sol est sec et calcaire la mortalité va jusqu'au quart, au tiers et dépasse parfois la moitié du troupeau." In the department of Seine-et-Marne and in the districts of Provins, Fontainebleau, and Meaux are certain farms known as *fermes à charbon*—"les meilleurs cultivateurs ne les louent qu'en tremblant." Also in Le Cantal charbon is known as "mal de montagnes" and certain hills are known as "montagnes maudites" because of their evil reputation in relation to charbon. The animals stricken with charbon show for a few days some excitability and passing dyspnœa and they become distended after feeding. Next the urine becomes bloody and it is a sign of bad omen to see fleeces spotted with blood. The dung also is noticed to be soft and slimy, of a whitish colour stained with blood. They die at last somewhat suddenly and in doing so usually void some blood-stained dung and urine and expel bloody froth from the nostrils. Post mortem decomposition is rapid and the animal swells up and blood is expelled from the nostrils. Hæmorrhages are found in the skin and cellular tissue, as also in the viscera which are engorged with blood.

The discovery of bacilli anthracis in the blood clinches the diagnosis. It was in 1850 that Rayer and Davaine described the bacilli and in 1877 Pasteur communicated to the Academy of Sciences the important fact of sporulation observed in these bacilli by Koch and himself, and further pointed out that the bacillus anthracis was essentially aerobic and was quickly destroyed in the blood of the dead animal after the onset of putrefaction. It is important to take notice of the extent to which the ground is soiled by the dung, discharges, urine, and bloody wool of an animal ill with anthrax.

In August, 1878, M. Pasteur fed sheep on lucerne previously watered with a pure cultivation of bacillus anthracis. He says that "in spite of the immense number of spores taken in with the food many of the sheep escaped death. ...... The communication of the disease in this way is still more difficult in the case of guinea-pigs." "Nous n'en avons pas obtenu d'exemple dans d'assez nombreuses expériences. Les spores, dans ce cas, se retrouvent dans les excréments. On les retrouve également intactes dans les excréments des moutons." The mortality is much increased when the infected food is mixed with prickly material such as the leaves of thistles and the chopped beards or husks of barley, and the post-mortem examination of sheep rendered "charbonneuses" by fodder of this kind gave reason to suspect that they were in fact really "inoculated" by definite injury by the prickly food to the back of the throat. Of 19 sheep fed on lucerne polluted with spores three died after four, seven, and nine days; of 11 sheep fed on polluted lucerne and thistles three died after three, four, and six days.

It is recognised by professional "knackers" that they run little risk of contracting "charbon" by manipulating dead animals far advanced in putrefaction and both Pasteur and Koch have shown that putrefaction soon destroys the bacilli in the blood and tissues of an animal and that the bacillus anthracis being aerobic sporulation does not take place inside the putrefying body, but is very liable to occur in the blood which escapes from it whether the blood flow upon the earth or upon a dung-heap.

In August, 1878, Pasteur made a necropsy on the body of a sheep then buried the carcass in M. Maunoury's garden. 10 months and 1 months afterwards Pasteur found spores of anthrax in the earth of this animal's grave and established the fact by the inoculation of guinea-pigs. The spores were found in the surface soil over the grave, although since the burial the ground had not been moved. Similarly spores were found in the soil over the grave of a cow buried two years previously and at a depth of two metres. These spores were found over the graves of dead animals after all the operations of cultivation and harvest. Earth taken at a distance from these graves did not give charbon.

In announcing these facts to the Academy of Sciences in July, 1880, Pasteur says: "I shall not be surprised if doubts arise in the minds of the Academy as to the correctness of these facts. It will be asked, 'Does the earth, which is so potent as a filter, allow these microscopic spores to rise to the surface?' These doubts seem to be supported by facts already published by M. Joubert and myself. We have announced that water from even superficial springs is sterile. ...... These, in spite of conditions above which make for pollution, keep perfectly pure, which shows that a certain thickness of earth arrests all solid particles." Pasteur attributes the uprising of spores to the action of earthworms and he claims to have actually recovered spores from the bodies of earthworms living in soil polluted with anthrax.

"May not 'earthworms,'" asks Pasteur, "bring other noxious germs to the surface? They are always filled with a mixture and the spores of charbon are in them mingled with germs of putrefaction and septicæmia." Pasteur at this time regarded the earthworm as the great cause of the dissemination of anthrax. In a footnote Pasteur calls attention to the fact that in Le Cantal there are pastures which from time immemorial have escaped (*sont épargnés*) and others in which from time to time the cattle were decimated and which are known as "*montagnes dangereuses*" which are abandoned without deriving the least profit from them, "at least during several years," says M. Baillet.[4] "This last circumstance deserves great attention. It proves that the cause, whatever it may be, which produces charbon in a locality disappears with time." In Beauce Pasteur saw certain fields in which the folding of sheep had been interdicted for several years—i.e., since the last death thereupon from charbon. "Now we placed flocks of sheep on five of these fields and the mortality was *nil* except in one flock where it amounted to 1 per cent."

M. Colin of Alfort, a professor at the Veterinary School, not being satisfied with some of Pasteur's experiments, a further report was made on May 17th, 1881, by a commission composed of M. Bouley, M. Darvaine, M. Alphonse Guerin, and M. Villemin. Earth from a 12-year grave, a three-year grave, and from virgin soil was kept at a temperature of 90° C. for 15 minutes and the fine sediment was injected into guinea-pigs. Of five guinea-pigs inoculated with 12-year

[4] Mémoires du Ministère de l'Agriculture, 1870.

earth on March 19th four died on March 21st and 22nd from septicæmia and one died on March 23rd from charbon. Of five guinea-pigs inoculated with three-year earth on March 19th, four died from March 21st to 23rd from septicæmia and one died on March 23rd from charbon. Of five guinea-pigs inoculated with virgin soil on March 19th none died. One had a small abscess at the seat of puncture. Of six guinea-pigs inoculated with 12-year and three-year earth on March 30th five died from septicæmia on April 3rd and one died from charbon (12-year earth) on April 3rd. Of three guinea-pigs inoculated with excreta taken from the bodies of living earth-worms two died from septicæmia and one from charbon on March 30th. Of the 19 animals killed by the above experiments 15 died from septicæmia and four from charbon.

Since 1879 M. Pasteur had asserted that most soils when inoculated were capable of causing death from septicæmia quite apart from any contamination by the death of anthrax animals. Of three guinea-pigs inoculated on March 28th with worm castings taken from above the graves of some of the victims of the commune situated on waste land one died from septicæmia on April 1st and two were unharmed.

Pasteur had clearly demonstrated that the anthrax bacillus is essentially aerobic, that it is soon destroyed by putrefaction, and that for sporulation free exposure to air and a temperature above 15° C. and under 45° C. are necessary. These facts seem out of harmony with the view that earthworms bring spores from a deeply buried carcass to the surface.

The following case is quoted by Pasteur.[5] On August 21st, 1796, a mare fell dead from anthrax on a causeway (digue) at Houë (Eure-et-Loir). The animal was skinned and the carcass was dragged by two horses all along this causeway (along which farm animals passed to and fro), with the result that the ground was soiled by the blood and other débris of the dead animal. A large number of the sheep and cows which used this soiled path died. These animals were skinned and buried with the result that the foci of contamination spread and ultimately 500 or 600 sheep succumbed to anthrax. The skinning and transportation of an animal dead from anthrax must necessarily be a most dangerous process.

All are agreed that anthrax is a disease liable to haunt localities. Thus, in the report of the Board of Agriculture for 1895 I find the following :—

An undoubted fact in connexion with anthrax is its tendency to recur on certain farms. An examination of the agricultural returns received shows that during 1895 the disease reappeared on 23 farms or other premises in England and six in Scotland where it had been reported in the previous year. From this cause farms come to be regarded as dangerous and their value is very greatly depreciated. In a report issued by the German Government[6] allusion is made to the farm of Parkisch where anthrax was rife. "Numerous outbreaks of the

[5] Annales de l'Agriculture, 1ère Série, tome xxx., p. 332.

[6] Report of the British Board of Agriculture, 1894.

disease were especially remarked when certain portions of the farm were used as pasture and when fodder from these portions was used in the stalls. The former tenant of the farm is said to have buried on different parts of the farm carcasses of animals which had died of anthrax and also to have put the carcasses into the dung-heap to use them as manure."

Again, "Dlouie is a large estate in Kroloen, district Posen, and is known as a hot-bed of anthrax. ...... It is stated that carcasses of animals which have died from anthrax have been buried with great carelessness on different parts of the fields, especially behind the sheep sheds and in a small wood situated some 100 paces from the farm, which also serves for pasturage, and even in the dung-heaps, which together with the straw from under the diseased animals were used for manure."

It is alleged by Friedberger and Frohner that the spores may vegetate in the soil and surface water quite independently of the animal body. The disease is said to occur among horses, cattle, and buffaloes in Eastern Bengal, Manipur, and Burma without the agency of infection and to be in that part of the world a truly miasmatic disease. As spore formation requires something like a blood heat, it is only what might be expected to find the disease becoming endemic among cattle and horses in tropical countries. Where infected animals drop dung and other discharges on the soil it becomes impossible to say whether the infective spore originates in the soil or in the animal. The distinction which separates soil from dung is somewhat subtle. These authors assert that "there exists a well-marked connexion between the disease and the amount of moisture in the soil. It appears most frequently in lowlands and plains exposed to inundations and great heat." Copeman also asserts that the disease is prevalent on damp soils containing much humus, as, for instance, upon peat bogs and near the borders of lakes and rivers which have overflowed. On the other hand, we have Pasteur speaking of *montagnes maudites* in connexion with anthrax and asserting that the mortality is great in soils which are *secs et calcaires*.

Many of the outbreaks of anthrax in this country have been in the neighbourhood of Bradford and have been traced to the use of infected wool-refuse as manure. A map published by the Board of Agriculture shows that the outbreaks of anthrax are most frequent in those counties of Great Britain where dry foreign wools, hairs, hides, and skins are manufactured into goods. In 1892 there were 42 outbreaks of anthrax in the West Riding of Yorkshire, as against two in the North Riding and one in the East Riding. Wool when used as a manure must take a long time in becoming disintegrated and humified. In this respect it is very different from dung and if wool be infected with anthrax spores it must be a very dangerous manure for a pasture. The chief sources of danger are said by Dr. Bell of Bradford to be the dry wools of goats, alpacas, and llamas which are imported very dry from hot countries. It is the anthrax spore which is the danger and if, as is the case, a high temperature and free admission of air be necessary for sporulations an excess of water would be unfavourable for that process. There seems a concurrence of opinion that the bacillus anthracis is killed by putrefaction and soon disappears in the unopened and unskinned body. Schmidt-Mühlheim inoculated guinea-pigs with anthrax and as soon as they were dead he skinned them and placed the limbs in an incubator at 39° C. The surface of the flesh was soon covered with a whitish film which was found to consist exclusively of anthrax bacilli, in many of which commencing spore formation was apparent. There can be little doubt that the soil becomes infected by the discharges from the living animal and the skinning and other manipulations of the dead one. The advice which is usually given in this country to bury anthrax carcasses deeply and unopened and unskinned is doubtless sound, although it is doubtful if the depth of the grave adds materially to the anaerobism of the surroundings. It is very doubtful if in an unopened body spore formation be possible after a short period of burial. It is clear that the animal should be buried at the spot where it dies and that the spot should be enclosed and planted with a few saplings of some indigenous tree. The value of "quicklime" is doubtful. Whether it be advisable to delay burial until quicklime can be obtained is still more doubtful.

All Pasteur's experiments in relation to graves appear to me to be vitiated by the fact that they took place in an anthrax district and it is very difficult to say whether the spores were derived from the buried animal or from the dung of infected ones which had been used as manure, or from the blood-stained wool which, we are told, is of "bad omen" in a flock. It is a noteworthy fact that of the 19 guinea-pigs inoculated by the Alfort Commission four only died from anthrax and 15 from septicæmia, and that the earth from the three-year-old grave and from the 12-year-old grave conveyed anthrax in the same proportion—i.e., one in four inoculations. There seems no doubt that spores may be found in earthworms or their castings and there is equally no doubt that if the worms have brought the spores from the depths of the earth such spores must have originally been formed on the surface. It is, of course, quite impossible to say whether a worm swallowed the spore on the surface or below it. It is certain that recently dead bodies have no attractions for worms. Such carrion usually forms the food of maggots hatched from the eggs of diptera deposited before burial and of beetles which live in the earth and are soon attracted to it.

There are some discrepancies amongst observers as to the infectivity of food grown on anthrax ground. On the one hand, Pasteur was unable to do much harm to sheep fed on lucerne sprinkled with spores and, on the other hand, we have a story quoted by Pasteur of an old woman whose goat and cow died from anthrax when fed with clover stolen from over a grave two years after the burial of an anthrax animal. It is, of course, impossible to get away from the *post hoc* fallacy in these cases, especially in a country where animal hygiene was utterly neglected and where anthrax was, or diseases resembling it were, rife. In this country we have had no outbreaks of anthrax at all comparable to those which have proved such a scourge in France and other parts of the continent. The loss of sheep from anthrax in England is very slight and the explanation is probably to be found in the relative vulnerability and immunity of the flocks. Sheep in England are rarely housed but are allowed to breathe at all times the freshest of fresh air. Their pastures are changed before the ground gets foul and when food is short they are either killed at once or fed upon imported food. Such a condition of things would be likely to breed immunity to disease of all kinds; and it is noteworthy that tubercle is much less common among sheep than amongst animals which are housed. When flocks are kept partly for dairy purposes and when sheep are housed and breathe a foul air and lie upon filth mixed with earth it is no wonder that disease, especially such a disease as anthrax, is liable to be rife and to be difficult to eradicate.

Anthrax in the human subject is a rare disease. Man is never infected through the alimentary tract as appears to be the rule among animals. Dr. Bell of Bradford says that "no such case has been recorded in this country." Cutaneous anthrax (malignant pustule) is caused by direct inoculation. It occurs (1) in those who come into contact with infected animals alive or dead; (2) in those who handle offal, skins, hoofs, horns, hairs, wools or other derivatives from such diseased animals; and (3) in countries where the disease is common among animals women and children who do not come into direct connexion with infective material are not infrequently attacked with the disease through the medium of persons, animals, or insects.

Pulmonary anthrax or wool-sorter's disease was first noticed in the Bradford worsted district after the introduction of alpaca and mohair as textile materials in 1837. "This form of anthrax may attack any person exposed to the inhalation of anthrax spores in *dust* arising from the products of diseased animals." The fact appears to be undoubted that anthrax may be a dust disease and that the spores when perfectly dry may be inhaled into the lungs. And yet I have hitherto found no records of pulmonary anthrax from the inhalation of dust from highly manured ground which must, one would suppose, especially in the West Riding of Yorkshire, often contain anthrax spores. The lungs of the agricultural labourer and the market gardener appear to be immune to the infectivity of anthrax spores. It seems to be of very great importance to bear in mind: (1) that anthrax spores persist even in the finely pulverised soil of worm castings, which must be very easily dried and converted into dust; (2) that anthrax may undoubtedly infect man by the inhalation of dust; and (3) that pulmonary anthrax among agriculturists has not been recorded. In India it is believed by some that dust is a common cause of enteric fever among Europeans, a statement which is insusceptible of proof or of disproof. Does pulmonary anthrax occur among the rural population of the tropical countries where the disease is endemic amongst cattle? In this connexion we must bear in mind that anthrax bacilli may change their virulence without undergoing any morphological changes and in this form when inoculated may confer immunity on susceptible animals without apparently producing other effects. The virulence is diminished by cultivation at high (from 108° to 120° F.) or low (from 66° to 75°) temperatures, by cultivation under pressure of three or four atmospheres, by exposure to sunlight, or by admixture with other bacteria. The modified organisms thus produced are not pathogenetic but confer immunity on susceptible animals for nine or 12 months. Morphologically they are indistinguishable from the most active and virulent forms of the organism and they will generally regain their virulence when favourable conditions are restored although the degree of virulence varies in different species of animals. The persistence of the anthrax spore in the earth does not admit of a doubt but there is no evidence that man is ever infected directly from the earth. How far anthrax in animals is due to inoculation rather than to feeding requires further and very careful investigation.

Diarrhœa.

Diarrhœa is a disease which in its epidemic form has been supposed to be engendered in the earth.

The third quarter of the year 1898[7] was characterised by a very large infantile mortality, mainly attributable to diarrhœa. The rainfall for the quarter was unprecedentedly small, the temperature was above the average, and the harvest was one of the best on record.

Of the 141,540 deaths registered 52,837 were those of infants under one year of age. The mortality of infants, measured by the proportion of deaths under one year of age to registered births, was 225 per 1000 which is the highest proportion in any quarter for which the figures are available and is 55 per 1000 above the average in the 10 preceding third quarters. In the 33 great towns as a whole infant mortality was equal to 275 per 1000 births, being higher than the proportion in England and Wales by 50 per 1000.

Excluding the towns infant mortality in the remainder of England and Wales was in the proportion of 184 to 1000 births. *Diarrhœa* caused 22,524 deaths, equal to an annual rate of 2·85 per 1000, or 1·21 above the average rate of mortality in the third quarters of the previous ten years.

The death-rate from this disease ranged from 0·7 in Rutlandshire, 0·58 in Hertfordshire, 0·66 in Shropshire, and 0·68 in Dorsetshire, to

[7] Quarterly Return of the Registrar-General.

3·63 in Leicestershire, 3·70 in Staffordshire, 3·94 in Lancashire, 4·23 in the East Riding of Yorkshire, and 4·40 in Warwickshire. Among the 33 great towns the diarrhœa rate averaged 3·85 per 1000, the highest rates being 5·85 in Hull, 5·94 in Sunderland, 6·30 in Sheffield, 6·38 in Wolverhampton, 6·41 in Preston, and 6·47 in Salford. In the 67 other large towns the rate averaged 3·27 per 1000. In the rest of England and Wales the diarrhœa death-rate was equal to 2·07 per 1000.

It will be observed that the mortality from diarrhœa was mainly urban. Among counties it is the rural counties which have least and the industrial counties which have most diarrhœa and if we turn to the mortality returns for those counties where diarrhœa was especially rife we shall find the mortality greatest in the urban districts. It is a point not without interest to note that the diarrhœa death-rate and the fever death-rate in this quarter bore no relation to each other and that, while the diarrhœal death-rate was 1·21 above the fever death-rate was 0·03 below the average for the corresponding quarter of the last 10 years. In the following table some figures are collected which show this very strikingly.

Table showing the Death-rates per 1000 from Fever and Diarrhœa during the Third Quarter of 1898.

—	Fever.	Diarrhœa.
England and Wales	0·16	2·85
London	0·11	3·19
Wolverhampton	0·18	6·38
Leicester	0·13	5·34
Manchester	0·09	5·38
Preston	0·28	6·41

Diarrhœa is a disease of hot weather. Ballard thought that when the four-feet temperature of the earth reaches 56° F. diarrhœa becomes common. Tomkins of Leicester (Leicester is a "diarrhœa town") shows that the disease becomes common when the one-foot thermometer stands at 60°. Snow of Buffalo, U.S.A., showed that in 1886–88 diarrhœa mortality was highest when the minimum atmospheric temperature attained its highest average range. The London statistics for 1887 and 1888 collected by Dawson Williams show a similar relationship between diarrhœa and a high average minimum range of temperature. Copeman considers it highly probable that the disease is due to "microphytic processes" going on in the upper layers of the soil. This would afford an explanation of the fact that summer diarrhœa is especially a disease of cities having a polluted soil. Ballard's conclusions (as given by Copeman) were: "That the essential cause of diarrhœa resides ordinarily in the superficial layers of the earth where it is intimately associated with the life processes of some micro-organism not yet detected, captured, or isolated. That the vital manifestations of such organism are dependent, among other things, perhaps principally upon conditions of season and on the presence of dead organic matter which is its pabulum. That on occasion such micro-organism, capable o getting abroad from its primary habitat, the earth, and having become air-borne, obtains opportunity for fastening on non-living organic material and of using such organic material both as nidus and pabulum in undergoing various phases of its life-history. That in food, inside of as well as outside of the human body such micro-organism finds, especially at certain seasons, nidus and pabulum convenient for its development, multiplication, or evolution. That from food, as also from the contained organic matter of particular soils, such micro-organisms can manufacture by the chemical changes wrought therein through certain of their life-processes a substance which is a virulent chemical poison (probably ptomaine). That this chemical substance is in the human body the material cause of epidemic diarrhœa."

