EXTRACTS FROM
THE CAVENDISH LECTURE
ON
SOME POINTS IN THE ETIOLOGY OF
TYPHOID FEVER.

Delivered before the West London Medico-Chirurgical Society.

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WHILST the zymotic death-rate has declined in a very marked manner in Dublin, and in British and Irish towns generally, there has not been a corresponding reduction in the mortality ascribed to typhoid fever; on the contrary, in some towns it has remained stationary, or even shown a tendency to increase. In Birmingham, for example, it has not declined, and in Belfast and Dublin it has increased. In Dublin typhoid fever causes a greater waste of life than in any English town, except St. Helens, and in Ireland is only exceeded by Belfast. Both Dublin and Belfast are rather low-lying cities, situated upon the estuaries of rivers, and at present are badly drained. The persistence of typhoid fever in so many towns in which other zymotics, notably small-pox and typhus fever, have died out or are dying, indicates that the sanitary measures hitherto adopted have had less effect upon this fever than upon other infective maladies.

Rodet and Roux have stated very positively that the typhoid bacillus of Eberth is merely an altered and virulent form of the bacillus coli communis described by Escherich. Their researches seem further to show that this bacillus, which may exist in the human organism without injury, can become highly virulent and infective when introduced into water, hence they conclude that not only typhoid dejections, but simple faecal pollution of water, may produce typhoid fever in those who drink it. This view would seem to favour Murchison's pythogenic theory, but they really differ completely. In the latter it is assumed that the toxic principle of typhoid fever may originate in decomposing faecal matter, but, according to Rodet and Roux's theory, a harmless sacrophytic organism acquires by mere contact with water new and infective properties.

It seems not improbable, then, that an organism which can exist for at least some weeks in earth and water is the *materies morbi* of typhoid fever. The organism may be harmless until it has undergone certain transformations in the system, or it may be immediately infective. The condition of soils or water has little relevancy to such affections as gonorrhœa, typhus fever, or measles, and most other of the infective diseases; but it has a great deal to do with remittent, intermittent, and typhoid fevers—perhaps, also, with dysentery and diphtheria. The connection between the sinking of ground water and the occurrence of typhoid fever has been investigated with great care by Professors Pettenkofer and Buhl, of Munich. They found that the cases of typhoid fever increased whilst the ground water was sinking, and that they were most numerous when the water, having been unusually high, sank rapidly to the lowest level. This theory has been supported by many eminent epidemiologists and by others.

Localised outbreaks of typhoid fever can frequently be directly traced to the use of a particular supply of polluted water or milk, but the widespread epidemics of this disease, and even its persistent occurrence in so many towns, must be due to some other cause or causes. For example, in Dublin it was epidemic in 1891-2, and in 1889 it appeared in all parts of the city and adjacent districts. The city and all its suburbs, with one exception, are supplied with water procured from a gathering ground twenty-six miles distant, in a moun-

tainous region of the county of Wicklow. There are very few persons living on the drainage shed which furnishes the Dublin pipe water, and of those few nearly all reside in a small village close to a reservoir in which the water is impounded. Last year it was asserted that a portion of the drainage of the village passed into the reservoir, but the statement was refuted. I believe there are few cities in the world supplied with such good water as Dublin fortunately possesses. I make this statement from the result of many careful examinations of the reservoir and its surroundings, and of hundreds of chemical and biological examinations of the water. There are very few wells now in Dublin, and only an almost infinitesimal proportion of the water drunk by the inhabitants is obtained by those sources. The one suburb of Dublin (Rathmines Township, population 27,410), which has an independent supply of water derives it also from a pure source, the gathering grounds being districts in the Dublin Mountains, composed of granite and silurian rocks. In Rathmines typhoid fever prevails much to the same extent as in the other townships which are placed under similar conditions as regards site and drainage.

