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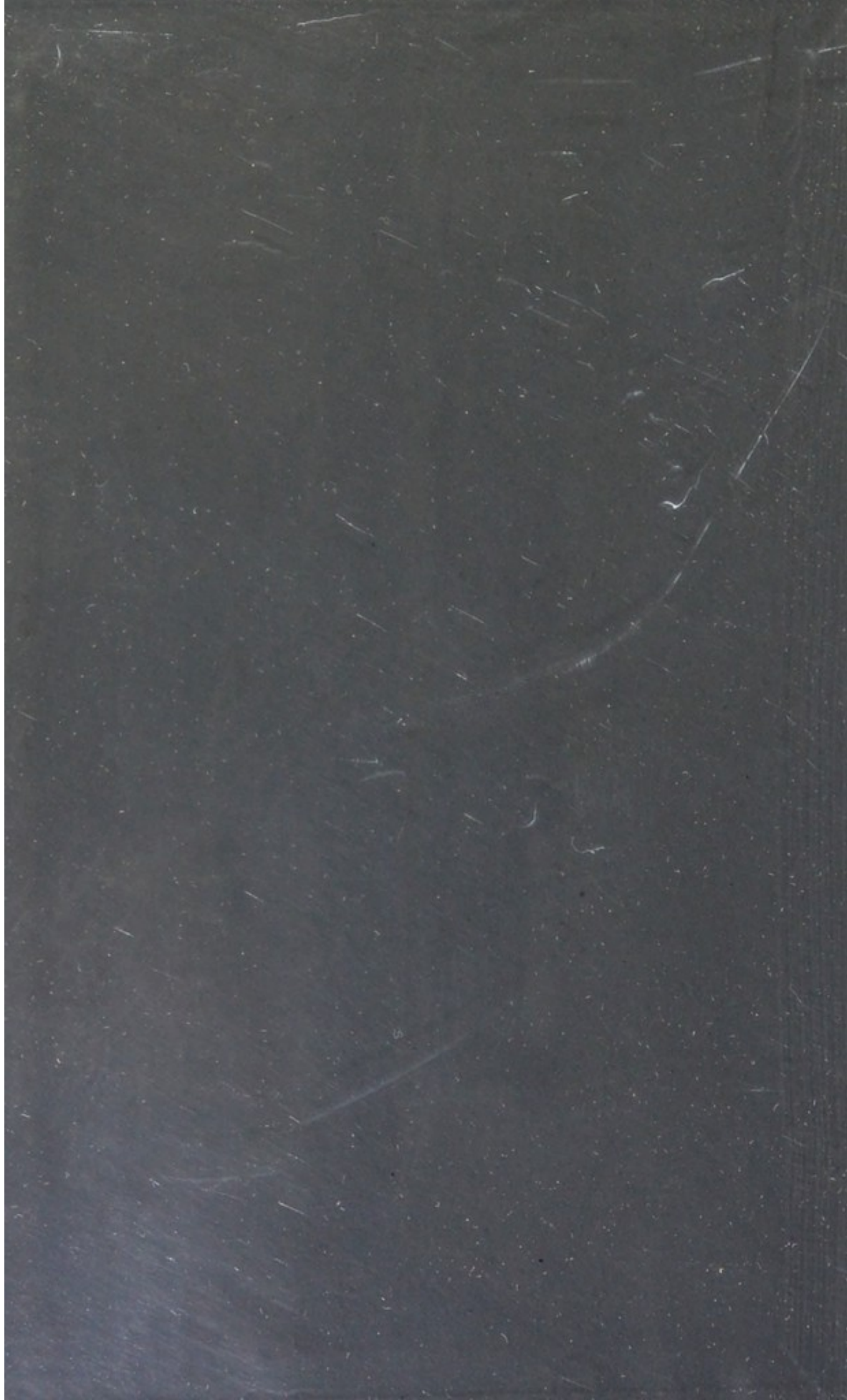
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DIPHTHERIA