It is most important to remember that these speculative notions of Ballard's are not facts.

The bacillus enteritidis sporogenes is believed by Klein to be the cause of infantile diarrhœa.[8] It is an anaerobic bacillus which forms spores and may be easily cultivated in milk. It is fatal to rodents when injected hypodermically and produces a foul-smelling bloody œdema of the cellular tissue and adjacent muscle tissue. The spores were found in four out of 10 cases of infantile diarrhœa examined and in six out of eight cases of cholera nostras. It was found in eight out of 10 samples of milk purchased in London milkshops between April and the end of June (when diarrhœa was not epidemic?) including samples of so-called "pure sterilised milk." It has been found in large quantities in sewage and in sewage effluents. It is found in horsedung and in all matters polluted with it. It has not been found in pigdung or cowdung or in the dung of a healthy human being.

In face of the wide distribution of the microbe it is evident that the vulnerability of the individual must be an important factor in determining an attack of diarrhœa. If we are to consider diarrhœa as a soil disease it is evident that it exists only in the upper layers. It is more common among city streets than in agricultural districts. According to Klein the probable cause is largely to be found in horse dung which is pulverised and blown about generally. Temperature, as we all know, is most potent as a cause of infantile diarrhœa in cities. That it is a "soil" disease in any true sense is certainly not proven.

Dysentery.

Andrew Davidson[9] says:—"In keeping with the predilection of endemic dysentery for marshy localities accounts of its endemo-epidemic extensions in temperate climates generally point to the temporary establishment of paludal conditions." Thus in 1873 an outbreak arose from the cleaning out of the lateral canal of the Loire and the desiccation of the mud. A similar result followed at Leymen (Haut-Rhin) from the clearing out in August, 1850, of a vast slimy reservoir situated in the middle of the village. In tropical countries dysentery appears to be more independent of soil than in temperate climates, but an imperfectly-drained or marshy soil is everywhere favourable to its prevalence. The geological nature and the mineralogical constituents of the soil are secondary in im-

[8] Twenty-seventh Local Government Report, 1897–98.

[9] Allbutt's System of Medicine, vol. ii., p. 408.

portance to its physical conditions—its dryness, humidity, and aeration. These again are of less moment than its state of organic purity. That a soil charged with dysenteric or perhaps even with fæcal (simple fæcal) evacuations is capable of giving rise to the disease is amply proved. The epidemics which occurred in the Cumberland and Westmorland Asylum in 1864–65 and in 1868 were shown by Dr. Clouston to be due to the effluvia from a stiff clay field over which the sewage of the asylum was allowed to flow. The soil was quite unfit for irrigation purposes. Among the causes of the frightful dysentery mortality which made Secunderabad a byword none was more effective than the saturation of the soil of the site itself with organic impurities, the extreme pollution of the vicinity with fæcal matters, and the bad privy accommodation. The dysentery of war and famine shows little respect for climate or season ; under the given conditions it appears in countries most free from the endemic disease and at all seasons of the year. The dysentery of war and famine is extremely fatal and it has a greater tendency than any other to become complicated with typhus, typhoid, and malarious fevers. In the Irish workhouses during the 10 years ending June, 1851, no fewer than 50,019 persons perished from dysentery and 20,507 from diarrhœa. The dysentery of war and famine frequently assumes a contagious character. The bacteriology is rather uncertain owing to the numbers and variety of the micro-organisms which are found.

Davidson concludes: 1. The healthy intestine is capable of much resistance to the infective agents of dysentery. 2. The healthy human being carries with him organisms capable under certain conditions of giving rise to inflammation of the intestinal tract, and besides organisms of suppuration, putrefaction, and sepsis are everywhere present which have the power of determining dysenteric inflammation of the bowels when its nutrition is impaired. 3. A simple catarrhal condition of the bowel is sufficient in itself to produce true dysentery. 4. When we observe a body of men seized with an infectious form of dysentery immediately after being subjected to hardship and depressing meteorological influences while another body in the vicinity having the same food- and water-supply but not subjected to the like fatigue and hardships escape, we are led to infer that the common exciters of inflammation rather than any specific agent must have given rise to the disease.

Cholera.

Ernest Hart says: "Within certain areas in India cholera is endemic, especially in the country of the lower Ganges. There the air, the water, and the soil are never cold, the ground is often damp, and when it is dry the tanks are foul, so that there is always a fit breeding-place for the contagion, &c." Koch's vibrio (Kanthack) grows in dilute peptone at from 30° to 35° C. It is commonly said to be destroyed by drying. It is a facultative anaerobe and highly saprophytic. Cultures retain their vitality on silk threads for 86 days and dried on glass for 120 days. "From flies fed on choleraic material the vibrios could be separated after 14 days." The inoculation test practised on the lower animals is inconclusive. According to Pettenkofer (quoted by Copeman) cholera occurs when the ground-water after having attained a higher level than usual commences again to fall.

Malta Fever.

Malta fever[10] is caused by the micrococcus melitensis discovered by Bruce in 1887. It is common to the shores of the Mediterranean and Red Seas. "It was early apparent that its presence in Malta and Gibraltar was connected with fæcal and organic matter from human sources. Sewers and sewage works where these have been undertaken, as in Valetta and Naples, appear to have little influence in diminishing the attacks. Indeed, the channels are so frequently pervious and allow the fæcal matter to soak into the pores of the soil that they virtually become elongated cesspools and increase rather than diminish the dissemination of the poison. Tomaselli notices the same fact in relation to the prevalence of the fever and the introduction of sewers into Catania. In his opinion the immense quantity of sewage and sewer air which is developed in these sewers and finds its way out of them is to be placed in the first rank of its causation and is an argument in favour of the aerial dissemination of the morbific agent. The micro-organism grows best in nutrient material the alkalinity of which is slightly less than human blood and at a temperature of from 37° C. to 39° C. It fulfils Koch's postulates at all points. It lives for a long time in the dry state."

Plague.

Plague has been regarded as a soil disease, but recent evidence must materially modify this opinion.

The alleged facts which support this view are, according to J. F. Payne in his article on Plague in Allbutt's System of Medicine: (1) its limited geographical distribution; (2) because ground animals such as rats perish in large numbers—"they have buboes and their organs contain immense numbers of the plague bacilli; it cannot therefore be doubted that the virus exists underground before it affects human beings"; (3) its recurrence at the same spot while places near and in direct communication escape; (4) the escape of water populations such as Canton and in London in 1665; (5) the fact that the ground floor is affected more than the first floor—"Plague does not go upstairs" (?); and (6) "the beneficial effect of local sanitary measures."

It would appear from the above reasons that the endemic prevalence of plague is comparable to that of cholera or typhoid fever and is governed by somewhat similar laws, though in other respects it differs very much from those diseases. In the double infection of the soil and the organism it resembles anthrax. Along with the infection of the soil there appears to be a passage of the virus in some form into the air, so that it has always been believed that the disease may be acquired by inhalation like typhus fever. Scientific explanation of this method of receiving the virus is still wanting. Epidemics have often been preceded by drought; epizootics, famine, and abundance of flies have been noticed. Epidemics are usually checked by cold and heat. It is pre-eminently a filth disease invading by preference the crowded, ill-ventilated hovels of the miserable. "A soil contaminated with fæcal discharges and decaying animal matter of all kinds appears to be an essential condition for the vitality of the virus." Widely different opinions have been held as to its "contagiousness." "The infection is doubtless generally conveyed by persons either infected with the disease or in the state of incubation. Such persons convert the house they occupy into a focus of infection till possibly the virus passes into the soil and a severe epidemic may result." The rate of extension is variable but generally slow; plague has taken weeks or months to pass from one side of a city to another; it creeps along from point to point so as to be compared by some to a drop of oil on paper. Such gradual exten-

[10] Allbutt's System of Medicine, vol. ii., p. 463, by Lane Notter.

sion suggests the slow progress of a virus in the soil itself, and probably that is in some places the explanation, but obviously only transmission through short distances can be thus accounted for.

It is encouraging to observe how the habit of calmly observing and recording the phenomena of different epidemics together with carefully devised experiment has thrown light upon many of the obscure points connected with plague. We now know that plague is protean in its forms and that all forms are not conveyed from individual to individual with equal readiness. The unfortunate accident which occurred last year in Vienna ought to have, and doubtless has had, the effect of dispelling many of the superstitions in regard to plague. It has clearly demonstrated to the people at large (1) that the poison is something tangible which may be conveyed from one part of the world to another in a test-tube; (2) that the poison may infect the lower animals; (3) that the lower animals may infect man; (4) that the pulmonary form of the disease is terribly infectious and communicable through the air; and (5) that measures of disinfection and isolation are capable of cutting short an epidemic. Experiments carried out in districts where a disease is epidemic or endemic necessarily acquire a measure of uncertainty from that fact alone. The occurrence at Vienna, much as one may deplore it, was an object-lesson of the greatest value and converted what many regarded as mere theories into facts which all can read and understand. In the recent epidemics in the East the theory that plague grows "in the soil" has received no support whatever and that it spreadsin the soil like a drop of oil permeating paper appears to be unlikely. In India two facts have come to the front—viz., the danger in relation to plague of (*a*) rats and (*b*) abrasions on the skin. The rat lives in burrows in the soil and swarms in our sewers. He feeds largely at night and comes out of his hole in search of food and prey. It has long been recognised that the rat is susceptible of plague. In Bombay, according to Simpson, as many as 100 affected rats were counted in one small grain depôt in one day. Hindoo writings 800 years old warn the inhabitants to leave a district when they observe a mortality among rats. The infection of rats usually follows infection of a distant locality by men. Nowhere has this been more decidedly proved than during the late epidemic in India, where the infection of the rats has unfortunately followed the introduction of the virus by man, from a primary seat of infection situated at considerable distances from the secondary area of infection. Rats may convey infection from infected burrows on their feet or fur; they also become infected by eating each other. When dying they usually leave their holes and run about the rooms of a house and then die. Carelessness in dealing with or han dling them, especially in the filthy surroundings and associated with the dirty habits of the inhabitants of these houses, along with the possible convection by vermin, must all necessarily be in favour of the infection being carried to man. The amount of such infection spread by rats cannot be gauged. The infection of the rat is no proof whatever of infection of the soil except by filth deposited on the surface. Lowson in his report to the Bombay Government in 1897 says: "That the disease is primarily a soil disease is certainly borne out neither by observation nor experiment. Takaki and I carried out bacteriological experiments in Hong-Kong by which we were able to prove that even in houses in which the earthen floors had been severely infected no cases of plague infection could be obtained and later experiments on the artificial infection of earth with a culture of the plague bacillus have shown that the mixture of earth and bacilli loses its infecting power, sometimes in a couple of days." Indeed, there has been no proof forthcoming so far that the plague bacillus has ever been found below the surface of the earth.

In Hong-Kong the soldiers who were attacked by plague were in the cleansing squads, and were well booted, but worked with trousers open at the bottom. In India the military parties who assisted in this work were ordered to wear putties to prevent plague-infected dust and animals from coming in contact with their legs, with the result that none of those engaged in this work became infected, and that, too, amongst probably eight or 10 times more soldiers than were doing the work in Hong Kong. To sum up, it may be said that the following are the most important items in the spread of plague: (1) filthy habits of the people, such as spitting over the floor and others mentioned above; (2) filthy houses; (3) overcrowding and consequent rapid increase of contagious disease when once imported; (4) presence of rats, insects, and other vermin; (5) the naked condition of the people going about, such people presenting almost unlimited opportunities for the entrance into their tissues of plague poison by inoculation and through abrasions; (6) pollution of soil and houses with the excretions of man and animals; and (7) filthy clothing and absence of bodily hygiene.

Diphtheria.

Arthur Newsholme in his work on Epidemic Diphtheria (1898) while admitting that personal infection is the chief means by which diphtheria is spread, contends that:—

> The specific micro-organism of this disease has a double cycle of existence, as have the specific micro-organisms of enteric fever, erysipelas, scarlet fever, rheumatic fever, &c. One phase is passed in the soil, another in the human organism. One is saprophytic, the other parasitic.[11] It is not strange, therefore, that the epidemic

[11] It is not contended that there is a regular alternation of saprophytic and parasitic generations; but that such alternations do occur.

prevalence of all the above diseases is favoured by deficient rainfall if this is sufficiently long continued. This deficient rainfall implies a low subsoil water and a subsoil above the level of this water which is relatively dry and warm, probably the optimum conditions of the saprophytic life of the above pathogenic micro-organisms. The causes of the transition of the diphtheria bacillus from the saprophytic to the parasitic phase of life may be surmised both as regards (*a*) season and (*b*) years of special epidemic prevalence. Diphtheria is most prevalent in the autumn and early winter months, when the optimum temperature and the optimum degree of humidity of the soil are rapidly disappearing or have departed. It is also most prevalent after the wet weather occurring in or immediately following exceptionally dry years. Both these conditions tend to raise the ground water and to drive out any pathogenic micro-organisms from the soil.

Newsholme is of opinion that in order to account for the epidemic and even pandemic waves of diphtheria "the diphtheria bacillus under certain conditions becomes more actively virulent and infective—more remote from its saprophytic phase of life, and that thus persons who can resist the ingress of the feebler fall victims to the more powerful micro-organism." The latter is probably the correct hypothesis and the evidence already given clearly points to the conclusion that of the external cultural conditions leading to increased virulence of the diphtheria bacillus and 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.

The above is a very ingenious hypothesis, but it is essential to point out that the diphtheria bacillus has not been recovered from the soil and that the bacilli of rheumatic fever and scarlet fever have not yet been identified. Before Newsholme's hypothesis can be accepted a great deal more evidence will be necessary.

Newsholme's figures and tables show clearly that the amount of diphtheria is very great in the American cities. He records death-rates (per 100,000) for diphtheria of 109 in New York (average of 28 years, 1868-95), 77 in Chicago (36 years, 1859-94), 100 in Boston (35 years, 1861-95), 114 in Brooklyn (1875-95), and 129 in Pittsburg (1877-94). The highest death-rate from diphtheria ever recorded in London was 76 (per 100,000) in 1893. The average death-rate per 100,000 was in Salford 32 (1860-95), Manchester 18 (1871-96), Liverpool 14 (1860-95), and Sheffield 15 (1859-96). The figures were still lower in others of our great industrial towns. In Holland we find death-rates per 100,000 from diphtheria alone of seven in Rotterdam, 12 in The Hague, and 31 in Amsterdam (all three for 1879-95). Berlin gives 101 (1869-96), St. Petersburg 65 (1879-95), and Moscow 64 (1878-96). The death-rate in Japan appears to be low.

Newsholme's figures generally seem to show that diphtheria is now a disease more of the towns than of the rural districts. It is not very easy to understand how in a city where pavements and other impermeable coverings to the soil are general the bacillus is driven by the rising subsoil water into the air. Of course, it may be driven out of the sewers and sewer ventilators, in which case it becomes a sewer disease rather than a soil disease. Why is it not an air disease? Nobody who has ever smelt the air of Bond-street in a hot July or who has watched the impurities descending from the upper air when they are driven downwards by the first showers after a drought would refuse to allow to the air of a city any amount of potential infectivity. Most of the facts collected by Newsholme are explained as readily, if not more readily, on the theory that diphtheria is an air disease as upon the theory that it is a soil disease. If we remember that a theory is not a fact these speculations will do no harm. Unfortunately this is not always remembered. Diphtheria (Copeman) has been supposed to show a preference for houses on damp clayey soils (Greenhow, Airy) and dampness of habitation (Thursfield). "Although," says Copeman, "dampness of site is undoubtedly a factor in the production of outbreaks of diphtheria, particularly if such dampness be due to persistent leakage from imperfect sewers or cesspools," it does not appear to bear any relation to the rise and fall of the subsoil water.

That diphtheria is a soil disease is certainly not proven.

Malaria.

A few years ago I should have spoken of "malaria" as undoubtedly caused by something in the soil itself and I should have indulged in the stock phrases about miasmata, mephitic vapours, and the like. The discovery of hæmatozoa in the blood of sufferers from malaria has altered our point of view. The most widely spread poison in the world has become something which is visible and tangible and inoculable. No discovery which has ever been made in the domain of medicine is likely to have such far-reaching effects. Further it seems certain that the infection of human beings may take place viâ the mosquito and we are now concerned to find out whether this is or is not the only medium through which the blood of man receives the parasite. Some who are well qualified to speak would answer in one way and some in another. This is not the place for weighing arguments *pro* and *con* nor can I claim any special knowledge which qualifies me to sit in judgment. Let us assume that it may possibly be shown hereafter that what we have hitherto regarded as "malaria" is a parasitic disease wholly and solely inoculated in us by insects of the mosquito class and that in respect of its mediate infection by animals malaria will fall into line with rabies. We cannot issue a muzzling order to be enforced against mosquitoes nor can we lure stray mosquitoes to their death in some tropical Battersea. We shall have to go more to the root of the matter and while on the one hand we may be able to show Europeans the importance of protecting themselves against the attacks of insects we must still continue to make use of our accumulated knowledge as to the conditions of soil which indirectly cause remittent fevers to be endemic. Old and well-established facts will now be re-examined by intellects strengthened and widened by the discoveries of Laveran and Ross and our knowledge is sure to be extended and increased. Although the conditions of soil which give rise to malaria are too well known to need any lengthy discussion here it may be well to give some of the latest utterances on the subject.

Sir Joseph Fayrer writing on the "Climate and Some of the Fevers in India" in Allbutt's System of Medicine[12] says of malaria: "It often appears with great virulence after excavation or turning up of soil and in land that has recently been denuded of jungle." ...... "On the other hand, draining and cropping seem after a time to diminish or destroy the poison. Maclean calls attention to the fact that when excavations were made in the island of Hong-Kong which consists entirely of weathered and decaying granite and is liable to be permeated with a peculiar fungus, violent and fatal remittent fever appeared."

Osler says: "An interesting feature in connexion with the disease is the gradual disappearance from certain regions under the influence of drainage and cultivation. In England, even in the fen country it is now almost unknown. In New England, too, it has gradually disappeared. In parts of Canada bordering Lake Ontario which were formerly hotbeds of the disease cases only exceptionally occur." It well called a soil disease. "Excavations of all sorts, extensive cuttings for railways, and the breaking up on a large scale of virgin soil have in many instances been followed by outbreaks of malaria.[13] "The greater prevalence of fever in the Royal Engineers in comparison with other troops is probably to be accounted for by their more frequent employment in the excavation of the soil. Manson,[14] speaking of Ross's work in connexion with the mosquito, says that although he believes that malaria may be acquired by the bite of the mosquito, he does not believe that this is the only way. Rees of the Seamen's Hospital[15] gives details of an outbreak of intermittent fever (confirmed by examination of the blood by himself and Manson) which affected 22 of the crew of a ship nine days out from Colombo and 14 from Calcutta on her homeward voyage. Air-borne infection or water-borne infection cannot be lightly dismissed.

Blackwater Fever.