The street sewers in Dublin are of excellent construction, and many of the more important ones have been recently reconstructed. Unfortunately at present they deliver their contents into a tidal river (the Liffey) which bisects the city. The mouths of the sewers are provided with valvular gates, which close and open as the tide in the river rises and falls. Some of the sewers are sealed up for the greater part of the twenty-four hours, and consequently their contents accumulate, and have to be in part removed by the usual methods of pumping them up to a higher level, from whence they are run into the river. The sewers are provided with the usual ventilators, which allow a free communication between the street air and the sewers. Dublin is a low-lying city; the floors of the basement stories of houses are not above the level of the highest tides, and some are actually below it. It is evident, then, that the soils, subsoils, and rocks in the low-lying districts of the city have but a poor natural drainage, and that for a large portion of the day drainage is altogether suspended, except from the more elevated parts of the city into the lower. There is much stagnation of the water in the ground. A railway which, passing over the Liffey, connects the Dublin and Kingstown Railway with the Great Northern Railway, has recently been constructed. In sinking for foundations for the many bridges required by this line, a good opportunity for examining the nature of the subsoils and rock was afforded. I took advantage of it. I found that near the river the deep-lying gravel was more or less filled up with mud, which often possessed an offensive odour, and even evolved sulphuretted hydrogen gas. The water taken from the excavations was loaded with organic matter, and literally teemed with micro-organisms. Fraenkel found a similar condition of things in the soil of Berlin near the river Spree. In the case of stagnant water in wells he found that when first pumped up it contained 10,800 microbes per cubic centimetre. After pumping up 500 litres the number of microbes fell to 54 per cubic centimetre. The following day, however, the water when pumped up first gave 7,000 microbes per cubic centimetre, which number fell subsequently to 42. Dr. P. F. Frankland, F.R.S., found that water which contained when collected 7 microbes per cubic centimetre included 495,000 when kept for three days.

All this shows the wonderful development of microbial life which takes place in soil water. But in the soil itself aerobic and anaerobic organisms are also to be found in vast numbers. Duclaux found two millions of them per centigramme of the upper soil. A study of the distribution of typhoid fever in Dublin would seem to show that there is a relation between it and the geological character of the soil. Dublin and its suburbs are built partly upon stiff clay, partly upon gravel, resting upon hard rock or clay. The gravel bed was once the bottom of the sea, and now consists of raised ancient sea beaches. One thousand nine hundred and eighty cases of typhoid fever have, so far as I can ascertain, occurred in Dublin during the ten years ended in the year 1891. Dr. Grimshaw, Registrar-General for Ireland, has ascertained the number of persons living upon the gravel and also upon the clay. I have placed in diagram form the facts relating to typhoid distribution in Dublin:—

	Population of the City of Dublin by 1891 Census.	Cases of Typhoid Fever in 10 years ended 1891.		Ratio of Cases to Population.
		No.	Per cent.	
Living upon gravel soils ...	76,259	813	0.41	1 in 94
Living upon the clay ...	168,782	1,167	0.59	1 in 145
Total ...	245,041	1,980	1.00	

The prevalence of typhoid fever in Dublin in 1889 and 1891 was by many persons attributed to the use of oysters, and, for a time, so great was this oyster scare, that the sale of the mollusc nearly died out. In Belfast the same idea prevailed, but not so generally. I have repeatedly detected sewage in oysters taken from the shores of Dublin Bay. It is possible that salad, radishes, and other vegetables taken from an infected soil might be the vehicle of the disease if eaten without being perfectly washed. Although infected food may cause cases of typhoid fever in Dublin, it is not probable that they are more numerous there than elsewhere; we must, therefore, look for some other more common source of the disease than infected water, milk, and other foods. Of course, the house drains may be blamed, and in a large proportion of the houses in which it occurs defects are detected. On the other hand, the disease constantly makes its appearance in houses where no defects can be detected. The w.c.'s, house drains, and street sewers do not vary much from year to year, and when they do vary it is generally because they are improved. In the soil, therefore, we must look for the cause of the endemicity of typhoid fever in Dublin and in other places. The streets of Dublin have lately been to a large extent paved with stone setts, which circumstances may, perhaps, account to some extent for the increase of typhoid fever. The underground air cannot now diffuse into the atmosphere over the roadway, and therefore may be drawn in larger quantities into the houses, the basement floors of which are rarely concreted.

[The lecturer here made some experiments which exhibited in a novel and striking manner the diffusion of air through soils.]

Hoffmann¹ has pointed out that there is in porous soils what he terms a superficial zone of evaporation, in which the moisture varies from saturation to zero. In the hot summer weather the zone is considerable in extent, and when rain descends on it, after a period of heat and drought, it is often capable of retaining the whole of the latter without its lower border becoming wet. In such there is always a dry layer between the surface part which is temporarily wetted by the rain and the deeper strata in which the water lies. Under these conditions the impurities which reach the soil become deposited in the dry zone; under this zone is situated a layer which is always wet. When the upper zone is filled with rain the amount of water in the second zone remains constant, for any excess which it may receive passes down into the third zone, or that of the underground water. If the typhoid bacillus exists in the first zone it must alternately be immersed in water and in air. In the former case it remains in the soil, in the latter it may be transported to the atmosphere by air currents. The deeper the ground water sinks the greater will be the extent of the zone in which the movements of organisms can take place; but even while the ground water is sinking the outermost layer of soil may be kept moist by slight and long-continued rain. In this case, however, large the dry zone, none of its organisms would escape from it into the air.