DIPHTHERIA:

ITS NATURAL HISTORY AND PREVENTION

BEING THE MILROY LECTURES
DELIVERED BEFORE THE ROYAL COLLEGE OF
PHYSICIANS OF LONDON,

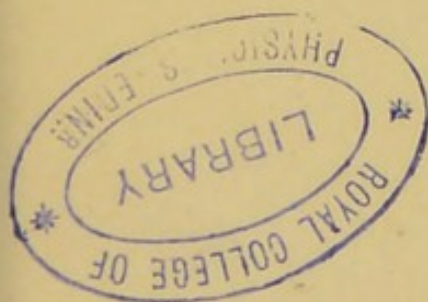
1891

BY

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CHAPTER I

SEVENTY years have elapsed since Bretonneau in 1821 submitted to the Académie Royale de Médecine in Paris his first Memoirs on Croup and Malignant Angina. In these Memoirs he maintained that a number of differently named diseases, associated with a membranous inflammation of the fauces and upper part of the air-passages, constituted, in fact, but one "specific phlegmasia," for which he proposed the name diphthérite (*διφθέρα*, pellis, pellicle, membrane). But whilst he held this view, he took occasion to urge that there were other affections of the throat which it was important to distinguish from the specific Pellicular or Diphtheritic Angina he had described; and to prevent confusion between a group of diseases merely because they had certain features in common, he urged that microscopic research should be resorted to in order to a correct diagnosis; adding, for his part, how deeply he was imbued with the dictum of Laennec: "that diseases cannot be more certainly distinguished than by their anatomical characters." More than twenty years after, he admitted that the distinction he had sought to secure

by the application of a "specific name" to a "specific phlegmasia" had failed in its object; and Hirsch, referring to the confusion which at that time prevailed on the subject, says: "Into this chaos no light could come until medical science had advanced so far as to recognise that *causes of various kinds might underlie one and the same anatomical morbid process*; and, conversely, that *one and the same morbid cause operating on a given tissue may be able to call forth, under varying circumstances, nosological forms of different sorts*; that in forming our judgment of the peculiarity of a disease, or of the identity or distinctness of two or more diseases in a group, we must place ourselves, not in the anatomical point of view alone, nor exclusively in the clinical point of view, but have regard also and most especially to the etiological aspect, while we keep in mind all three factors together."¹

Again, a long term of years has elapsed. The disease has been studied anew from the anatomical point of view, and an attempt has been made to differentiate from amongst the inflammatory conditions of mucous membranes a special fibrinous (false membranous) one; this being in turn subdivided and regarded as croupous or diphtheritic according to the different appearances of the implicated mucous membrane. But no such distinctions have even sufficed to secure for diphtheria a trustworthy definition. Clinical medicine has made rapid strides

¹ *Handbook of Geographical and Historical Pathology*, by Dr. August Hirsch; translated by Charles Creighton, M.D. Vol. iii. p. 69. New Sydenham Society, 1886.

during recent years, and to the clinical aspects of diphtheria much attention has been devoted by cultured and skilled physicians ; but it cannot be pretended that we are as yet even able to discriminate between a throat affection having at one or other stage a specific infectious quality and one devoid of this quality. With regard to the etiological aspect of the disease, I trust I may be able to show how, by continuous inquiry into the behaviour of diphtheria under varying circumstances, and by the aid of the modern science of bacteriology, substantial progress has been made in our knowledge of the disease. New light has been thrown on some of the more obscure phases of its natural history ; and fresh lines of research, which are full of promise, have been opened up. But after all, the stage we have reached is only a transitional one ; and whether the anatomical, the clinical, or the etiological relations of diphtheria are considered, we are bound to admit that we have not yet emerged from the difficulties with which Bretonneau found himself unable to deal.