Crosse, writing on blackwater fever,[16] says: "Some will ask, Why has blackwater fever become so common recently? The first case on record in the Niger Territory was, so far as I know, my own 10 years ago. The first case on the Niger Delta is said by some old coasters to have occurred in 1882. It seems to me that since we have begun to turn up virgin soil for coffee and other plantations the disease has become common. ...... It is significant that our first three gardeners died of blackwater fever and that for some considerable time cases only occurred near the plantations, and as plantations became common so the disease spread to the other stations in the territories. Castellote notes a case in which a white man personally superintended the digging of a grave and stood about in the sun for two or three hours; next day he had severe fever which developed into blackwater fever." According to Battersby "many virulent attacks after the turning up of virgin soil have been recorded. Almost equally remarkable, according to this observer, is the diminution of the disease which has been brought about in certain localities by drainage and cultivation of the soil."

It is generally conceded that the turning up of virgin soil is one of the most fruitful causes of malignant malarial

[12] Vol. ii., p. 311.

[13] I recently discussed this subject with two gentlemen who were intimately connected with Indian railways and who professed ignorance of any danger arising from recent cuttings.

[14] Brit. Med. Jour., Sept. 24th, 1898.

[15] Ibid., Sept. 24th, 1898.

[16] Ibid., Oct. 8th, 1898.

fevers and numberless examples of this are given in text-books on the subject. Surgeon Bowden, R.N., D.S.O., informs me that the turning up of fresh soil is often followed by an influx of mosquitoes. On the other hand, the cultivation of the soil seems ultimately to lead to the decrease and disappearance of malaria. The broad facts of nature must convince us that this must be so for if man in his attempts to grow food merely increased the deadliness of his surroundings the human race would soon become extinct.

There is a group of diseases which (like malaria) seem to be dependent upon the bites or stings of insects and which, although they affect animals rather than man, throw much light upon the pathology of infection and teach us that so-called "climatic diseases" may be due to something very gross and palpable.

Ngana or Tsetse Fly Disease.

Kanthack, Durham, and Blandford,[17] show that this disease is due to a hæmatozoon (trypanosoma) in the blood inoculated by a fly. Cats, dogs, mice, rabbits, rats, hedgehogs, donkeys, horses and their hybrids seem susceptible. The disease seems to be communicable only by some form of inoculation and is not probably conveyed by feeding on infective material in the absence of superficial lesions. Material taken from the dead body 24 hours after death is not infective. The nearest lymphatic glands to the inoculated spot are the first to suffer. The hæmatozoon gets through the lymphatics to the blood. In the late stages of the disease the animals (especially dogs) may become infected by pyococci, i.e., a spontaneous infection to which the animal is rendered prone by its marasmus. The blood may contain 3,000,000 hæmatozoa per millimetre or may prove infective though none be visible. The trypanosoma sanguinis which is found in a certain proportion of rats has no apparent relation to tsetse fly disease. A similar parasite is said to cause "surra" in India and an allied disease among horses in Algeria. Surra is probably conveyed by flies. Lingard thinks the fodder soiled with rat-dung may give the disease, but that is doubtful. The tsetse fly is a dipterous insect somewhat resembling the common house fly. It has a long thin proboscis, chestnut thorax marked longitudinally by four black lines, and a yellowish white abdomen of five rings. It inhabits principally the low-lying and swampy valleys of the Zambesi and Chobe.

"Louping Ill."

This disease, which is common in the North of England and Scotland and which has been noticed as fatal to sheep frequenting certain pastures, has now been shown by Williams, Meek, and Greig Smith [18] to be caused presumably by a special kind of sheep "tick" found on these pastures, which tick is supposed to be hatched in the upper layer of the soil and to inoculate the sheep with micro-organisms which cause the disease—a disease which is characterised by staggering and lameness due to congestion of the brain and spinal cord which have been found post mortem.

[17] Proceedings of the Royal Society, vol. lxiv., p. 100.

[18] Veterinarian, 1896-97.

Texas Fever of Cattle.

This appears to be caused by a hæmatozoon with which the animal is inoculated by a tick (ixodes or boophilus bovis) which is parasitic. The Australian tick fever and the ixodic anæmia of Jamaica appear also to be produced by allied if not identical parasitic animals. Principal Williams, F.R.C.V.S. of the New Veterinary College, Edinburgh, in writing on ixodic anæmia or Texas fever[19] (which he studied in Jamaica) which is due to the infection of cattle with a blood parasite by the agency of a tick (ixodes bovis) insists that every attempt should be made to get rid of the ticks which breed especially in the vegetable rubbish left upon the pastures. "Every effort should be made," he says, "to conserve and increase tick destroyers such as the black tick birds. .... I have had much amusement in watching these birds, as there seems to be an understanding between them and the cattle whereby they are assisted and encouraged to destroy the ticks." Domestic fowls should be encouraged and starlings and song-thrushes might be imported. To a stranger visiting the island (Jamaica) the scarcity of birds is a striking feature. I have been told that it is due to the mongoose, which has not only diminished the number of wild birds and domestic fowls, but other tick-destroying creatures such as the ground lizard. Now this destruction of the natural tick-destroyers should, as far as possible, be prevented, firstly by legal protection, secondly by encouraging the slaughter of the mongoose." (For further remarks see *Veterinary Journal*, 1896.)

South African Horse Disease.

South African horse disease has no apparent connexion with insects or surface wounds, but appears to depend not upon conditions of the surface soil, but on temporary conditions of the vegetation which forms the pastures.

South African horse disease (œdema-mycosis) is described by Captain Hayes, F.R.C.V.S., in his translation of Friedberger and Frohner's Veterinary Pathology, and is supposed by Edington to be caused by a mould (penicillium) which grows in the vessels causing thrombosis and exudation of serum with fatal results. It appears to occur chiefly among animals which are allowed to graze while the dew is on the grass and the growth of the microbe is supposed to be connected with the dampness of the grass. The disease once contracted is almost always fatal, but the prophylactic appears to be dry fodder and the folding of horses until the sun has dissipated the moisture of the dews.

The history of those diseases which appear to depend on inoculations points with no uncertainty to the advisability of keeping a whole skin. The "verminous person" has assumed an importance in relation to the public health which the Legislature has already recognised, while the "tramp" with his special liability to small-pox is one to whom the anti-vaccinationist is likely to discover a "conscientious objection." The special liability of the "tramp" to suffer from small-pox—if such is really the case—seems to offer a field of investigation well worthy of being methodically explored.

There are other diseases more or less suspected of being soil diseases, but the facts are at present too few to make any discussion profitable. These are yellow fever, beri-beri,

[19] Principles and Practice of Veterinary Medicine, p. 416, et seq.

swine fever (undoubtedly propagated by fouling of the surface soil), cancer (?), thread worms, hydatids, and ankylostomum duodenale. Malignant œdema is an infective disease of wounds undoubtedly caused by a ubiquitous anaerobic saprophyte which occasionally manages to grow in the cellular tissue and to generate gas (CO_2, H, SH_2, CH_4) therein.

LECTURE II.[1]

ENTERIC FEVER.

MR. PRESIDENT AND GENTLEMEN,—Enteric fever has of late years much occupied the attention of epidemiologists and bacteriologists and our knowledge of its definite relationship to filth, milk, and water has undergone considerable increase. The laboratory experiments connected with enteric fever are of great interest and value, but it would be, to say the least, hazardous to build upon them any measures intended for practical sanitation. It must never be forgotten that the typhoid bacillus does not fulfil one of Koch's postulates. The disease produced by the inoculation of guinea-pigs with pure cultivation of typhoid bacillus has but a remote resemblance to the disease which we clinically know as enteric fever, a disease which seems limited to the human species. Sidney Martin[2] found that "none of the ordinary cultures of the typhoid bacillus obtainable in the laboratories will kill an animal[3] but that it may be rendered virulent by inoculation and transference through a succession of peritoneal cavities and also by injecting simultaneously the products of other micro-organisms, such as streptococcus or bacillus coli communis. It is noteworthy that the bacillus coli communis and Gaertner's bacillus when subjected to similar manipulations are as toxic to rabbits as is the typhoid bacillus. It must be remembered that "pure cultivations" of the bacillus typhosus cannot be said to exist in nature. We recognise, and it may be taken as proven, that the main cause of the endemicity and epidemicity of enteric fever in this country is to be found in the fæces of the patient, and yet Martin tells us that while the bacillus is invariably found in the spleen and mesenteric glands and in intestinal lesions "it is found in some cases in the motions of typhoid fever and also in the urine."

1 Delivered on February 28th, 1899.

2 Croonian Lectures, 1898.

3 When therefore Sir Richard Thorne in commenting upon Martin's pure cultivations of bacillus typhosus in sterilised soil says that they yielded the bacillus "presumably in virulent phase" (Local Government Board Reports, 1897-98, p. 23.) his presumption is scarcely warranted by the facts.

Dr. J. R. Carver, working under Delépine at Manchester, found the typhoid bacillus twice in 20 samples of typhoid fæces and once in 16 samples of typhoid urine.[4] Martin working with sterilised soils has shown that in soils which are more or less "polluted" with organic matter the bacillus typhosus will continue to live and spread at ordinary temperatures, but that in virgin soils (both sandy and peaty) the pure cultivations of the bacillus die out from some unexplained cause. Martin gives one experiment[5] to show that in unsterilised soil containing much organic matter the bacillus may continue to live, but as yet there has been no evidence of spreading. John Robertson and Maitland Gibson[6] collected 30 samples of soil from areas which they considered likely to be infected. "I not one single instance was the bacillus typhosus found."

These gentlemen carried out experiments in a field (soil: eight inches of clayey loam on 10 inches of sand and clay on stiff yellow boulder clay); each experimental patch had the turf removed and nothing was allowed to grow upon it. The patches were 18 inches square. Three patches were inoculated with 200 cubic centimetres of a pure cultivation of the bacillus typhosus mixed with one and a half gallons of tap water; No. 1 on the surface, No. 2 nine inches deep, and No. 3 18 inches deep, the top soil being removed and replaced. This was done on May 30th, 1896, and on August 26th the bacillus typhosus was found three inches below the surface of each, and at nine inches below the surface of No. 2 and No. 3, and also at 18 inches below the surface of No. 3. On Oct. 20th there were practically the same results. On Nov. 27th the bacillus typhosus could not be found in either patch. Towards the end of August, 1896, three other patches (Nos. 4, 5, and 6) were inoculated in the same way and on Nov. 27th no bacillus typhosus could be found. These patches were three feet square. On Jan. 17th, 1897, patches Nos. 4, 5, and 6 received two gallons of very weak beef tea which was repeated at fortnightly intervals till June 3rd, 1897, when on examination the organism was easily found. No organism was found at this date in patches Nos. 1, 2, and 3, which had not been fed with bouillon. Practically the same result was obtained on July 11th. The persistence of the bacillus typhosus appears to depend on feeding it with fluid nourishment. A sewer leaking into the soil would do this or liquid filth in a privy. It was shown that the organism would grow three inches downwards or upwards from a depth of 18 inches. The slight downward growth might be due to mechanical conditions. The effect of sunlight does not penetrate far.

Laboratory experiments went to show that vegetation (grass) prevented the growth of the organism. This may go to explain "why typhoid fever is so much more prevalent in towns than in rural districts." Attempts to prove the aerial conveyance of the organism from liquid filth failed.

Further allusions by Dr. J. Robertson to these experiments were made later in the year,[7] in the course of which he said: "During the winter months organisms disappeared from the surface soil and from these

[4] The Lancet, August 20th, 1898.

[5] Local Government Report, 1897–98.

[6] Brit. Med. Jour., Jan. 8th, 1898.

[7] Ibid., August 13th, 1898.

experiments I was led to believe that the deeper layers acted as a sort of shelter during the winter months from which the organism sallied forth to the surface during the warmer months." He had not noticed any relation between typhoid fever and the rise and fall of the ground-water, but he thought it was most common in places where the ground-water is near the surface. The bacillus typhosus quickly dies out in grass-covered areas.

Let us now turn from these experiments which, after all, are very artificial to the practical experiences of sanitarians in the matter. It may be premised that Martin's experiments show that the bacillus typhosus will grow in any soil rich in organic matter and that although aerobic it can be cultivated as an anaerobe even in an atmosphere of carbonic acid,[8] and the bacillus seems to be definitely destroyed by sandy or peaty "virgin" soils. Robertson and Gibson cultivated the bacillus on a soil in which clay predominated. Sir Charles Cameron is of opinion that it flourishes in gravel. At Dublin on August 23rd, 1898, he said, speaking of enteric fever: "That there is a connexion between enteric fever and the soil is shown by the results of observations of the distribution of more than 4000 cases of the disease in Dublin. Where gravel forms the site of streets there is far more typhoid fever than in districts which rest upon the stiff boulder clay. This is clearly owing to the fact that the bacillus typhosus, which is aerobian—that is, requires oxygen—can get it more freely in the loose gravels than in the stiff clays. In the gravel, too, there is a much greater space for the development and movement of the bacilli."

Dr. Scurfield of Sunderland said that "the greater part of the county of Durham in which typhoid fever had been prevalent during the last few years was covered with stiff boulder clay, and in the urban district of Sunderland typhoid fever had been just as prevalent in the boulder clay as in the houses built on sand or gravel." Pettenkofer, the chemist of Munich, is the person who is mainly answerable for the theory that enteric fever is due to a soil organism which grows with maximum vigour when the level of the ground water falls.

Dr. Christopher Childs, in a valuable paper which appeared in The Lancet,[9] has placed us in possession of important facts. Munich lies on a bed of gravel 1700 feet above sea-level. Between 1851 and 1896 the population has increased from 124,000 to 412,000, so that modern Munich is largely a new city. Up to 1865 Munich was a city of soakaway cesspools and filthy surface wells, and it was not till 1858 that the cesspool system began to be remedied and not till 1865 that the water-supply began to be improved. Pettenkofer's early investigations, Dr. Childs says, led him to the conviction "that in Munich there was not the slightest connexion between the drinking-water and the typhoid,[10] and this in spite of the fact that the water was shown on analysis to be organically polluted. The analyses and general investigations of the earlier date have been very imper-

[8] Local Government Board Report, 1867.

[9] The Lancet, Feb. 5th, 1898.

[10] This may have been due to the fact that the wells were all equally bad.

fectly recorded, but there is evidence, says Dr. Childs, that the water was much worse in the earlier periods than latterly. Of Pettenkofer's personal investigations Dr. Childs says: "I have not succeeded in finding recorded details but they derive their weight from the high authority of Pettenkofer himself." The enteric death-rate, which (per 100,000) was 202·4 for the decade 1851–59, fell to 147·8 in 1860–69; to 116·7 in 1870–79. In 1880 it was 72; in 1881 it had fallen to 18 and has not risen since.

The water in Munich is derived from the mountains and when these are covered with snow the subsoil water falls. It is a most interesting fact to note that Pettenkofer's Munich typhoid fever was a disease of winter. The incidence of the Munich typhoid fever between the years 1851–67 was, according to Pettenkofer, in monthly averages as follows:—

February	36·8	April	23·1	September ...	16·1
January	33·5	November... ...	19·0	July	15·8
March	31·8	May	17·6	June	15·2
December	28·5	August...	16·7	October	15·0

The average English sanitarian reading this account of Munich with its soak-away cesspools and foul drinking-water would not need any new theories to account for the prevalence of typhoid fever. If we accept Pettenkofer's theory that the fever was due to organisms in the subsoil it is interesting to observe that the Munich fever, unlike typhoid fever in other places, reached its maximum in February and was most rife in the coldest weather when the surface of the ground must have been often frozen. During the winter months when the big houses were closed and the stoves were lighted the interior of the houses must have been filled with cesspool air. An organism permeating the soil might be expected to die out gradually. The sudden fall of the death-rate from 72 in 1880 to 18 in 1881 seems to imply that the organisms suddenly died over the whole area of the city. Munich is a city in which the general sanitary condition has undergone gradual amelioration. Sewers on modern lines were begun in 1878 and 800 private slaughter-houses were destroyed in the same year. There is now a highland water-supply and typhoid fever has gone. But it is needless to say that the subsoil water rises and falls precisely as it did half a century ago. The connexion of typhoid fever in Munich with organisms growing in the soil is to my mind not proven.

In 1896 there were 111 cases of enteric fever at Chichester, of which the majority occurred in July and August and of which only two died (one committing suicide while delirious). 76 houses were attacked in localities which had been repeatedly invaded in former years. Of these houses 39 had well water (quality doubtful) and 36 had company's water. In 62 of the cases the patients were males and in 49 they were females. There had been recent works of drainage and it was found that the percentage of incidence of fever on the whole of the undrained houses of the town was slightly in excess of that of the drained houses. There was no evidence that the disturbance of the soil in this ancient walled city for works of drainage had influenced the incidence of fever. Many of the houses attacked had old privies, &c., and the back yards were soaked with organic matter. Enteric fever, as usual, showed a preference for filthy surroundings. This outbreak has been spoken of as due to the growth of the bacillus typhosus in the soil round the houses attacked, but the evidence is certainly not conclusive and the fact that the women who mind the house suffered less than the men is rather opposed to such a theory. The epidemic, which departs somewhat from ordinary epidemics in the time of its maximum virulence and its very low mortality, remains unccounted for. Chichester is built on a bed of gravel. (The facts as to this epidemic are culled from Dr. Bulstrode's report to the Local Government Board.) In 1898 76 houses in Chichester were again infected with enteric fever. Of these 58 were "drained" and 18 "not drained"; 44 consumed town water, while 32 had well water. Mr. Jones, the medical officer of health, points out that the percentage of incidence was markedly in excess in the "well water" houses and slightly in excess in the "undrained" houses.

Enteric fever has long been regarded as a filth disease and there is abundant evidence that filthy surroundings in some way or other predispose to it. Water-logged privies soil-sodden with the leakage of sewers, the air of cesspools and traps, proximity of water-closets to the kitchen, and other conditions of filth are all bad. While we agree as to the fact we may differ as to the explanation. Some would assert that the bacillus typhosus is actually growing and spreading in the filth, and indeed that is possible, but direct evidence of it is wanting. Some would even say that the soil being inoculated the specific organism may continue to grow and spread in it far away from the point of inoculation and so (by growth, not irruption) may poison the local water at a distance. Of this there is positively no evidence whatever. If for the sake of argument we allow that the bacillus typhosus may grow in the soil we have to ask how it emerges from the soil to do us harm? We are here confronted with contradictions. Robertson and Gibson showed that the bacillus disappeared in the winter to reappear in the summer, while at Munich the increase of enteric fever was a phenomenon of midwinter. In Budapest it is associated with a rising ground-water and at Munich with the opposite condition. In this country it is a disease of autumn and the period of floods, while others assert that it may be conveyed by dust which ought to produce a prevalence in March. The opinions held by sanitarians and bacteriologists on this question differ widely, but there seems to be a consensus of opinion that a water-logged soil rich in organic matter is the one in which the bacillus typhosus is most likely to flourish. If this should be true the official position that in sewage treatment filtration through earth is a *sine qua non* becomes untenable.

In the discussion which followed a paper which I had the honour to read before the Royal Medical and Chirurgical Society in November, 1897, on the Prevention of Enteric Fever, and which has been published in vol. lxxxi. of the Transactions of that society, many eminent sanitarians and bacteriologists made most valuable statements. Sir Richard Thorne said (p. 56): "I do not think nature made any provision for the disposal of specific excreta. Nature provides an easy means of dealing with the ordinary healthy excreta of healthy people living on the land, but dangers arising from specifically contaminated excreta are, I fear, much more difficult to be thus got rid of.[11]

The danger from flies is, in Director-General Jameson s opinion, a very real one in tropical countries. By their agency fæcal poisons are probably carried to the food or milk. Dr. Sims Woodhead said: "We stand in need of further information in respect of the continuance of the typhoid bacillus in soil. I agree ...... that the typhoid bacillus has a much greater chance of persistence in a water-logged soil containing a moderate amount of organic matter than in a dry, well-aerated soil, however large an amount of organic matter it may contain. In this, however, my actual experience is limited, though I hold a strong opinion on the subject." When we consider that the bacillus of typhoid fever may remain in the intestine for some time after recovery as well as in the urine and gall-bladder, and when we also remember what Metchnikoff pointed out in relation to cholera—viz., that the vibrio may be present in the intestine a long time before an attack of cholera occurs, it would seem that we can have typhoid bacilli under very similar conditions present in the intestine in practically healthy individuals, and that this bacillus may remain in the intestine a considerable time before the intestinal tract becomes so altered that the bacillus has a chance of doing its special work. Then it is that bad, though not actually infected water, may help the typhoid bacillus to do its work."