During the winter and early months of the year the surface soil, and often all the layers beneath it, are so wet that but few, if any, organisms can escape from it. There is very little difference in Dublin between the rainfall of the different quarters of the year, but in the summer the water which falls upon the ground is not only carried off by drainage but it is largely evaporated. In the latter part of summer and in the autumn the superficial layers of soil often become sufficiently dry to permit of the passage through them of micro-organisms. The autumn and early winter are the periods during which typhoid fever attains its maximum, and the majority

of writers on the subject agree that the disease often becomes epidemic after an unusually hot and dry summer. I admit that the chances of detaching micro-organisms from most surfaces are slight, but it must occur now and again.

A very fascinating theory is that which assumes that the micro-organisms which cause disease are saprophytes which have acquired, under at present unknown conditions, toxic properties. This theory fits in better with our knowledge of malaria and typhoid fever than with that of most of the other zymotic diseases. It would, perhaps account for the great variety of forms which the disease assumes.

As typhoid fever presents considerable diversity, not only in individual cases but in its epidemics, it is only reasonable to suppose a similar variety in the microbes which produce it. This may account for the somewhat conflicting accounts which bacteriologists have given in reference to the micro-organisms found associated with the disease.

I must deprecate the common practice of referring every case of disease to polluted water, defective sanitary accommodation, or leaking sewers. The fact is undoubted, that an improved water supply in Dublin has not been followed by a diminution of typhoid fever. The expeditious and efficient removal of the excreta and other objectionable matters from our dwellings is certainly a point of prime importance. I have waged war against the privies and ashpits of Dublin for the last ten years, and have now got rid of by far the greater number of them. London is a city in which the water carriage of excreta is general, but it is fairly free from typhoid fever. Bolton, Preston, Salford, and other towns where w.c.'s are few, have excessive typhoid fever death-rates.

I attribute in part the prevalence of typhoid fever in Dublin to the system of storing excreta in pits generally having a mere clay bottom. This practice (continued for centuries) has ultimately caused the soils to become impregnated with filth and its organisms. The development and retention of those organisms are favoured by the circumstances that sub-soil drainage of a large part of the city is very defective; I attribute in part to this condition of the soil the undue amount of typhoid fever to which I have so often referred. A main drainage scheme has recently been adopted by the Corporation, and will soon be commenced. I have every hope that when in operation for some time it will materially lessen our typhoid fever death-rate. I look to its thorough drainage and its freedom from pollution as the two important means of lessening the amount of typhoid poison in it. As the microbes can only escape when the outer layer of soil is dry, it is well to prevent dust rising from the roadways by having the latter well watered in hot and dry weather. The most important preventive measure is to keep the soil from pollution by faecal matter, or any kind of organic matter upon which microbes could develop. We should be as careful not to pollute our ground as our air. I am convinced that typhoid fever is often caused by underground air entering our dwellings. This may be to a great extent prevented by having even the thinnest layer of asphalt or allied material covering the whole of the site upon which the house rests. No air or moisture can pass through such a layer.

As microbes are most abundant in the upper layers of soil, the water from superficial wells should not be drunk. The fact that typhoid fever is the one zymotic almost equally fatal in town and country may be due to the use of water from very shallow wells by the rural population. The lower the well, the more likely is its water to be free from microbes. I found in a very deep well that two kinds of water were present: near the bottom it was hard and comparatively free from bacteriological life, near the top it was soft, loaded with organic matter, and teeming with micro-organisms.

PHYSICAL INSTRUCTION IN NEW YORK SCHOOLS.—The Superintendent of the Public Schools of New York has prepared a scheme of instruction in physical exercise as a guide for the principals of the various schools in teaching gymnastics to their pupils. At present, though there is more or less drilling in most of the schools, there are appliances for gymnastics in only five of them. Next year, however, it is expected that this number will be quadrupled. The very wise step has further been taken of appointing a medical man to superintend the physical instruction in the schools, under the control of the Board of Education.

¹ *Archiv für Hygiene*, Vols. i and ii, Part ii.