It is only since 1861 that rates of death from "diphtheria" have been available for any complete decennium. Before the decennium 1861-70 it was grouped with scarlet fever for the purposes of the Registrar-General ; but though diphtheria has now for thirty years been differentiated in our statistical returns, yet even at the present date, as I shall have occasion to point out, the statistics relating to it are deprived of the accuracy needed for many etiological and other purposes by reason of faulty nomenclature and classification. But, such as

they are, the available statistics supply some useful lessons.

Comparing the two decennial periods 1861-1870 and 1871-1880, as also the period 1881-1889, it will be seen that whereas the diphtheria death-rate per million living for England and Wales during the first decennium was 187, it fell to 121 during the second ten years, and that although the rate rose again to 159 during the third period, yet the latter rate was still short of that which had prevailed in 1861-70.

TABLE No. I.
DIPHTHERIA MORTALITY PER MILLION PERSONS LIVING
AT ALL AGES.

DATE.	ENGLAND AND WALES.	LONDON.
1861-70	187	179
1871-80	121	122
1881-89	159	244

With regard to the excess during the first period there are some indications to show that it was probably in part due to maintained confusion between diphtheria and scarlet fever ; but at the same time the first half of this decennium corresponded with a considerable diffusion of the disease in England following on its alleged importation from Boulogne in 1855. In London the oscillations in the rates have been somewhat similar to those for England as a whole ; but there are certain marked differences. Thus, while the Metropolitan rate for 1861-70 was lower than that for the country generally, it exceeded it during the two next periods, and the rise

which has taken place in the rate for 1881-89 is far in excess of the corresponding one for England and Wales. And it may be added that the increase which has been taking place in the country generally during the later part of that period is found to be notably parallel to the excess occurring in the Metropolis. In short, there is thus far evidence that diphtheria as a cause of death is increasing in the country as a whole, and that this increase is very conspicuous in our greatest urban community. These two points, which are indicated more in detail in the annexed Table, call for serious consideration.

TABLE No. II.

DATE.	ENGLAND AND WALES.		LONDON	
	Diphtheria.		Diphtheria.	
	Deaths.	Rates per million living.	Deaths.	Rates per million living.
1871	2525	111	344	105
1872	2152	93	267	80
1873	2532	108	320	95
1874	3560	150	419	122
1875	3415	142	581	167
1876	3151	129	387	109
1877	2731	111	316	88
1878	3498	140	566	155
1879	3053	120	575	155
1880	2810	109	544	144
1881	3153	121	657	171
1882	3992	151	857	220
1883	4218	158	952	241
1884	5020	185	951	236
1885	4471	163	904	221
1886	4098	147	851	205
1887	4443	157	953	226
1888	4815	168	1311	305
1889	5368	185	1616	371

Diphtheria has very properly been classified for statistical purposes with a number of diseases the spread of which has shown itself to be greatly amenable to efficient sanitary control; but whilst the rate of mortality per million living, from the so-called "zymotic diseases," has almost continuously fallen in England and Wales from a mean of 3724 for 1871-80 to 2405 for 1889, we find that the contrary is taking place as regards diphtheria.

And this circumstance is the more serious because, whilst diminution in the amount of death from a majority of the diseases included within the "zymotic" group has gone hand in hand with increase in our knowledge of their natural history, and especially of the circumstances which are associated with their spread, we are bound to admit that information of like scientific accuracy and scope has not as yet been the reward of investigations into the etiology of diphtheria. And thus it comes to pass that whilst an evil is increasing in our midst we lack the knowledge adequately to cope with it.

But the increase of diphtheria mortality in this country has been by no means one of uniform distribution. I have already adverted to the excess of its incidence during recent years on the Metropolis, and I have shown in Table II. the rate at which London diphtheria has been increasing. London, however, is not singular amongst our urban communities in this respect, and in illustration of this point I would draw attention to a paper on "The Geographical Distribution of Diphtheria in England and Wales," by Dr. G. B. Longstaff, which was issued in a recent report of the

medical officer of the Local Government Board.¹ Dr. Longstaff has in this paper submitted to very careful examination the mortality statistics from registered diphtheria in England and Wales for 26 years from 1855, when that disease first appeared in the returns of the Registrar-General, to the close of 1880—a period during which 89,603 diphtheria deaths had been recorded. For the purposes of his study he divided these twenty-six years into three periods; and with a view, amongst other things, of comparing the relative mortality from diphtheria of town and country districts, he classified the districts within the several counties as Dense, Medium, and Sparse, according to the density of their population.