Dr. Corfield insisted on the importance of sewer air and cesspool air as factors in producing the endemicity of enteric fever. He instances Lyons as a city in which cholera has never spread but in which typhoid fever is endemic. Lyons is a city of cesspools.

Loesener, in a paper[12] on the Viability of Pathogenic Bacteria in Interred Corpses, states that he injected into the vessels and cavities of dead pigs a great quantity of pathogenic bacteria so that their number should exceed that of the saprophytes. In the first experiments the animals were not interred and under these conditions the viability of the bacilli of typhoid fever and cholera did not exceed four or five days. When the animals were treated in this way and buried in a porous soil the pathogenic bacteria manifested a maximum viability as follows: Typhoid fever (one instance only) 96 days, cholera 28 days, tubercle 95 days, bacillus pyocyaneus 33 days, pneumo-

[11] This opinion is not quite in harmony with Sidney Martin's repeated demonstrations that the bacillus typhosus is killed by virgin sand or peat, and the death of it in Robertson and Gibson's soil which had not been watered with beef tea and its extermination by growing grass.

[12] Arbeiten aus dem Kaiserlichen Gesundheitsamte, vol. xii., f. 11, p. 448.

bacillus of Friedländer 28 days, micrococcus tetragonus 28 days, and tetanus 361 days (showed complete virulence after 234 days). The bacillus anthracis preserved its complete virulence during the whole year of the experiment and the bacillus of *rouget du porc* and septicæmia of mice 234 days. As for the typhoid bacillus it was possible to isolate it from the buried corpses *only once.* "I believe," he says "with Koch that the value of Pfeiffer's reaction of immunity is relative and that outside the human body it is not in our power to identify the typhoid bacillus."

Loesener's conclusion is that cemeteries are not harmful (even when graves made in a permeable soil are liable to inundation either temporarily or permanently) provided the graves be surrounded by a layer of earth sufficient to filter the liquids traversing them.[13]

The epidemic of enteric fever in Maidstone in 1897 is of great importance in relation to the influence of the earth on contagion and the Report to the Local Government Board by Mr. J. S. Davy, Dr. T. Thomson, and Mr. G. W. Willcocks has put us in possession of most of the essential facts.

The date of the attacks (the notifications were later) in the town and in the County Lunatic Asylum as given in Table I. of the report were as under:—

TABLE I.

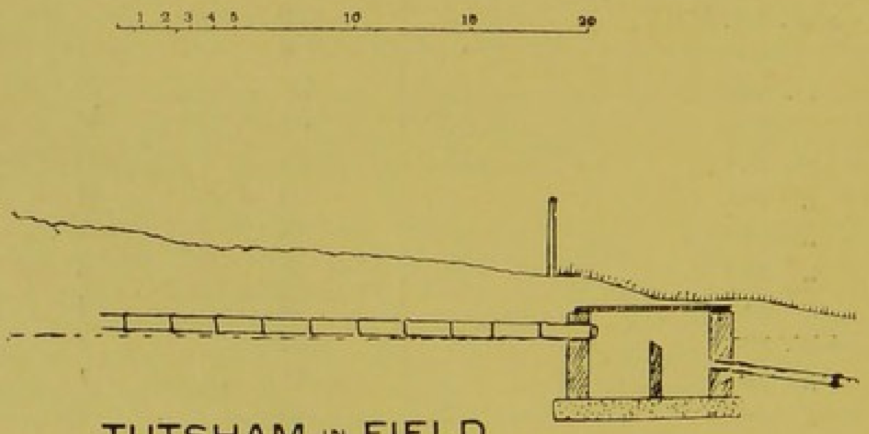
Week ending.	Borough.	Asylum.
Sept. 4th, 1897	29	—
" 11th "	165	1
" 18th "	434	18
" 25th "	432	48
Oct. 2nd "	274	12
" 9th "	134	15
" 16th "	64	4
" 23rd "	45	2
" 30th "	33	4
Nov. 6th "	25	2
" 13th "	23	1
" 20th "	19	—
" 27th "	13	—
Dec. 4th "	4	—
" 11th "	5	—
" 18th "	3	—
" 25th "	2	—
Jan. 1st, 1898	3	—

[13] From Annales d'Hygiène Publique et de Médecine Légale, troisième série, tome xxxvii., Janvier, 1897.

It was conclusively shown that the outbreak was due to the pollution of a spring or springs belonging to the Farleigh water-system. Of persons drinking this water nearly 8 per cent. were attacked, while of those drinking water belonging to other systems of supply less than 1 per cent. were attacked. The Farleigh springs, which are 15 or 16 in number, crop out on both banks of the Medway (mainly on the left bank) where the overlying and permeable green sand (locally known as "ragstone") rests upon the impermeable clay beneath. The water of these springs is for the most part pumped to the Barming reservoir, whence it is distributed mainly to the higher parts of the town. The Farleigh springs yield collectively over 3,000,000 gallons a week and they were treated collectively and their waters were all mixed in one reservoir, holding 500,000 gallons, before distribution. That this reservoir and the pipes connected with it became polluted with enteric poison was beyond doubt but it was not quite so clear which of the contributing springs was at fault. When, however, the springs were examined on Sept. 19th one and one only was found to be dirty—viz., the spring known as "Tutsham-in-Field." In order to condemn this spring, which yielded only 35,000 gallons per week, both chemical and bacteriological analyses were wholly superfluous and accordingly it was cut off from the supply on the following morning, Sept. 20th. This spring was reported as still dirty a month later and when I saw it on Nov. 5th it was still turbid and manifestly unfit for drinking purposes.

"Ragstone" is often fissured and there had been experiences in the Borough of Maidstone of the pollution of an old municipal supply known as "the Conduit," and of a well known as "Hill's Well" by leakage of sewage from broken pipes and similar well-understood causes. Bacteriological investigations were made by Dr. Washbourn and Dr. Durham on behalf of the corporation, by Dr. Sims Woodhead and Dr. Cartwright Wood on behalf of the water company and by Dr. Tew and Mr. Foulerton on behalf of the rural authority. The first four

FIG. 1.



TUTSHAM IN FIELD

were all agreed that Tutsham-in-Field water afforded evidence of animal pollution on Sept. 19th and 20th, and the last two found similar evidence in the mixed Farleigh waters taken at Barming on Sept. 22nd. It is noteworthy and of very great importance that diligent search was made for the bacillus typhosus by the six eminent bacteriologists engaged but without success. The situation of the Farleigh springs was such as to render them liable to pollution, and on chemical grounds they were open to suspicion, but only one of them (Tutsham-in-Field) was really convicted of animal contamination and was obviously dirty and unfit to drink. The facts of the epidemic are, I think, quite consistent with the theory that it was caused by pollution of the spring at Tutsham-in-Field.

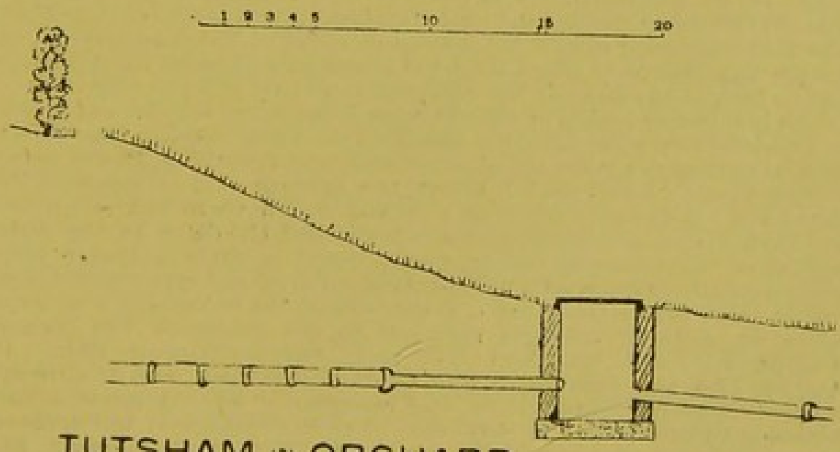
The Tutsham-in-Field spring derived its immediate supply from the underdraining of a hop garden and a reference to the diagram will show that its natural flow was assisted by some 20 feet of earthenware pipes with open joints which lay immediately on the Atherfield clay and at a depth below the surface which varied from two feet near the catch-pit to four feet at the end which was farthest in the hop garden (see Fig. 1). Immediately above the spot where the open pipes are nearest to the surface was a fence made of stakes driven into the ground which may have served as direct conducting channels down to the open-jointed pipes. (Parenthetically, I would remark that the danger of a dead fence in such a connexion is much greater than a hedge with living roots.) Close to this fence were deposits of fæces. The line of the spring occupies a slight depression in the ground and the natural surface drainage must have been to a spot very close to that at which the collecting pipes were shallowest. This spot was only a few yards from a path which crosses the hop garden fence by means of a stile and in short the circumstances were such that the risk of befoulment of the ground close to the collection pipes was very great[14] (see Fig. 2).

FIG. 2.

TUTSHAM IN FIELD

If the diagrams of Tutsham-in-Field be compared with those of Tutsham-in-Orchard and Ewell (Figs. 3 and 4) it will be observed that

FIG. 3.

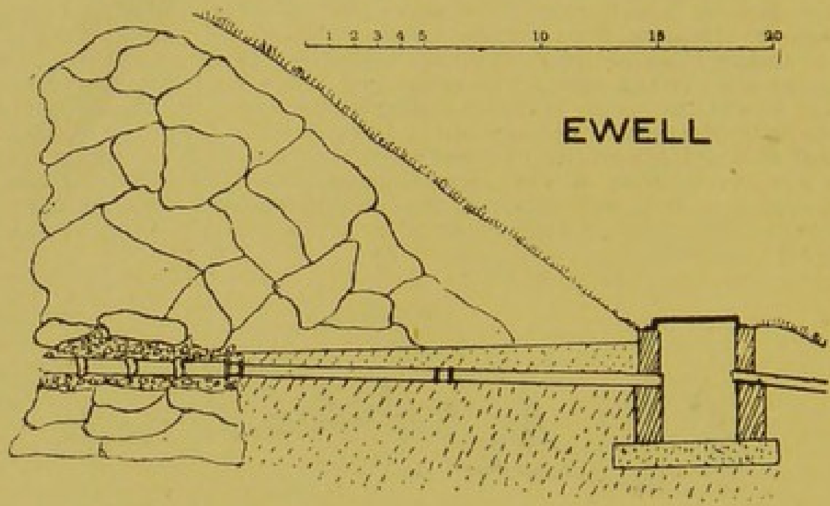


TUTSHAM IN ORCHARD

[14] In his report to the Local Government Board Mr. P. Adams speaks of this fence as a "hedge," but both the photograph and the plan show that it was a "fence." The point is not unimportant when the tendency of fences to rot at the foot is considered.

earthenware pipes with open joints are used in all of them, but while in the first-named these open joints came to within two feet of the surface they did not come nearer than five feet at Tutsham-in-Orchard and 14 feet at Ewell. The surface of the ground above the pipes was formed of turf at Tutsham-in-Orchard and Ewell. The Tutsham-in-

FIG. 4.



Orchard spring was bright and apparently wholesome and the Ewell spring appeared to be the purest water of the whole of the Farleigh group.

It must be remembered that the three feet of hop ground which covered the open jointed pipes at Tutsham-in-Field was of a sticky, clayey nature liable to crack and fissure in times of drought and there can be little doubt but that the rain which washed this spot ran with its washings almost direct to the reservoirs. Under the circumstances which existed it is very important to study the rainfall and the exact times of its incidence. It is obvious that without rain no infective material could be washed into the "spring," and it is also obvious that a short sharp shower might do infinite mischief at Tutsham-in-Field and yet be insufficient to affect the level of the subsoil water in Maidstone. Let us look at the facts of the epidemic from this point of view.

The incubative period of enteric fever is stated by the Clinical Society of London to vary between five and 23 days. I am justified, therefore, in assuming that the majority of those who might receive a dose of poison to-day would be attacked between the seventh and twenty-first day following. Between June 28th and August 7th there had fallen only 0·21 inches of rain. At the end of a dry period the delay in the distribution of water would not be great, but it is obvious that a house cistern might be charged with infective material and considerable delay might occur before the attacks, if the bulk of the household were away. After 40 days of drought rain fell to the extent of 0·44 inch on August 7th and 8th, and 0·13 inch fell on August 15th. On August 17th and 18th there was a fall of 0·53 inch, and if this rain washed infective material to the reservoir it should cause attacks between August 24th and Sept. 9th. The first attack of the epidemic is stated to have occurred on August 28th and between that and Sept. 8th there were 101 attacks. On August 26th hop-picking commenced and the population round the Tutsham spring was necessarily increased. On that day there fell 0·35 inch of rain, the heaviest fall in any one day since May 30th. The effect of this shower should become manifest between Sept. 2nd and Sept. 16th. The attacks down to August 8th have been previously given, but between the 8th and 16th there were 385 attacks. On Sept. 1st there was 0·31 inch of rain, again on Sept. 5th in the very middle of the hop-picking there fell 0·44 inch the heaviest fall since March 2nd. The effect of this should become manifest between Sept. 12th and 26th. Omitting the cases down to and including the 16th we find that between the 17th and 26th inclusive there were 625 attacks. There was 0·27 inch on Sep. 8th, hop-picking being still in progress. This would carry us on to Sept. 27th, 28th, and 29th, in which days there were 122 cases. On Sept. 18th and 19th (hop-picking having come to an end on the 13th) there fell 0·51 inch. This would take us down to Oct. 9th and we find that from Sept. 30th to Oct. 9th there were 237 attacks. On Sept. 20th the Tutsham springs were cut off, the effect of which would not be fully manifest for three weeks. On Oct. 12th the daily attacks suddenly dropped from 18 to seven.

It must be borne in mind that the Tutsham spring had presumably sent a considerable dose of muddy water to the Barming reservoir on Sept. 18th and 19th, the very day before it was cut off, when there fell 0·51 inch of rain, and the influence of this would be felt up to Oct. 11th at least. On Oct. 11th and 12th the daily attacks fell from 18 to seven and never rose again above nine. We must remember that after the Tutsham springs had been cut off there was the possibility of poison lurking in the foul Barming reservoir, the water pipes, and the house cisterns. On Sept. 29th there fell 0·83 inch of rain, a shower of tropical severity, and it is exceedingly likely that in the stirring up of the town sewers there may have been some leakage into the water service. There is no evidence on the point, but such things do happen at such times. In any case the effect of the wholesale poisoning of part of the water system which had taken place would be likely to endure for some time. It was not till Oct. 18th that the implicated water system was in great part (but not wholly) disinfected and this process was not completed entirely until Nov. 4th. The full benefit of this would show itself three weeks later (Nov. 25th). In the weekly returns of attacks (see Table I.) there were only four for the week ending Dec. 4th, as against 13 for the week ending Nov. 27th. Subsequent to Nov. 27th there were only 17 attacks.

The epidemiological facts of this outbreak are quite compatible with the theory that the dirty water supplied from Tutsham-in-Field was the main cause of the outbreak, and I do not think that the effects of the contamination could be expected to finally disappear until three weeks after the completion of the disinfection of the water service on Nov. 4th. The inspectors in their report fix Oct. 18th as the day when the influence of the Farleigh water ceased to be felt in Maidstone and they say (p. 32): "Nearly all the cases notified after Oct. 18th (some 280 in number) are to be regarded as having had a cause other than the consumption of Farleigh water." This opinion seems to imply that in the estimation of the inspectors the disinfection of the Farleigh water system which began on Oct. 16th and continued until Nov. 4th was superfluous and useless.

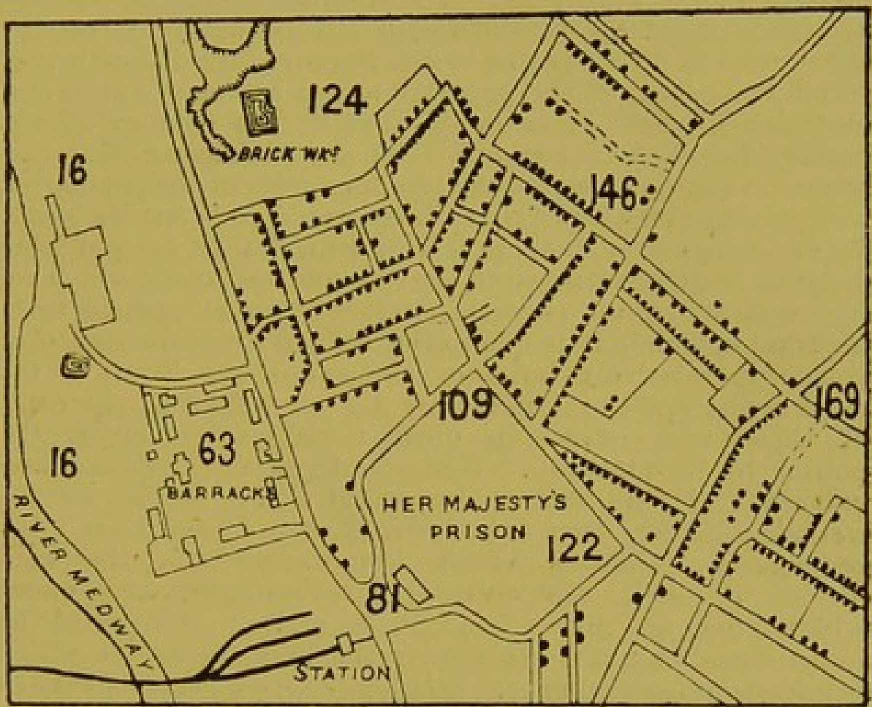
Speaking of the 280 cases they continue: "By Mr. M. A. Adams they were referred to direct infection from previous cases and to unsanitary conditions of water-closets, drains, and sewers. This explanation appears to us to be the probable one if the unsanitary conditions referred to be taken in the wide sense of including the fouling of the soil by leakage from these defective drains and sewers. Recent researches into the life-history of the bacillus of typhoid fever go to show that this organism finds in a soil contaminated with foul matters from leaky sewers, drains, and cesspools conditions especially favourable to its vitality and multiplication. *That the soil on which Maidstone stands is thus contaminated was set beyond doubt by the evidence put before us.* To the existence of these conditions is mainly, we consider, to be attributed the remarkable persistence of fever in Maidstone after the primary cause of the outbreak had been removed by cutting off the Farleigh water-supply."

Do the facts of the case really establish the conclusion which the inspectors say is "set beyond doubt"? I do not find a single word in the report or a single experiment to prove that the bacillus typhosus was growing in the soil of Maidstone. The epidemic is remarkable not only for its severity but from the fact that six gentlemen, all eminent for their skill in bacteriology, failed to discover a single typhoid bacillus. The bacteriological investigations were upon a scale which was quite unprecedented and in so far as the bacillus typhosus was concerned were entirely and absolutely negative. It may be, as the inspectors hint was the case, that the bacillus typhosus was permeating the soil of Maidstone in November, December, and January very much as a blue mould permeates a cheese, but no examination of the soil is recorded in the report. There are facts, however, which make strongly against any such contention. These were the total escape of the barracks and prison.

On page 26 of the report is the following paragraph: "The barracks and the Maidstone prison are both within the borough and both are connected with the town sewers. The population of the barracks was 300, this total including 166 men, 44 women, and 88 children. The water supplied to the barracks is that of the Boarley system of the water company's supply. No case of typhoid fever occurred in the barracks during the year. At the prison the average population throughout the year was 171, the total number of prisoners received being 1925. The water used on week days is from a well 34 feet deep sunk in the Hythe beds of the lower greensand. On Sundays water is turned on to the prison from the Boarley mains. There have been no cases of typhoid fever or diarrhœa among the prisoners or staff during the whole of 1897." During the five months (August to December) there were probably 800 persons who drank water from the 34-feet well sunk in the "contaminated" soil of Maidstone. A reference to the map (Fig. 5) will show that the area of the prison is closely hemmed in on the north and east by fever-stricken houses and the escape of the prison and barrack populations is most remarkable. Neither rise nor fall of subsoil water brought typhoid fever or diarrhœa to the prison.

The investigations connected with the Maidstone epidemic are of great interest as pointing to the wonderful protection which the humus affords to the underlying water against pollution from above. The whole of the Farleigh springs were of the same character, the catch-pits of many of them were liable to invasion in time of flood, and the gathering ground of most of them was highly cultivated and manured land. And yet none of them (always excepting Tutsham-in-Field) afforded evidence of serious bacterial impurities. It may be added that in the third quarter of 1898 there was one death from enteric fever in Maidstone and another death

Fig. 5.



"Spot" plan of surroundings of Maidstone barracks and prison. The big numerals show the height above sea-level. The black dots are fever-stricken houses.

from the same cause in the fourth quarter, so that the "contaminated" soil of Maidstone was not able to contaminate the inhabitants during the drought of July, August, and September or the rains of October, November, and December of last year.

Immunity.

Bacteriologists have abundantly proved that the germs of disease are ubiquitous. They are found in earth, air, water; in the dust and on the walls of our dwellings, in clothing, in meat, milk, bread, and even occasionally, as Andrewes has shown, in hot baked rice-pudding. With regard to most of the necessities of life we hear the cry of "unclean," "unclean," until the wonder is that we are any of us left alive to warn our neighbours. The fact that many of us manage to live to a respectable age and to die from something which is non-infective cannot but make us consider whether after all the immunity of the individual is not the fact which tends more than any other to the improvement of the public health. It is wholesome for us to remember that the greatest sanitary achievement of our time has been the practical disappearance of typhus fever. Of the *causa causans* of this disease we know nothing. Its absolute disappearance has not been produced by successful germ hunting. Its disappearance is probably due to the improved conditions under which the masses of the population live as regards food and cleanliness. Few of us doubt that if this country should become involved in war and food should become dear and scarce in consequence the relative immunity of the population would be lessened and typhus fever would re-assert its sway. Whether we succumb to an infective disease or not probably depends in great measure to the dose of the poison which we receive. When an endemic disease such as enteric fever becomes epidemic it is due to the sudden dissemination of a poison in relatively large or virulent doses. Even in the most severe epidemics it is rare for more than 10 per cent. of those who have run obvious risks of receiving the poison to be attacked. The questions of virulence and vulnerability are most important. It seems to be well-established that the virulence of some of the pathogenic microbes varies immensely with the conditions of soil, temperature, air, sunlight, &c., under which they are grown, and it is a fact that must be remembered that it is not always the pure cultivation which manifests most virulence. Many infective diseases assume a virulence in the tropics which is rarely met with in temperate countries. This appears to be true of tropical malaria, enteric fever, cholera, yellow fever, anthrax, and tetanus. In hot countries where a temperature equal to the optimum for the growth of many pathogenic microbes is often continuously maintained for weeks in succession, the risks of contagion and the danger of uncleanliness must often have become apparent in a manner more convincing than is the case among us. The repeated injunctions as to uncleanliness in the Mosaic law and the rigid rules laid down as to the conditions which made a man unclean and which necessitated his subsequent purification must have been the outcome of experience. To eat with unwashed hands in a tropical country and without knives and forks would clearly be to run considerable risks. The regulations in force among the Hindus were even more stringent, and although some of the regulations may appear to us to be extravagant and nonsensical it is impossible not to admit that most of them have for their aim the protection of the individual and his fellow man from the risks of infection.[15]

There can be no doubt that the health and vigour of the individual is all-important in relation to infective disease. The enervating influence of a tropical climate upon Europeans is recognised as a potent predisposing cause of infective disease and if to the effects of climate be added those of inordinate fatigue and insufficient food the risks of infection getting a hold of the organism are greatly increased. Director-General Jameson told us last year in the debate on enteric fever already alluded to that "in almost all the posts occupied by European troops coöperating with the various columns in Afghanistan, extending from the British territory up to Kabul and Kandahar, cases of enteric fever appeared, some of which posts were occupied probably for the first time since the world began." In the Nile expedition in 1889 those troops suffered most which had undergone most exposure and fatigue "and it becomes difficult to resist evidence tending to show that in the causation of this disease there may be more factors than are generally acknowledged." Dr. Maclean, R.N. (in a letter to Sir J. Fayrer), alludes to the occurrence of enteric fever in the Island of Ascension, under circumstances of close observation

[15] In the Abbé Dubois's book on Hindu Manners, Customs, and Ceremonies, translated by Beauchamp (Clarendon Press, 1897), will be found a chapter (vol. i., p. 238), largely culled from the great book of Brahmin ritual called "Nittia-Karma," on hygienic rules and among them a section on "Rules to be observed by Brahmins when answering the Calls of Nature." 1. Taking in his hand a big *chembu* (brass vessel) he will proceed to the place set apart for this purpose which should be at least a bowshot from his domicile. 2. Arrived at the place he will begin by taking off his slippers which he deposits some distance away and will then choose a clean spot on level ground. 3. The places to be avoided for such a purpose are, the enclosure of a temple; the edge of a river, pond, or well; a public thoroughfare or a place frequented by the public; a light-coloured soil; a ploughed field; and any spot close to a banyan or any other sacred tree. 4. A Brahmin must not at the time wear a new or newly-washed cloth. 5. He will take care to hang his triple cord over his left ear and to cover his head with his loin cloth. 6. He will stoop down as low as possible. It would be a great offence to relieve oneself standing upright or only half stooping; it would be a still greater offence to do so sitting upon the branch of a tree or upon a wall. 7. While in this posture he should take care to avoid the great offence of looking at the sun or the moon, the stars, fire, a Brahmin, a temple, an image, or one of the sacred trees. 8. He will keep perfect silence. 9. He must chew nothing, having nothing in his mouth, and hold nothing on his head. 10. He must do what he has to do as quickly as possible, and rise immediately. 11. After rising he will commit a great offence if he looks behind his heels. 12. If he neglects none of these precautions his act will be a virtuous one, and not without merit; but if he neglects any of them the offence will not go without punishment. 13. He will wash his feet and hands on the very spot with the water contained in the *chembu* which he brought. Then taking the vessel in his right hand and holding his private parts in his left, he will go to the stream to purify himself from the great defilement which he has contracted. 14. Arrived at the edge of the river or pond where he purposes to wash himself he will first choose a suitable spot and will then provide himself with some earth to be used along with the water in cleansing himself. 15. He must be careful to provide himself with the proper

where no connexion could be traced with defective sanitary arrangements, though it is probable that malarial influences did occur. "There is no such thing as a drain or a cesspool in the island, all the sewage and other filth being removed daily and thrown into the sea to leeward of all dwelling-houses. The water, partly collected from the roofs of buildings during rain and partly condensed, is stored in iron and cemented stone tanks and removed from all possible sources of contamination." It is of course possible that in a case such as this the bacillus typhosus may be lying dormant in the body ready to assert itself when bodily enfeeblement reaches a certain pitch. It has been asserted (and the assertion received the support of the late Professor Kanthack) that the bacillus typhosus may be found in an abscess years after the attack and the same thing holds good in a less degree with regard to the microbes of diphtheria and cholera.

Nothing is better established with regard to tubercle than its relation to overcrowding and unwholesome occupations. Three times as much tuberculous disease occurs in the centre of London as at the outskirts and an hotel servant in London runs a risk of dying from tubercle nearly 10 times as great as that of the farm labourer. In our combat with this disease we must by no means confine our efforts to microbe hunting. So again with "filth diseases," we must remember that almost all infective diseases are especially fatal to those who live in the midst of filthy surroundings. It is not, I think, at all necessary to assume, although it is possibly the case, that specific organisms are growing in the filth. In

kind of earth and must remember that there are several kinds which cannot be used without committing an offence under these circumstances. Such are the earth of white ant nests, potter's earth, road dust, bleaching earth, earth taken from under trees, from temple enclosures, from cemeteries, from cattle pastures, earth that is almost white like ashes, earth thrown up from rat-holes and such like. 16. Provided with the proper kind of earth he will approach the water but will not go into it. He will take some in his *chembu*. He will then go a little distance away and wash his feet and hands again. If he has not a brass vessel he will dig a little hole in the ground with his hands near the river side and will fill it with water which he will use in the same way, taking great care that this water shall not leak back into the river. 17. Taking a handful of earth in his left hand he will pour water upon it and rub it well on the dirty part of his body. He will repeat the operation, using only half the amount of earth, and so on three times more, the amount of earth being lessened each time. 18. After cleansing himself he will wash each of his hands five times with earth and water, beginning with the left hand. 19. He will wash his private parts once with water and potter's earth mixed. 20. The same performance for his two feet, repeated five times for each foot, beginning, under the penalty of eternal damnation, with the right foot. 21. Having thus scoured the different parts of his body with earth and water he will wash them a second time in water only. 22. After that he will wash his face and rinse his mouth out eight times. When he is doing this last act he must take very great care to spit out the water on his left side, for if by carelessness or otherwise he unfortunately spits it out on the other side he will assuredly go to hell. 23. He will think three times on Vishnu and will swallow a little water three times in doing so.

the cramped dwelling of the artisan where the privy is often barely six feet from the back door the risks of fæcal befoulment of the food or person are very great and when in such places large pails of fæces are left to putrefy for a week or more it is not to be wondered at that the inhabitants should show an undue predisposition to the infection of enteric fever, as has been pointed out by Boobbyer and others. But it must be remembered that wherever putrefaction is going on and wherever anaerobic organisms are growing in a filth-sodden soil unwholesome gases, such as CO_2, H_2S, CH_4, and H, are being given off and it is impossible not to admit that the breathing of these gases, from week end to week end in the crowded courts of a great city may so lower the vitality of the body as to increase its vulnerability to infection of all kinds. But these gases which are naturally given off from sewers and sewer traps, from cesspools, from privies and from water-logged and filth-sodden soil are accompanied by "odours" which are often too subtle for the chemist to analyse but which, nevertheless, are sufficiently potent to make a strong man sick and faint and to reassert themselves in the excreta 24 hours after being inhaled. The odour given off by a tropical arum at Kew some few years since during the time it was in flower and just ripe for fertilisation was of a kind which could only be described as appalling and which made it impossible to enter the house where it was growing without putting a clip on the nose and holding the breath. I merely want to emphasise the fact that odours may have a power which neither the chemist nor the bacteriologist can gauge and that we must be ready to admit that to live in stinks and filth must depress the health and increase the susceptibility to infection by microbes some of which have perhaps a greater measure of ubiquity than we are definitely aware of.

Professor Stewart Stockman[16] reports an investigation which he carried out on a septic organism which proved fatal to 380 fowls out of 400 on a poultry farm. He says: "The most important thing about this bacillus seems to me to be its fatal effect on tuberculous birds while it appears to be non-pathogenic, or nearly so, for healthy birds. It is also interesting to note that it killed a rabbit affected with the coccidium oviforme although the healthy ones were little affected by it. This observation, I think, affords fresh evidence in favour of what is taught about certain other microbes—namely, that they are only pathogenic to the enfeebled organism."

Danger of Wounds.

It is an established fact and is now universally accepted that infective organisms may gain access to the body through

[16] Veterinarian, September, 1898.

the smallest conceivable wound whether of the skin or the mucous membrane. The various forms of septicæmia as well as erysipelas and malignant œdema are due to this cause. Tetanus, as we have seen, is always due to the inoculation of a wound and it is a question whether anthrax of cattle is not more often caused by inoculation of a skin abrasion than hitherto has been suspected. Whether any of our common infective fevers are communicable by accidental inoculation is a moot point and one which is certain to receive a full share of attention in the immediate future. It is certain that in the transmission of plague a broken skin bears a most important part, and it may be that other infections may be conveyed in the same way. A distinguished pathologist is credited with having infected himself with enteric fever by a post-mortem wound. The infections brought about by flies, ticks, and mosquitoes are at present attracting much attention from pathologists and it seems probable that the danger of certain "soils" and climates may be shown to be due in an increasing degree to the insects which find in the localities the various conditions necessary for their existence. It may be that in some instances an abrasion of the skin made by an insect may merely serve as a point of entrance for infective organisms abounding in the surface of the soil or in the immediate surroundings of the individual and having no necessary connexion with the insect itself. It seems certain, however, that in the majority of instances which have been worked out a particular species of insect serves as an intermediary host for a specific organism which affects a specific animal. We hear a good deal in a loose and speculative way about flies conveying fever. This may be true, but we must always bear in mind what I feel inclined to call the excessive specialism of nature. Insects which feed on dung and carrion are seldom attracted by the food of human beings and I confess to being somewhat sceptical as to the accidental conveyance of infection by "flies" which heedlessly buzz first into the fæces and then into the milk. The pathologist of the future will clearly have to call in the help of the entomologist.

Practical Considerations.

The Maidstone epidemic has been very useful in directing attention to some of the common conditions which endanger water-supplies. Pasteur and all subsequent bacteriologists have directed attention to the value of the earth as a filter and it is a matter of common knowledge that a very shallow layer of compact earth will remove the bacteria and much of the organic matter from water percolating through it.

The greatest danger to shallow wells is to be found in subterranean collections of filthy fluids which leak through fissures in the earth and with a gradually increasing hydraulic pressure. If there be no such dangers in the immediate neighbourhood, then a properly constructed shallow well is safe. The lined well five feet deep which I have in the middle of my garden has given water of exceptional purity for years, notwithstanding that the ground is cultivated with human excreta to within six or seven feet of the well. Dr. Macmartin Cameron, medical officer of health for Kirkcudbright and Wigtown,[17] shares my opinion that a "surface well" properly constructed and in a selected situation is a safe source for water. Dr. Cameron's paper embodies much experience obtained in his official capacity and many of his observations are worthy of quotation as showing some of the limits of danger and safety in relation to shallow wells.

"*The construction of new village wells.*—When the wells of a village are shown to be contaminated and a new water-supply becomes imperative it is not, as a rule, necessary—not, at least, in the province of Galloway, for which I have the honour to be medical officer of health—to press on a gravitation scheme as the only way of meeting the difficulty. A simple and inexpensive well scheme will often suffice. All that is requisite is to sink new wells outside the precincts of the village on higher ground if practicable. Commonly enough the self-same water that feeds the old wells may be tapped at a point before it has entered the polluted ground of the village. All that is then required to secure perpetual immunity from pollution is to obtain possession of a sufficiency of ground around each well to be devoted for all time to purposes of filtration. With a sufficient reserve (anything, say, from half to one acre, according to circumstances) little or no danger will accrue from ordinary agricultural operations beyond, but it would be better that as much as possible of the outlying ground should be left under grass. There is no safer or better water than that which a surface well in an old grass park can be got to yield. This is an ideal site. I should have no fear even of a top dressing of manure, provided the ground in the immediate vicinity of the well were not profaned.

"Professor Hunter Stewart (Edinburgh) remarked that Dr. Vivian Poore's experiment with a six-feet well carefully cemented at the sides gave water which contained seven micro-organisms to the cubic centimetre and the bacillus coli was conspicuous by its absence. A part of the supply of the city (Edinburgh) was from wells near the Pentland Hills not more than eight feet deep, situated in highly manured land and exposed to pollution from neighbouring middens. From the water of these particular wells of a maximum of eight feet in depth he found a maximum of micro-organisms of 11 to the cubic centimetre and a minimum in three out of eight wells of absolute sterility. These observations abundantly supported the observations of Dr. Poore."

Reverting to the conditions which obtained at Maidstone I will mention a few considerations which, though obvious enough, are often neglected. During a drought such as occurred in June, July, and August, not only would the stiff hop land be liable to crack, but the earth-worms would retire to the lowest point in search of moisture. At such times they go deeper and deeper into the soil and lie coiled up in oval knots at the bottom of their burrows. I have upon the table a piece of a worm-burrow removed from my garden in September last at a depth of more than two feet. It is more

[17] Brit. Med. Jour., August 13th, 1898.

than a quarter of an inch in diameter and would act as a drain from the surface to the deeper parts. This question of worm-burrows is one of great practical importance to sanitarians because, especially after a drought, they may serve to conduct surface water to considerable depths without its really being influenced by that biological filter the humus. Darwin [18] says that although worms generally live near the surface they may burrow to a considerable depth during long-continued dry weather and severe cold; the depth varies with the soil.

"In a bed of fine sand overlying the chalk which had never been disturbed a worm was cut into two at 55 inches and another was found here at Down in December at the bottom of its burrow at 61 inches beneath the surface. Lastly, in earth which had not been disturbed for many centuries a worm was met with at a depth of 66 inches and this was in the middle of August. The burrows are lined with viscid earth voided by the worm which gives at once smoothness and a certain amount of durability to the burrow."

Then, again, we must not forget the effect of harvest on the soil. Before harvest the amount of moisture retained upon the growing plant and absorbed by the still active root would prevent anything except the heaviest rain from penetrating, although even at such a time one must admit that even half a pint of water if thrown on a suitable place might travel *viâ* clay-crack and worm-burrow to a depth of five feet or more. When harvest begins not only is the earth deprived of its green protecting mantle but the upward drainage of the root action ceases and with the falling temperature of autumn and the lessened evaporation the rain which falls has an ever-increasing power of penetrating the soil. In a hop garden the first step in harvesting is the removal of the pole, and the hole thus left is capable of conducting rain water to a depth in the soil of two feet or more. If, therefore, there be open-jointed stoneware pipes in a hop garden at a depth of two or three feet from the surface it is possible (nay, likely) that when the hop-poles are removed a surface channel three or four inches in diameter may communicate with these pipes and a heavy rain may wash solid matters into them from the surface.

There are other practical matters which need consideration in relation to liability of springs to suffer from surface contaminations. If a plant or tree dies—be it hop, beech, hazel or what not—the roots, instead of helping the upward drainage of the soil and preventing surface water from reaching the springs may serve as a direct guiding channel from the surface to the spring. And if the spring be artificially maintained by under-draining it with open-jointed pipes (an operation which involves a considerable disturbance of the ground and its artificial re-making) this danger is considerably increased. Burrowing animals are necessarily

[18] Vegetable Mould and Earth-worms, p. 111, *et seq.*

a danger in this connexion and if rats or rabbits establish themselves anywhere near the outcrop of a spring they must be exterminated. Rats and rabbits sometimes burrow very deeply, but I have not been able to get any authentic statement as to the maximum depth in the soil to which they may penetrate. Rats are animals which the sanitarian is bound to regard with some suspicion. In relation to the plague they seem to be a very definite danger and when they crawl from the sewers (their favourite lurking place in towns) to our houses it is possible that they may be at least as dangerous as sewer gas. Rats occasionally make their homes in dung-heaps, especially if such heaps be made in outlying places and are long neglected. It is well known that they invade corn ricks in spite of elaborate precautions, but it is safe to regard the rat as a haunter of foul places and a lover of filth and its presence among us is often due to our permitting accumulations of filth and our delay in putting filth to its proper use.

Although it is probable that a very few inches of soil may, if properly tilled and cultivated, serve as an efficient protection to the subsoil water, we must nevertheless be mindful of the accidents which may serve to conduct filth from the surface to the springs. The danger of having a catch-pit flooded from the surface is one which can easily be guarded against by covering with suitable structures. The ground above the outcrop of a spring ought to be carefully turfed to a point which is six or seven feet above the level of the spring. A spring used as a water-supply must be very carefully watched. If the water become turbid or if a worm find an entrance to the catch-pit the use of such water should be discontinued or it must be boiled and filtered until the cause of the turbidity be satisfactorily demonstrated. Such springs should always be carefully inspected during heavy rains, because it is at such times especially that shallow springs establish surface relations.

The question arises whether it is safe to allow the gathering ground of a spring to be cultivated? This is a national question of the very greatest importance. No nation which is dependent upon its native soil for food production could possibly afford to raise such a question. What would a Chinese say if you told him that the water of his well contained a trace of ammonia and had a permanent hardness above the local standard and therefore his tea-gardens and rice-fields must remain unmanured and be converted to permanent pastures? His answer to the "foreign devil" who ventured to propound such a theory had better go unrecorded. But in China they boil the water before drinking it and they do not seek to fix the responsibility for the absolute purity of the water of a district upon a single underpaid individual; nor do they talk about "manslaughter" when a break-down in the arrangements from some cause, natural or artificial, brings about an outbreak of disease.

Provided there be a fairly thick layer of earth above the spring I am inclined to think that there is safety rather than danger in the cultivation of the overlying soil. Any spring which is covered by seven feet of soil—that is, six inches more than the depth of the deepest recorded earth-worm, might be considered safe from the risk of unchanged organic matter soaking into it from above.[19] In the first place, the cultivation of the land ensures that it is visited more or less frequently by individuals more or less intelligent. A gathering ground for water which is remote from the haunts of man has dangers of its own. Rats or rabbits may burrow in it and these as well as other animals and birds may provokingly die in the runnels which primarily collect the rainwater and I cannot understand how anybody who has ever walked over a moor can maintain the thesis that water running off a neglected waste is safer to drink than that which has percolated through well-cultivated land.

Last year I visited a spring which was being used for public purposes and which was and had been supplying water of excellent quality. The spring which rose in a little copse lying in a natural dell in a remote and seldom visited spot was enclosed and protected against surface washings which the configuration of the ground would certainly conduct towards it in times of flood. Some of the trees were dead and their stumps and roots were permeated with fungi and were rotten and one could not but regard it as possible that these rotten roots might serve as conducting channels from the surface to the water which was running beneath to the neighbouring town. Possibly the workings of rabbits or other burrowing beasts had hastened the death of some of the trees. If so, the burrows might run very close above the gathering water. Further, there was evidence to show that this dell was visited by an occasional tramp and had been made a playground by the children from the nearest group of cottages. It is clear that the non-cultivation of this particular spot was a source of danger rather than of safety to the purity of the spring.

Enteric fever is a disease especially liable to become epidemic in the autumn. The autumn is the time of year when after removal of the crops the parched earth is soaked and it is also the time of year when there are large accumulations of manurial matters waiting to be spread upon the land. In the summer the yield of springs is seldom increased no matter how heavy may be the rains. The water which falls upon the earth is all absorbed by the roots of growing plants and to a large extent mounts upwards in the plant to help metabolism and to quicken growth. With the ripening and harvesting

[19] For the same reason, although I agree with Dr. M. Cameron, I am of opinion that the first eight feet of all "shallow" wells should have an impermeable lining.

of the crops root action ceases, water which falls upon the earth tends more and more to percolate, and when the early frosts have given their death-blow to the greenery of summer then the springs begin to rise and to yield more water. The nitrification and final solution of organic matter in the soil goes forward mainly, if not entirely, in the upper layer and it is doubtful if any appreciable amount of oxidation takes place in the parts which are beyond the reach of tillage. A certain proportion of the mineralised organic matter necessarily escapes absorption and percolates with the water and if there be much unused nitrates remaining in the soil after harvest the amount which percolates to the springs may be considerable. If nitrates be placed upon the soil in the form of artificial manures they are often dissolved and washed beyond the reach of plant roots with the first heavy shower. Not only nitrates but soluble salts of ammonia are placed on the ground in large quantities and the presence of free ammonia in the drainage water of cultivated land which has been *artificially* manured need not be an indication of pollution in the proper sense. It must be very hazardous to draw just conclusions as to the wholesomeness or otherwise of water from the amount of nitrates in it.

LECTURE III.[1]

AGRICULTURE.

MR. PRESIDENT AND GENTLEMEN,—The facts with which we have been dealing in these lectures show :—1. That there are certain organisms which are indigenous to the soil and ubiquitous. These organisms, if they contaminate a surgical wound or are inoculated, may cause septicæmia, erysipelas, malignant œdema, or tetanus. They are very possibly necessary saprophytes, and we recognise that it is useless to attempt to "stamp out" the germs of these surgical contagia, although (thanks to Lord Lister) the surgeon is able to protect his patient from the evils which arise from them and to prevent their cultivation in hospitals. Apart from accidental inoculation these organisms are not dangerous. We must often swallow them with our food and drink and inhale them with our breath and no practical harm results. These contagia are persistent in the soil and are probably most common in soils which are richest in organic matter. 2. The contagium of anthrax is apparently difficult to eradicate from a soil which has once been contaminated with it. This is probably due to the fact of sporulation and to the spore being very resistant to external influences of all kinds. The evidence, such as it is, points to the fact that in temperate countries at least the contagium dies out of the soil in time. M. Pasteur's experiments were vitiated by the circumstance that they were made in districts where the disease was and had been rife. More information is needed as to how far the infection of animals depends upon wounds of the skin or mucous membrane and on the vulnerability of the animals by the mal-hygienic conditions in which they live. It is possible that in tropical countries the bacillus anthracis is indigenous to the soil. Man apparently does not acquire anthrax by inhaling or swallowing pulverised earth. He is always infected through the medium of infected animals or their skins, flesh, or wool. 3. To what extent malaria is directly a soil disease, apart from the mosquito as a connecting link, is in the present state of our knowledge doubtful. There is no doubt, however, that malaria disappears before drainage and cultivation. 4. With regard to enteric fever, diarrhœa, plague, and some other diseases there can be no doubt that they are all favoured by filth although we are ignorant of the precise way in which filth favours the occurrence of these diseases. Some might say that a filth disease is a soil

1 Delivered on March 2nd, 1899.

disease and that there is no line of demarcation between the two. This is true, but it is nevertheless very necessary for practical purposes to distinguish the one from the other. We are all agreed that it is dangerous to allow the purlieus of a house to become sodden with liquid filth, but it might be equally dangerous to the public health to encourage the idea that it is dangerous to dung the land for fear of inoculating it with infectious disease. Happily, from the laboratories we get comfort in this matter. Sidney Martin has shown (as Dempster had previously shown with regard to peat) that "virgin soil," whether sandy or peaty, is, even when sterilised, fatal to the bacillus typhosus, and one naturally asks, What is virginity? and whether cultivated soils by excessive production do not tend, paradoxical as the question may sound, to return to that condition of virginity in which they are able to grapple with infective organisms? The evidence goes to show that cultivation and production are the enemies of dung infections. Robertson and Gibson found that a growth of grass was fatal to the bacillus typhosus. That dung contagia must be destroyed or their virulence be diminished by tillage is self-evident. Were it otherwise our race must long since have been extinguished. The race which has shown the greatest persistence in this world (the Chinese) is precisely that one which has systematically inoculated its native soil with dung contagia for three or four millennia. Politically they are said to be sick but physically and economically they are "going strong" and are likely to continue. 5. The fact that most of the alleged soil diseases are more rife in the crowded centres of population than in the rural districts is a fact which must not be lost sight of. Whether this be due to the greater vulnerability of town populations or to the soakage of the purlieus of the house from leaking sewers it is difficult to say. In any case it is incontestable that soil diseases (so-called) are most rife precisely in those spots where the ground is not cultivated.

Infective organisms contained in dung have to run the gauntlet of many enemies, such as dogs, sparrows, rats, flies, maggots, beetles, earthworms, moles, sunlight, fresh air, innumerable saprophytes (both aerobic and anaerobic), and the chemical action of the roots of plants. Of course, there may be spores which emerge from these ordeals unharmed and still virulent, but it is evident that, being mortal as we are, they are likely to succumb before the digestive and disintegrating processes which they encounter. The bulk of the evidence goes to show that contagia must be largely destroyed in the soil and that agriculture is really the cornerstone of preventive medicine. It becomes of great importance, therefore, to devise means by which the fertilising material of our towns may be applied to the soil with safety and despatch.

I may be pardoned for reverting to the method of dealing with human excreta which I have practised now for 12 years in my experimental garden at Andover: (1) the excreta are moved every day so that there is no accumulation of filth near the dwelling; (2) they are put just below the surface of freshly-dug ground so that they are out of the reach of flies; and (3) the ground is planted with plants of the cabbage order as quickly as may be so that very soon there is no possibility of dust being blown off the surface of the ground, and the mass of living cabbage leaves freshens the air. I cannot believe that dust from agricultural land is a danger in this country whatever it may be in the tropics. In my garden the ground treated in the manner stated, apart from the growth of cabbages, soon becomes coated with a green growth of alga. Mr. A. Gepp of the Natural History Museum who visited my garden last summer took some of this growth away and very kindly examined it and he pronounced it to be an alga—"chiefly vaucheria sessilis (in good fruiting state) with a little ulothrix, a gloeocystis, and an oscillatoria." Such a growth effectually prevents the possibility of dust.

Dr. Samuel Hyde[2] speaking on the Open-Air Treatment of Consumption says: "Sparseness of vegetation, like thinness of population, is a climatic factor favourable to the treatment of consumption. Where vegetable life abounds there vegetable decomposition must also abound and *vice versâ*. Wherever there is life we have a corresponding amount of death accompanied necessarily by the products of decomposition." This is quite true and our experience teaches us that, provided the supply of food be adequate, a high level of health may be maintained in places where there is little or no vegetation, as upon the sea and on alpine heights and in arctic solitudes. "Wherever there is life," says Dr. Hyde, "we have a corresponding amount of death." That is true, but the converse is also true and we may say that wherever there is death we have the potentiality of a corresponding amount of life. I believe that what I have called the circulation of organic matter is a beneficent fact from which there is no escape and that whether we derive good or ill from the inevitable processes of death and decay depends very much upon ourselves. We must never forget that vegetation purifies the soil, freshens the air, rests the eye, and prevents dust, and these facts must be recognised as to a great extent counterbalancing the evils of dead leaves.

There are always *pros* and *cons* which have to be weighed. Nothing makes entirely for good or entirely for evil and we have always to balance our accounts and to see whether the general effect be good or ill. The British sanitarian is so circumstanced that he need not trouble himself at all about the most important of all sanitary considerations—viz., food-supply. He is busy in burning or washing into the sea every kind of fertilising matter, and if a general coal strike or a war were to suddenly bring famine with its attendant diseases to our doors he would protest that that was no concern of his. With our steadily diminishing birth-rate and the daily increase of institutions for the reception of

2 Brit. Med. Jour., Oct. 8th, 1898.

those whose moral, mental, or physical diseases prevent them from earning their own living it is difficult to believe that the stamina of our highly civilised urban populations is increasing. Apart from the question of food-supply, it is, I believe, absolutely necessary to encourage agriculture in order that our race may be maintained in vigour. The strong contrast which exists between the agriculturist and the town worker in the matter of health is well known.

Dr. Tatham's letter to the Registrar-General on the mortality of males engaged in certain occupations in the three years 1890–92, which constitutes Part II. of the Supplement to the Fifty-fifth Annual Report to the Registrar-General, shows clearly enough that the agricultural classes in this country enjoy a large measure of health. Dr. Tatham's statistics refer to occupied males between the ages of 25 and 65 years and the tendency to disease and death is indicated by a mortality figure, the mortality for all males between 45 and 65 years of age being taken as 100. The following table taken from p. 18 of this report shows the mortality of three great classes of the community with perfect clearness.

Table (deduced from Table IV.) showing the mortality from certain specified causes in each of three sections of occupied males, as compared with that among all occupied males, the mortality of the latter being taken as 100 in each case.

—	All occupied males.	Occupied males, London.	Occupied males, industrial districts.	Occupied males, agricultural districts.
All causes	100	120	131	72
Influenza	100	100	100	100
Alcoholism	100	138	146	54
Rheumatic fever	100	100	114	86
Gout	100	300	100	100
Cancer	100	134	109	91
Phthisis	100	150	121	73
Diabetes	100	114	100	100
Diseases of the nervous system	100	107	132	77
Diseases of the circulatory system	100	107	122	75
Diseases of the respiratory system	100	124	166	51
Diseases of the liver...	100	111	119	89
Other diseases of the digestive system	100	100	129	82
Diseases of the urinary system	100	137	122	78
Accident	100	86	105	79
Suicide...	100	129	114	86
Other causes	100	91	130	76

The following table which is deduced from Table IV. shows the mortality from certain specified causes in the agricultural class as a whole and in its several divisions as compared with the standard mortality among all occupied males, the latter being taken as 100.

—	All occupied males.	Occupied males in agricultural districts.	Agricultural class.	Agriculturists in agricultural districts.	Farmer, grazier, &c.	Farmer, grazier, &c., in agricultural districts.	Farm labourer.	Labourer in agricultural districts.	Gardener, nurseryman.
All causes	100	72	63	64	59	53	66	70	58
Influenza	100	100	109	112	115	112	112	118	82
Alcoholism	100	54	31	31	46	31	31	31	31
Rheumatic fever	100	86	86	71	86	71	71	57	100
Gout...	100	100	50	50	50	100	50	50	50
Cancer	100	91	82	84	82	77	82	86	82
Phthisis	100	73	57	63	43	44	62	70	61
Diabetes	100	100	86	86	143	157	71	71	57
Diseases of nervous system...	100	77	62	63	62	50	65	71	57
Diseases of circulatory system	100	75	66	68	61	52	71	75	61
Diseases of respiratory system	100	51	52	49	41	29	58	57	48
Diseases of the liver	100	89	63	59	96	81	48	56	63
Other diseases of digestive system	100	82	82	75	96	75	79	75	64
Diseases of urinary system	100	78	59	59	71	68	51	56	63
Accident	100	79	63	68	53	54	74	77	39
Suicide	100	86	71	71	100	129	57	50	71
All other causes	100	76	73	76	65	61	79	86	61

Out of the 16 causes specified in this table, there is only one in which the mortality of agriculturists as a class exceeds that of occupied males generally. The exception is influenza, the mortality from which disease shows an excess equal to 9 per cent. The chief excess under this heading probably occurred in the first quarter of the year 1892, which was marked by a severe outbreak of influenza specially affecting the country districts. The mortality among agriculturists from phthisis does not exceed 57 per cent., and that from diseases of the respiratory system does not exceed 52 per cent. of the standard mortality among occupied males, and their mortality from all other diseases of the local class is considerably below the same standard.

These tables show conclusively that agriculturists are among the healthiest class in the community and that even the farm labourer in the matter of health is 33 per cent. better than the average. This is a matter of great interest and importance. He is often represented as half starved, miserably housed, a martyr to rheumatism, and poisoned by filthy water. As a matter of fact as regards sobriety and health he might be taken as a model by the rest of the industrial classes. There is another point of view from which agriculture is of great importance. We are beginning to find out that a factory hand who has to keep pace with steam machinery becomes "too old for his work" at a comparatively early age. Defects of eyesight or hearing or a lessening of acuteness and nimbleness soon unfit a man for employments where dexterity is of more importance than experience. There has been much talk of late of "old age pensions," but it must be admitted that even if the financial difficulties of the question could be overcome the prospect of being *without employment* and existing on a pittance without any true interest in life after the age of 55 years is not cheerful. I believe that the practice of agriculture is the only remedy for this and that the best old age pension will be found in the possession of an acre or so of land. Not only are the ordinary horticultural operations all possible for a man long after he is capable of attending to machinery but such a possession would give him an interest in life and he would find that the productiveness of his land would certainly increase with time and in direct proportion to the amount of skill and labour expended in tillage and cultivation and the quantity of organic manure placed upon the soil.

The greatest need of our country at the present day I believe to be an increase in the facilities for the transfer of land. Many of the above facts appear to show that the practice of agriculture is absolutely essential, apart from the question of food, for the maintenance of the vigour of our race. Anything which discourages or increases the difficulties of agriculturists can hardly be in the interests of the public health.

The Maintenance of the Fertility of the Soil.

There is much evidence to show that dung is absolutely necessary to maintain the fertility of the soil. In a paper by Sir John Lawes and Sir Henry Gilbert on the valuation of unexhausted manures[3] the difference between organic manures and mineral manures is well brought out. The lasting effects produced by farmyard manure (14 tons to the acre) are shown in the annexed table.

[3] Journal of the Royal Agricultural Society, vol. viii., 1897, p. 674.

TABLE I.—*Experiments with Farmyard Manure on Permanent Grass Land.*

—	Unmanured every year.	Manured 1856–63; unmanured since.	Excess of manured over unmanured.
	cwt.	cwt.	cwt.
8 years 1856–63 } 1st crops only	23¾	42⅞	19⅛
12 years 1864–75 } 1st crops only	19⅝	32⅞	13¼
20 years 1876–95 (1st and 2nd crops)	25⅞	29⅞	4

In only one year—1893, a year of drought—did the manured plot give less produce than the unmanured. The authors say: "It is true that the application of 14 tons of farmyard manure per acre per annum for eight years in succession is an unusually heavy dressing; but it is of interest to know that the residue was very materially effective for some years, and that it was more or less so for THIRTY-TWO YEARS after the application" (the capital letters are my own). The following table giving experiments with barley tells the same tale.

TABLE II.—*Experiments with Barley 1852–96.*

—	Unmanured every year.	Mixed minerals every year (no nitrogen).	Farmyard manure.	
			Every year.	20 years 1852–71; unmanured since.
	Bushels.	Bushels.	Bushels.	Bushels.
20 years 1852–71 ...	20	27½	48¼	48¼
25 years 1872–96 ...	12⅞	16⅞	49¼	29

The above table shows that the effect of the farmyard manure is very appreciable for at least a quarter of a century. It also shows that when farmyard manure was used every year the yield for the final 25 years was greater than in the first 20 years. It also shows that the increase by using mineral manures without nitrogen is appreciable but slight. The use of rape-cake as an organic manure for barley gave interesting results which are set forth in Table III.

TABLE III.—*Rape-cake as a Manure for Barley 1852–91.*

—	Rape-cake alone.	Rape-cake with mixed mineral manures and nitrate of soda.
	Bushels per acre.	Bushels per acre.
20 years 1852–71 ...	45¼	49¾
„ „ 1872–91 ...	37⅛	41¼

It is to be noticed that the reduction in produce in the second 20 years as compared with the first amounted to more than eight bushels per acre. The reduction in the second 20 years was, in the opinion of the authors, mainly due to less favourable seasons, but nevertheless it is shown that the yield with farmyard manure for the 25 years 1872–96 was 49 bushels as against 48¼ for the 20 years 1852–71. The experiments made in growing clover on rich garden soil are of great interest. This has been done for 40 years in a part of the Rothamsted kitchen garden which has been in cultivation for two or three centuries. The average yield for the 40 years was 59¼ cwt. or nearly three tons of hay which "would be a very good yield for the crop grown only occasionally in the ordinary course of agriculture." The average yield in the first 10 years was much greater than in the subsequent 30 years and averaged 95½ cwt. and the maximum yield appears to have been about 148 cwt., or nearly seven and a half tons to the acre. In 1857, after the removal of the crops of the fourth year of the experiment, the surface soil nine inches deep contained four times as much nitrogen as the average of the Rothamsted arable soils to the same depth and nearly five times as much as the exhausted arable land where red clover had failed. The experiments on wheat with artificial manures are equally instructive.

TABLE IV.—*Showing the Yield of Wheat in Bushels per Acre.*

Period.	Mixed mineral manure— Alone.	And NH_3 86 lb. N.	And NH_3 129 lb. N.	And NH_3 172 lb. N for first 13 years (1852–64); unmanured for last 19 years.
	Plot 5	Plot 7	Plot 8	Plot 16
13 years 1852–64	18⅜	37⅛	39	39⅛
19 years 1865–83	13⅛	29¾	34⅜	14⅝

In the above experiments we find, no dung being used, that the yield is less in the second period than in the first, and that when the large amounts of artificial manure were withdrawn in Plot 16 the yield dropped almost at once. The authors say: "There is, in fact, abundant evidence to show that there is but little effective manure residue after the growth of a grain crop by the application of ammonium salts; and there is little doubt that the produce of one and a half bushels of grain and its straw per acre per annum more over the 19 years after the cessation of the application of ammonium salts than on Plot 5 with the mineral manure alone is, so far as it is to be attributed to residue, mainly due to the increased *crop residue*—stubble and roots accumulated during the 13 years of the application; and much the same may be said of the after-effects when grain crops have been grown with nitrate of soda." Again: "When organic matter, animal or vegetable, is applied to the soil as manure its complete decay and the complete liberation of its fertilising constituents extend over a considerable period of time. Poor land cannot be suddenly brought into *condition* by the consumption on the farm of purchased foods. Nor can condition—that is, accumulated fertility—be at once withdrawn by suddenly stopping the use of foods."

Food-supply.—Sir William Crookes, the President of the British Association, in his address (Bristol, 1898) drew attention to the fact that if population continued to increase we might expect to be short of wheat. Our remedy was to increase the fertility of the wheat-growing area of the world and, taking, as was perhaps but natural, a purely chemical view of fertility, he put forward the proposition that the productiveness of the soil might be expected to bear a direct ratio to the amount of fixed nitrogen which is applied to it and he found comfort in the fact that after the exhaustion of the nitre beds of Chili and the guano beds of Peru the chemist of the future would be able by the aid of electricity generated by Niagara and other natural forces to fix the atmospheric nitrogen for the benefit of the farmer. In the course of his address Sir William Crookes made allusion to the sewage question in the following words:

"There is still another and invaluable source of fixed nitrogen. I mean the treasure locked up in the sewage and drainage of our towns. Individually the amount so lost is trifling, but multiply the loss by the number of inhabitants and we have the startling fact that in the United Kingdom we are content to hurry down our drains and watercourses into the sea fixed nitrogen to the amount of no less than £16,000,000 per annum. This unspeakable waste continues and no effective and universal method is yet contrived of converting sewage into corn. Of this barbaric waste of manurial constituents Liebig nearly half a century ago wrote in these prophetic words: 'Nothing will more certainly consummate the ruin of England than a scarcity of fertilisers—it means a scarcity of food. It is impossible that such a sinful violation of the divine laws of nature should for ever remain unpunished, and the time will probably come for England sooner than any other country when, with all her wealth in gold, iron, and coal, she will be unable to buy one-thousandth part of the food which she has during hundreds of years thrown recklessly away.' The more widely this wasteful system is extended, recklessly returning to the sea what we have taken from the land, the more surely and quickly will the finite stocks of nitrogen locked up in the soils of the world become exhausted. Let us remember that the plant creates nothing; there is nothing in bread which is not absorbed from the soil, and unless the abstracted nitrogen is returned to the soil its fertility must ultimately be exhausted."

Sir John Lawes and Sir Henry Gilbert in a communication addressed to the *Times* on Dec. 2nd, 1898, point out that even supposing that atmospheric nitrogen could be fixed at a remunerative price, the addition of nitrates without the addition of the other mineral constituents necessary for wheat growing would be of no permanent use; but they express the opinion that the stores of nitrogen and other fertilising salts existing in our own soils and the soils of foreign countries can be made available by thorough tillage and proper rotation of crops. The land wants labour and the production of wheat is likely to be proportionate to its market value. They point out that the average wheat production of the *unmanured* plot at Rothamsted (over 13 bushels) is greater than the average of the whole of the United States, a fact mainly due to proper tillage and thorough weeding.

It is tolerably evident that fertility is not merely a chemical question. The year 1898 was remarkable for a fine wheat crop in this country. The yield is said to have averaged 35 bushels instead of 28 or 29 bushels per acre. Sir John Lawes, in his annual letter to the *Times* (Oct. 22nd, 1898) on "The Wheat Crop of 1898" states that at Rothamsted the yield on the experimental plots was as under :—

TABLE V.—*Wheat Crop in 1898.*

—	Bushels per acre.	Cwts. of straw.
Plot 3, unmanured	12	12⅛
Plot 9, nitrates	23¾	33⅞
Plot 7, ammonia salts	28⅝	44⅝
,, 8, ,, ,, ...	29⅝	54⅝
Plot 2, farmyard manure	38	55¾

In 1898 at Rothamsted the plot dressed with nitrate of soda yielded 23 bushels, as against 38 bushels on the farmyard plot, and in explanation Sir John Lawes says: "For only the second time during a period of more than 40 years the wheat plant was much injured where we have used the heaviest dressing of nitrate of soda for want of enough rain to form and distribute a sufficiently dilute solution of it; and a similar result occurred in the year of drought of 1893; whilst in this year, 1898, the barley plant was much injured with only half the amount of nitrate applied." Sir John

Lawes also gives the average yield of these five plots for periods extending over 46 years.

TABLE VI.—*Wheat Crop, 1852–97.*

—	Un-manured.	Farm-yard.	Ammonia salt.	Ammonia salt.	Nitrate of soda.
36 years 1852–87	13	33¾	32¾	36½	36¾
10 years 1888–97	12¼	40¾	34¼	37⅞	33⅞
46 years 1852–97	12⅝	35¼	33⅛	36¾	36⅛

From the above table it will be observed that not only has farmyard manure proved to be practically the equal of artificial manures for nearly half a century but that during the last ten years the yield from it has been considerably more than that of any of the artificially manured plots. It is interesting to observe, also, that had the wheat-growing area of this country in the year 1898 been sprinkled with nitrate of soda after the manner of Plot 9 at Rothamsted the yield might have averaged only 23 bushels instead of 35 bushels. On 2,000,000 acres, which is approximately the wheat area of the United Kingdom for 1898, this means a deficit of 24,000,000 bushels or 3,000,000 quarters. The chemical analysis of a soil often fails to give the clue to its fertility or sterility. Mr. Robert Elliot, in a paper on "The Value of Plant-roots as Tillers of the Soil,"[4] quotes Sir John Lawes to the effect that "All our experiments tend to show that it is the physical condition of the soil, its capacity for absorbing and retaining water, its permeability to roots and its capacity for absorbing and radiating heat, that is of more importance than its, strictly speaking, chemical composition." It is, in fact, abundantly evident that the biological side of fertility is quite as important as the chemical and that organic manures are absolutely necessary to maintain the fertility of the soil, and that of all organic manure there is nothing to be compared with dung. If all that comes from the land be returned to it there can be no reason why the agriculturist should trouble himself with chemical theories. He has only by labour to maintain the soil in a good physical condition and he may rest assured that its fertility will increase.

SANITATION IN HOLLAND.

In Holland the connexion of *sanitation* with agriculture is far closer than with us and it is possible that we may

[4] Journal of the Royal Agricultural Society, vol. viii., p. 469.

derive some useful hints from our neighbours. In Holland the sanitary problems are of a formidable kind. The level of the country varies from a few feet above to a few feet below the mean level of the German Ocean, and it is needless here to recount how the Dutch people, marvellous for their shrewdness and untiring industry, have maintained a successful warfare against the forces of nature. With the exception of two or three inconsiderable areas the whole of the Kingdom of the Netherlands is a flat plain intersected at very frequent intervals by canals and rivers. These watercourses are all sluggish and in some of them the slow current is maintained artificially by pumping. It may be said that every Dutchman lives within a few yards of a watercourse of some kind, be it ditch or canal. These canals form a very cheap and admirable means of internal communication and in consequence the barge population is very large indeed. The population of Holland tends steadily to increase, such increase being most marked in the big towns.

In no country in Europe, probably, has the state of public health improved more remarkably than in Holland. This is well shown by the following table which is taken from the "Annuaire Statistique de la Ville d'Amsterdam," 1896. The decline of the death-rate has been uniform and continuous since 1884, but for the sake of conciseness the years 1877, 1880, and every fourth year thereafter alone have been given.

Nombre des décès (mort-nés exclus) par 100,000 habitants de la population moyenne dans les cinq grandes villes des Pays-Bas, années 1877-96.

Années.	Amsterdam.	Rotterdam.	s'Gravenhage.	Utrecht.	Groningen.	Les 5 villes.
1877	25,00	25,32	21,66	23,91	29,51	24,70
1880	27,00	24,65	23,38	27,10	24,39	25,74
1884	27,87	27,01	24,87	26,38	22,00	26,67
1888	21,82	21,26	20,11	22,56	20,04	21,38
1892	19,78	23,26	20,32	23,84	17,27	20,89
1896	17,77	18,27	16,27	19,04	16,01	17,65

The causes of this improvement in the death-rate are probably the same as have operated throughout Western Europe generally. These causes are: (1) the improvement in the physical and moral condition of the lower strata of society; (2) sanitation in its widest sense; (3) the rapid increase of population especially in the towns, causing a dilution of the high death-rates in the old crowded portions by the lower death-rates of new settlers in the outskirts; and (4) the decrease in the birthrates. In Holland, as in England, the importance of pure water, especially for town populations, is abundantly recognised, and public supplies have within recent years been carefully protected from pollution and filtered before being distributed. The risk of drinking canal water must have been very great indeed. The mode of dealing with fæcal matters is necessarily different from ours. In Holland water-closets are the exception and not the rule and while the slop water of the houses is allowed to flow into the canals the fæces are collected and used for agricultural purposes. During a visit to Holland in September, 1898, I was able to obtain the Dutch death-returns for 1885-89 and for 1889-94, a period of 10 years in all. For this I have to thank Mr. Verryn Stuart, the secretary of the Statistical Commission at The Hague, who most courteously procured for me the volumes containing the returns in question.

The Netherlands.

Provinces.	1885—1890.			1890—1894.		
	Total deaths.	Deaths from typhoid and typhus fevers.	Proportion of typhoid and typhus fevers to total.	Total deaths.	Deaths from typhoid and typhus fevers.	Proportion of typhoid and typhus fevers to total.
North Brabant ...	60,436	245	1 in 247	62,808	257	1 in 244
Guelderland	53,706	313	1 ,, 171	55,713	308	1 ,, 181
South Holland ...	110,964	563	1 ,, 197	112,139	462	1 ,, 243
North Holland ...	90,959	621	1 ,, 146	89,494	713	1 ,, 125
Zealand	20,456	93	1 ,, 220	20,390	125	1 ,, 163
Utrecht	25,837	166	1 ,, 156	26,098	184	1 ,, 142
Friesland	31,851	263	1 ,, 121	30,893	227	1 ,, 137
Overyssel	33,765	280	1 ,, 120	34,145	238	1 ,, 143
Groningen	25,594	253	1 ,, 101	25,988	237	1 ,, 110
Drenthe	13,653	90	1 ,, 152	14,564	107	1 ,, 136
Limburg	26,352	100	1 ,, 263	28,701	125	1 ,, 229
Kingdom	493,573	2987	1 ,, 165	500,933	2983	1 ,, 168
1885-94 Kingdom	994,506	5970	1 ,, 166	—	—	—

Taking the population for 1885-94 at 4,500,000 the average annual death-rate is 18·26 and the typhoid fever and typhus fever death-rate is 0·13 per 1000.

It will be observed that in Holland generally the death-rate from enteric fever compares favourably with our own.

Knowing as we do the great risk of drinking sluggish water liable to fæcal contamination (which has been exemplified in the Tees valley) the low enteric death-rate in Holland is not a little remarkable. Enteric being a fever of slow and insidious onset it is impossible in sporadic cases to say where or how the patient may have been infected and in cities with an ever-shifting population this difficulty is accentuated. That being the case it will not be without interest if I give a few particulars concerning the provinces of Groningen and Friesland which I visited in the vacation of 1898. These two provinces are almost entirely devoted to dairy farming, the breeding of horses and cattle, and agriculture. The shifting and travelling population is a small one and it is here if anywhere that we may learn the effect of local habits and customs on the public health.

The town of Groningen with 63,863 inhabitants is in point of population the fifth town in Holland and a reference to the table will show that the improvement in its death-rate in the past 20 years has been as remarkable as that observed in the other Dutch cities or in any town or city in this country. In this town as also in Leeuwarden, the capital of Friesland, and in the great majority of Dutch towns the fæcal matter is collected in pails and it is probable that in the whole extent of the two northern provinces of Groningen and Friesland there is not a water-closet to be found. The whole of the fæcal matter is scrupulously and religiously collected and returned to the soil. Dutch cleanliness is proverbial and certainly I have never been in a town so exquisitely clean as is the town of Groningen. The accumulation of ordure in the streets and backyards is simply not tolerated and the inhabitants coöperate with the scavengers in clearing away all refuse as quickly as possible. The collection of fæcal matter is very simple. The closet-pails are much smaller than those which are commonly used in this country and they are emptied twice or thrice a week or daily if the householder is ready to pay a small fee. The collecting cart is really a tank upon wheels with a sort of hood projecting behind like the hood of a carriage facing the wrong way. The pails are brought out, and the man and pail are hidden by the hood as the contents are simply tipped into the tank. The pails even when full being such as one man can lift easily the collection is probably ten times as rapid as is the case in those English towns which make use of huge two-man pails which weigh 50 lb. and more when empty. Again it is obvious that the Groningen authorities do not make the mistake of hauling about an immense weight of pails which adds enormously to the expense. The depot where the material is collected is on the outskirts of the town where a wharf has been constructed with a view to its removal by barge for the purposes of the farmer. Here, again, the arrangements are very simple. The stuff is simply stacked beneath rough sheds covered with corrugated iron. The men employed have found out exactly how to do it and by arranging a layer of street sweepings and rubbish (dung, straw, paper, rags, &c.) with peat ashes (the fuel used in this district is almost exclusively peat) alternately with a layer of pail contents the whole mass drains and consolidates into a very rich black manure which the farmer highly appreciates. The floor of the depôt is concreted and provided with channels so that the urine drains away into a large tank whence it is pumped into barges for the use of the agriculturist. Considering the work which went on in it, this depôt was wonderfully neat, the stacks were as evenly made as the best hay stacks, and the paths between them were quite free from befoulments. The smell from the putrid draining was, to say the least, powerful but the solid stuff soon ceases to be very offensive. There were large numbers of flies in this depot but I frequently remarked that the flies in the town of Groningen were not nearly so troublesome as is the case in cities less carefully scavenged.

In the town of Leeuwarden the pails are taken to and from the depot but the pails are much smaller and lighter than those in use in England so that 54 of them (three tiers of 18 each) can be carried on a one-horse lorry. In the 10 years 1885-94 there were in each of the provinces of Groningen and Friesland 490 deaths from enteric fever and typhus fever, 980 deaths in all or an average of 98 per annum in a population of some 600,000, giving a rate for typhus fever and enteric fever of 0·16 per 1000. During the same period there were 97 deaths from the same cause in the town of Groningen and 27 in the town of Leeuwarden, or 124, giving a yearly average of 12·4. These figures are not large but they show that as regards these diseases the condition of Groningen was slightly worse than the town of Leeuwarden. As in England so in Holland, the death-rate from enteric fever has been falling steadily and the returns for the last available year (1897) are very instructive. From these returns I find that in the province of Groningen with 296,521 inhabitants there were 23 deaths from enteric fever in 18 parishes, giving a death-rate of 0·08, and in the province of Friesland, with 339,425 inhabitants, there were 19 deaths from enteric fever in 12 different parishes, giving a death-rate of 0·056 per 1000. It is a remarkable and most interesting fact that in 1897 there was no death from enteric fever in either of the capital towns of Groningen or Leeuwarden, containing over 95,000 inhabitants (Groningen 63,863 and Leeuwarden 31,598).

The figures given above must be taken to show that in these two provinces there is no serious endemicity of enteric fever. When we consider that dairy farming is the staple industry of these provinces, that milk which is most sensitive to typhoid fever infection is everywhere abundant, and that human excreta containing a certain proportion of typhoid fever excreta are used, and have been used for ages, to manure this fertile district, which lies almost in the water, the comparative freedom from enteric fever seems remarkable and very full of instruction.

These facts seem to me to afford a very large measure of proof that there is no inherent danger in the methods of sanitation pursued in Groningen and Friesland and, in fact, in Holland generally. Dutchmen are eminently shrewd, thrifty, industrious, and methodical. The interiors of their dwelling-houses and cattle-houses are, as a rule, exquisitely clean and neat and on the farm one is constantly confronted with the same characteristics. In the agricultural districts nothing is ever thrown into the ditches or watercourses. On the contrary, everything is taken out of them that can be turned to profit. These ditches must be kept clean and the banks of them need constant attention. The banks are kept in repair largely by the mud which is removed from the ditch and whatever the ditch will grow in the shape of rush or weed or willow is all carefully harvested and turned to account for thatching or for litter or for basket work. The Dutch farmer never feels the effect of drought and this is one secret of his success. His endless watercourses serve for fences and afford a cheap and ready means of transport. They are a source of small profit in various ways and most certainly they are never allowed to carry away from the farm anything which possesses manurial value. The methods of the Dutch agriculturist are slow and sure and steady. He has had to contend with the forces of nature and has got the upper hand and is now ahead of the whole world in exacting labour and profit from wind and water.

It is very difficult to appraise the fertility of a district. The area of Friesland is given as 331,030 hectares, of which 206,718 are pasture and 47,317 are arable. These 254,035 hectares of land under cultivation are farmed by 14,049 farmers, of whom 5374 are freeholders. The average holding would thus appear to be 18 hectares or about 43 acres, and as one travels through the province the substantial farmhouses appear to be dotted over the country with something like mathematical precision and the cattle (of which there were 233,582 in the province in 1897) appear to be innumerable.

Groningen contains a considerable amount of waste land. The pastures are less extensive than in Friesland and there is a greater area under the plough. In 1897 I find that in Groningen 7351 hectares of wheat produced 35 hectolitres per hectare; 4702 hectares of barley produced 41 hectolitres per hectare; and 33,135 hectares of oats produced 57 hectolitres per hectare. These returns are large and are the equivalents of 40 bushels of wheat to the acre, 46 bushels of barley to the acre, and 65 bushels of oats to the acre. Agricultural returns for a single year are not, perhaps, of great value but these figures show at least that the land is capable of an enormous yield. The yield of oats especially appears to be very large.

The returns issued by the Board of Agriculture show that in 1896 we imported from Holland 923 horses, 663,196 cwt. of dead meat, over 500,000 cwt. of butter and cheese, 861,887 cwt. of margarine, 217,891 cwt. of milk and condensed milk, 375,116 bushels of fresh fruit (apples, pears, cherries, plums, &c.), and 1,581,386 bushels of onions. In addition we imported from Holland 509,710 cwt. of grain and 40,127 tons of hay and no mention is made of the horticultural products in the form of "Dutch bulbs," &c., which we import in enormous quantities.

In the United Kingdom of Great Britain and Ireland there are, including waste lands, 77,672,000 acres supporting a population of 40,000,000, and in Holland there are (excluding lakes and rivers) 7,786,000 acres supporting 4,894,000, so that Holland supports a bigger population per acre than the United Kingdom. In the United Kingdom the area under cultivation (crops and grass) amounted to 47,868,553 acres in 1897 and this figure appears to be slightly decreasing. In Holland in 1895 the total area under crops and grass was 5,149,817 acres, showing an increase of 95,000 acres in the preceding three years. In the United Kingdom there are 1·2 acres of cultivated land per head of the population and in Holland there are 1·05 acres of cultivated land per head of the population. Statistics prove that Holland is a most fertile and productive country, but one requires to travel through it in order to be fully impressed with the extraordinary amount of produce which the Dutchman exacts from the soil. In Groningen and Friesland one cannot but be struck with the well-to-do look of the population. If there be wretchedness and squalor it is not visible to the traveller and must be, in any case, relatively small in amount. The people are well nourished and well clothed, the towns are handsome and clean, and the shops are excellent. Perhaps no better evidence of the high-level of comfort which pertains in this purely agricultural country can be given than the fact (which I take from "Baedeker's Guide") that the town of Leeuwarden with 31,000 inhabitants supports 25 firms of jewellers and silversmiths who are mainly engaged in making personal and household ornaments for the farmers and their families. Let it not be supposed that the Dutchman owes his position of agricultural supremacy to the "natural" fertility of the soil of his country. Doubtless he has found a large amount of well-watered pasture land ready to hand, but it is undeniable that some of the very best of his land has been won from the sea, the desert moorland, and the bog, by indomitable pluck and perseverance. Above all, the Dutchman is fully impressed with the necessity of returning to the soil everything that comes out of it. Nobody knows better how to facilitate that circulation of organic matter which is a law of Nature and he sees that his profit depends upon the completeness and rapidity of that circulation and that in farming as in other businesses a rapid turnover of capital is to be aimed at. In Holland everything which has manurial value is religiously returned to the land and we find that the population is increasing as fast as ours and that the land under cultivation is increasing although the area of land is less per head in Holland than in the United Kingdom. The level of public health is as high in Holland as in the United Kingdom and an enormous amount of farm, garden, and dairy produce is exported to this country where (albeit that many a tract of bog and waste moorland is waiting for the subjugation of civilisation) the land under cultivation is tending to decrease, where manurial wealth is being recklessly burnt or turned into the sea, and where one-half of the population is absolutely ignorant of the uses and value of dung and the other half is, if not ignorant, too squeamish to use it.

The municipal accounts of the city of Groningen for the year 1897 show that the total cost of keeping the city clean was 94,596 florins (12 florins = £1). The chief items of this expenditure were:—

	Florins.		Florins.
Salaries and wages	50,615	Disinfectants	263
Horse hire	21,441	Sundries	4,177
Repairs to carts	4,507	Clearing snow	11,281
Boat hire	1,500	Total	94,596
Brooms	812		

As a set-off against this expenditure the accounts show that the compost resulting from the stacking of ordure and refuse, which amounted to 1315 barge-loads, was sold for 58,075 florins, and the liquid manure which drained from the stacks and which is much valued by agriculturists was sold for 5339 florins. The total receipts from the sale of manure amounted, therefore, to 63,414 florins, which, deducted from 94,596, gives 31,182 florins (say £2600) as the net cost of cleaning Groningen. Taking the population of Groningen at 63,863, the cost of scavenging works out at something less than half a florin, or 10*d*., per head of the population. It will be noticed that of the total expenditure (exclusive of clearing snow) very nearly two-thirds go in wages, a great part of which is paid to the poorest class and must in some degree essen the poor-rate. It appears that the permanent staff consists of 102 persons, of whom 56 with 28 horses and carts are engaged mainly in collecting ordure, and 20 people with 10 horses and carts in collecting ashes and refuse. For cleaning sewers, canals, gutters, and gratings 19 men are employed. The collection of ordure is done in the early morning before 10 A.M.

Carrington Moss.

This seems to be the place in which to allude to the spirited action of the city of Manchester which has reclaimed Carrington Moss and which is about to reclaim Chat Moss by fertilising the ground with the organic refuse of the city. The ground is a virgin peat which is admitted to be deadly to one at least of the supposed earth organisms. The experiment is a splendid one and will certainly be the precursor of similar action elsewhere. I have gathered some figures which may give an idea of the gigantic task with which the cleansing committee of the city have to grapple. From the report of the Cleansing Department of the city of Manchester for 1897 I find that 354,364 tons of refuse—very nearly 1000 tons a day—were disposed of. Stated in cartloads there were of street sweepings, 61,248; of "Bell dust," 9823; of rubbish, 97,658; and of night-soil, 240,781; total, 409,510. Of the material collected nearly one-third of the weight is lost by evaporation (in the preparation of concentrated manure), leakage, and drainage, and nearly 100,000 tons find their way to the rubbish tip, so that about 140,000 tons remain to be accounted for. Of this 49,342 tons were sent to Carrington Moss and over 57,000 tons were disposed of to farmers direct. Over 6000 tons of concentrated manure (made from 108,000 tons of "daysoil" or pail-closet contents) sold for more than £17,000. Nearly 19,000 tons were converted to mortar and were sold for £4500 and some 9000 tons of clinker were used for road-making. The net expenditure of the cleansing committee in 1897 amounted to £131,793 so that the 354,364 tons of refuse were dealt with at a cost of 7*s*. 5*d*. per ton. The total cost for the year of the Carrington estate (including rent and interest of capital) was £2482. The material sent to Carrington in 1897 consisted of 37,082 tons of nightsoil, 587 tons of sweepings and garbage, and 11,673 tons of cinders. The Carrington Moss estate, therefore, regarded merely as a dumping ground for garbage and refuse, must be a source of satisfaction to the Cleansing Department of the city of Manchester.

On August 11th, 1897, I visited Carrington Moss and had the advantage of being shown over it by Mr. McConnell, the bailiff. Carrington

Moss was bought by the Manchester Corporation in 1886. It is 10 miles from the city, in close proximity to the famous Chat Moss from which it is separated by the Manchester Ship Canal which serves for the transit of material from Manchester. The estate, for which the corporation gave £38,000, has an extent of 1100 acres, of which 600 were wild moss commanding a rental of a shilling an acre for sporting rights. The corporation has spent £56,000 on light railways, roads, drainage, rolling-stock, buildings, &c., making the cost £94,000. (The outlay on the estate is given as £82,946 in the City Treasurer's Abstracts, 1897.) In the nine years 1889-97 491,686 tons of refuse material have been placed upon Carrington Moss, or very nearly 50 tons per acre per annum. The moss has been drained by a series of deep trenches with nearly vertical sides cut at regular intervals. The refuse as it arrives from Manchester is transmitted by means of a light railway to various part of the estate where for the most part it is placed in heaps and allowed to "ripen" before being placed upon the ground. These heaps soon cease to be in the least offensive. Nightsoil is frequently applied directly to the fields. At the time of my visit two barges estimated to contain 80 tons of refuse were unloading at the little wharf which has been especially constructed. The hay harvest was just over and the corn harvest was soon to commence. The crops one and all were in splendid condition. Oats, potatoes, carrots, wheat, and all the other usual farm crops appeared to be first-rate, quality excellent, quantity enormous. The roads were hard and firm having been brought to this condition by the application of clinker and other forms of hard material from the city. The farm is not quite a dead level but the inequalities of the surface are very slight so that from every point the spectator is able to survey an area of very considerable extent. Without previous knowledge there was nothing in the appearance of the farm (except the deep trenches) to indicate the character of the subsoil. All indications of bog had completely vanished. On reaching Mr. McConnell's house we walked out upon a pretty lawn surrounded by a flower-border brilliant with carnations and the ordinary garden plants. The lawn was firm and perfectly dry and I was not prepared for the demonstration which I was to have of the character of the subsoil. Taking an iron rod having a length of 11½ feet and a diameter of about half an inch Mr. McConnell with one hand drove it through the turf of his lawn completely up to the handle. I then did the same thing. As the rod passed through the first foot or so there was some resistance and a sense of grittiness was imparted to the hand, but this first obstruction passed the descent of the rod was progressively easier until it was finally stopped by the handle resting on the lawn. On withdrawing the rod the lower half was found to be wet while the upper part was dry. To the upper half clung a little grit and peaty earth, the lower half was clean but wet. It was then only that one recognised that this fertile paradise was literally floating.

Mr. McConnell informs me that Carrington Moss is everywhere about 12 feet in depth and that the variations in depth are very slight; whereas Chat Moss, although distant only a few miles, has a depth which varies from four to over 30 feet. On Chat Moss where the digging of drainage trenches was in progress I examined the peat which had been removed. These trenches are dug to a depth of about four feet to begin with. The peat near the surface had the ordinary fibrous character, whereas that from the bottom appeared to the naked eye to be smooth and structureless and saturated with moisture. It looked like brown jelly. The moss resembles a huge sponge. Mr. McConnell states that the surface of Carrington Moss is gradually sinking; that whereas when first he came to live on the estate he could, from a certain point see the spire only of a neighbouring church, he can now see the slates upon the roof. The sponge is being squeezed and drained, and rendered more compact. The half million tons of garbage which has been placed upon the surface must exercise considerable pressure and must serve to squeeze moisture into the deep trenches. Then, again, the upward drainage of the abundant crops is obviously very large indeed. The amount of moisture retained and evaporated by an acre of oats or mangel must be very great.

There are, as yet, not many trees upon the estate, but part of it, about 43 acres, is used as a nursery for the shrubs required for the parks and cemeteries of Manchester. These nurseries appeared to be most flourishing and contained a large variety of shrubs. The rhododendrons were extremely vigorous. Mr. McConnell assured me that the farm as a place of residence is by no means damp and that the rain which falls upon his lawn quickly drains away to the reservoir beneath and leaves the surface dry. He and his family and the employés on the farm have always enjoyed excellent health. There has been one case of enteric fever in nine years, the cause of which is doubtful.

Of the 1100 acres of land occupied, 372 acres are farmed by the committee, 639 acres are let to tenants, and the rest is occupied by roads, wharves, plantations, &c. The rental of the portion which is let amounts to £1516 19*s*., or about £2 7*s*. 6*d*. per acre, while the rent of the amount retained by the corporation is put in the accounts as £933 (i.e, £2 10*s*. per acre for the 372 acres farmed, or just £2 if the roads, &c., be included). In the year 1897 on the 372 acres farmed by the corporation there were produced : clover and clover hay, 430 tons ; carrots, 250 tons ; oats, 5500 bushels ; potatoes, 2500 loads ; swedes, 90 tons ; mangolds, 90 tons ; and straw, 200 tons. The value of this produce would appear in the accounts for 1898. In the year ended March 31st, 1897, the value of the farm produce amounted to £3632 or about £9 15*s*. per acre while the net profit on the farm appears to have been £1041 or £2 16*s*. per acre. The amount paid in wages was £1520 and the rent, as stated, was £933. If we may assume, as we have every right to assume, that the land rented was as productive as the land retained by the corporation, then the value of the produce of the 1011 acres under cultivation would, at £9 15*s*. per acre, amount to £9864 and we then arrive at the conclusion that each of the 49,342 tons of refuse sent to Carrington Moss in 1897 produced almost exactly 4*s*. worth of food. But now that the Moss is entirely reclaimed it will not take more than 30 tons of stuff to the acre, or, say, 30,000 tons per annum. Thus by a well-considered expenditure Manchester has provided itself with (*quâ* refuse) a destructor capable of dealing with about 100 tons per diem for ever and in its formation this machine has absorbed nearly half a million tons of refuse of which the city had of necessity to be rid at all costs. When the loans necessary for the purchase and development of this estate have been paid off it is certain that Carrington Moss Farm will cost the Manchester ratepayer nothing and will probably yield a return in crops of about 6*s*. 8*d*. for every ton of refuse used. Land which produced nothing and which let for 1*s*. per acre has been made to yield nearly £10 worth of produce and an eventual rental of £2 10*s*. per acre. This is a grand result and one of which Manchester may well be proud.

I am well aware that in farming, where results depend so largely upon the weather, it is hazardous to calculate returns on the yield of a single year, and that anything under a 10 years' average is likely to mislead. On the other hand, £10 worth of produce from an acre of land is no excessive return. My visit to Carrington Moss left upon me the impression that much of the land is ready to pass, as some has already done, from the hands of the farmer to that of the market gardener. In that case, when oats, grass, and carrots and mangels give place to fruit and high-class vegetables, it is certain that, with a market like Manchester at its door, the money value of the crops in Carrington Moss may be doubled or quadrupled. There is probably no city in the world where excreta are dealt with by methods other than water-carriage on so large a scale as they are dealt with in Manchester. In 1897 the city had an area of 12,911 acres ; it contained 534,299 inhabitants living in 105,728 dwelling-houses, or rather over five persons to a house. There were 76,913 pail-closets, presumably used by some 384,565 persons who provided 189,585 *tons* (nearly 425,000,000 lb.) of "pail contents." It would appear from the Cleansing Committee's accounts (p. 36) that at the Holt Town Works 108,394 tons of "day soil" were converted into 6304 tons of concentrated manure, and that for the production of this manure were used 4897 tons of coal and coke and 1674 tons of chemicals. Adding the weight of the chemicals to the weight of the "day soil" we arrive at the fact that 110,068 tons of raw material and chemicals were reduced to 6304 tons by the aid of 4897 tons of coal. Or we may say that 6571 tons of fuel and chemicals produced 6304 tons of manure from 108,394 tons of raw material. The amount of water and other volatile matter driven off amounted to to 103,764 tons. The price paid for chemicals (£5098) and fuel (£675) amounted to £5773 while the net profit on the sale of manure amounted to £2081 (p. 15).

It is instructive to compare the Holt Town Works concentrated manure accounts (p. 14–15) with the Carrington Moss Farm accounts (p. 28–31). At the former a turnover of £30,533 resulted in a profit of £2081, or rather more than 6½ per cent., while at the latter a turnover of £6202 resulted in a profit of £1041, or very nearly 17 per cent. Turning to the City Treasurer's Abstracts we find that whereas the Holt Town Works (p. 50), upon which the outlay has been £111,318, are now valued at £71,429, the Carrington Moss estate, upon which the outlay has been £82,946, is now valued at £118,617, so that while £39,889 of capital have been lost at Holt Town £35,671 have been made at Carrington.

Conclusions.

I have brought forward a considerable number of facts to prove that the dangers of applying dung to the soil are as nothing in comparison with the advantages—advantages which have been acknowledged from the dawn of historic time till now. It remains to say a few words on the financial side of the question. The great experiment at Manchester seems to prove conclusively that even in a huge city and with the heavy outlay which seems to be inseparable from all modern municipal undertakings a well-considered scheme of application of offal and ordure *in a dry state* to the soil is the most economic way of getting rid of it. I have shown how in Holland great cities may be kept spotlessly clean and in spite of obvious difficulties the public health be maintained by a well-devised system of scavenging. The cleanliness of Groningen is a thing which is scarcely realisable by one whose ideas of street sanitation are acquired in the West End of London, and the economy with which the scavenging is accomplished seems astounding to the London ratepayer. I have further shown that Holland with a smaller area of cultivated land in proportion to population than England is able to export to this country enormous quantities of farm and dairy produce and that while the English farmer can scarcely exist the Dutch agriculturist thrives and grows rich.

It will not be uninteresting, perhaps, if I give some of the financial results of my small experiment at Andover which is now in its fourteenth year of trial. In this experiment the ordure and house refuse of about 100 persons have been removed and applied *daily* for gardening purposes. The amount under the spade is now exactly one acre one rood and seven poles and I should like to say that the quantity of fæcal matter at the disposal of my gardener by no means satisfies him. I am also convinced that the garden might take with advantage at least double the quantity if not more. There is no evidence after a long experience that the soil is overdone. On the contrary, its "condition" has steadily improved. The produce of my garden has been sold on the principle of profit-sharing, so that the gardener is interested in extracting the greatest amount of produce from the soil. During the past year careful accounts have been kept, and I find that the produce fetched £71 19*s*. 6*d*., which works out to £56 per acre. Of this sum £41 12*s*. 7*d*. were received for fruit and £30 6*s*. 11*d*. for vegetables. Some of the chief items were as follow:—Apples and pears, £18 0*s*. 6*d*.; summer fruit, £17 1*s*. 11*d*.; peaches (out-door), £3 19*s*. 2*d*.; potatoes, £6 3*s*. 4*d*.; cabbage and cauliflower, £5 18*s*. 3*d*.; tomatoes (out-door), £2 3*s*. 0*d*.; asparagus, £2 1*s*. 1*d*.; and flowers, £2 2*s*. 5*d*. The method of agriculture which I pursue is well known, but this has caused no prejudice against the garden produce, which finds a very ready market.

Except in the vacation I certainly do not visit Andover more than once a month. My experience leads me to say that it is to me almost inconceivable that the daily scavenging of our towns should not yield enough profit to pay the wages. It is especially to be noticed that the yield of this garden has undergone steady increase and I have every hope that such increase will continue. But it would be a great mistake to suppose that an acre of ground cultivated and manured as my garden is is going to yield £50 worth of produce per annum at once. The test of true gardening is *increase*. With the lapse of years and without appreciable cost the increase of fruit trees is automatic and the yield of seeds is equally automatic and prodigious. My garden has gradually become fully furnished and to a large extent with its own offspring, and in that fact lies part of the secret of its increasing yield. What we see in the London parks in the summer is not "gardening" but a beautiful display, after the manner of the bouquetiste, of the results of gardening elsewhere. In the same way the filling of flower beds with a crowd of named and fashionable plants bought for the season is not gardening but a mere evidence of wealth. The real gardener in these cases is the nurseryman.

The gradual increase in the yield of a plot of land, at least for a very long series of years, is limited only by the amount of skill and tillage which it receives and the amount of dung which is available for it. All evidence goes to show that organic manure in the form of dung is absolutely necessary for the maintenance of the fertility of the soil. We are gradually becoming alive to the fact that fertility is a biological question rather than a chemical question. To imagine that chemicals can ever replace dung is a pure delusion from which we shall some day be aroused. The success or failure of agriculture is very largely a question of dung and it must be admitted that the dung prospects in this country are very bad indeed. Imported animal food yields very little dung for the land because it is mostly washed (ultimately) into the sea, while steam-engines and motor cars and bicycles must mean a diminution of horse dung. The sanitary pioneers of half a century ago thought that the huge expenses of modern sanitation would be compensated by the yield from sewage farms. That has proved to be a delusion. Sewage has proved to be merely the happy hunting ground of sanitary tradesmen who have fattened on the ratepayer. The century closes with the spectacle of a Royal Commission still discussing the best way of *destroying* the potentialities of life and prosperity.

In these lectures I have brought forward many facts to show that there is no proof of any danger arising from the use of dung for agricultural purposes, while it is undeniable that the practice of agriculture is pre-eminently healthy and invigorating. I have been unable to find any evidence that contagia spread in the soil. To live in filth and to inhale the products of putrefaction given off from privies or pails of fæces or sodden ground results in disease, but there is no evidence whatever that disease thus generated is able to spread through the soil and infect a neighbouring house or street. Looked at in another way we must admit that filth disease like many other forms of disease is proportionate to overcrowding. We may pave the backyard and provide it with a trapped gully (not always sweet) and we may wash the fæces into a ventilated sewer which then delivers part of its vapours near our bedroom windows. It is a difficult problem and there are *pros* and *cons*.

While we exult (not always reasonably) in our diminished death-rate, let us not forget the diminished birth-rate, the multiplication of asylums of various kinds, and the steady increase in the amount of help from public funds which is necessary to maintain the health and decency of the masses. The year just ended has been unsurpassed in the volume of trade and in the bounty of the harvest, but the infant mortality in our towns for the Michaelmas quarter was the highest on record. Yes; there are *pros* and *cons*. At present he who advocates any attempt to entice a fair proportion of the people "back to the land" is regarded as a Utopian dreamer. I feel convinced that the only chance of getting a living from agriculture lies in the due enrichment of the soil. There is no chance of this so long as the only form of sanitation which receives any official encouragement is one which involves a systematic starvation of the soil. One sometimes comes across statements which would lead one to suppose that cultivated land is a public danger—statements which are mere assertions. Some of our sanitarians careless of food-supply, are liable to be dominated by ideas and to fix their attention unduly upon one side of a question and upon one disease. The more enthusiastic of them, if they can secure a trifling diminution in the mortality of one disease, seem quite ready to "make a solitude and call it peace."

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