In the first period, 1855-60, in which the mean diphtheria death-rate per million for the whole country is given as 182, he found that the rate was 123 in the dense districts, 182 in the medium districts, and 248 in the sparse districts—rates which show that the disease was twice as fatal a malady in rural districts as it was in towns. In the second period, 1861-70, the results were similar, but the contrast referred to was much less marked; the diphtheria death-rates for the dense, medium, and sparse districts being 163, 164, and 223 per million living respectively. And coming next to the third period, 1871-80, the results were found to exhibit a great change in the degree to which diphtheria mortality affected areas of differing density of population,

¹ Supplement on Diarrhoea and Diphtheria in continuation of the Report of the Medical Officer of the Local Government Board for 1887. [C.—5638]—1889.

the rates being 114, 125, and 132 for the dense, medium, and sparse districts respectively. Thus, whereas in 1856-60 the rate for the sparse districts was double that of the dense districts, in the period 1871-80 the rates for these respective districts came to be nearly equal.

TABLE No. III

DEATH-RATES FROM DIPHTHERIA PER MILLION LIVING.

Districts.	1855-60.	1861-70.	1871-80.
Dense districts . . .	123	163	114
Medium districts . . .	182	164	125
Sparse districts . . .	248	223	132

In short, during each successive period, fatal diphtheria, which, though always maintaining a predilection for sparsely populated rural areas, came more and more to hold its own in densely-peopled urban areas. This is a subject to which I shall have on more than one occasion to refer again. But in the meantime I would point out that since 1880 this incidence of diphtheria on towns has become more marked than ever before, and that diphtheria, which, as Dr. Buchanan has pointed out, "has always displayed a marked tendency to prevail in sparsely-populated districts rather than in centres of population," is undergoing a change of distribution by which "the chief urban districts seem to be approaching nearer than before to rural districts in their rate of suffering from this disease."

The following statistics, which are compiled from the

Annual Summaries of the Registrar-General, and which relate to the large towns and cities of England and Wales, serve to illustrate this point, and show how between 1881 and 1889 this urban diphtheria death-rate has nearly doubled.

TABLE No. IV

ANNUAL DEATH-RATES FROM DIPHTHERIA PER THOUSAND LIVING IN 28 LARGE TOWNS OF ENGLAND AND WALES.¹

Period.	Diphtheria death-rate.	Period.	Diphtheria death-rate.
1881	0·14	1886	0·16
1882	0·16	1887	0·18
1883	0·16	1888	0·21
1884	0·17	1889	0·26
1885	0·17		

And reverting for a moment in this connection to the Metropolis, I would recall the words of the Registrar-General, who, in his Annual Summary for 1889, referred to the "formidable" increase in the London mortality from diphtheria, "which disease had been increasing steadily for many years, but in the last two years, 1888 and 1889, made the most alarming bounds, the deaths rising from a total of 953 in 1887 first to 1311, and then in 1889 to no less than 1588, whereas the decennial average after correction for growth of population was only 932." And he goes on to explain that this increase can only

¹ The rate for 1881 is calculated on 20 large towns, having an aggregate population in that year of 7,608,775; the subsequent rates relate to 28 towns, having at the middle of the decennium (1885) an estimated population of 8,906,446.

very partially be accounted for by a diminution under the heading "croup," which, "in accordance with the classification of the College of Physicians, is separated from diphtheria and placed with the respiratory diseases," since the deaths from diphtheria and croup together amounted to 2068 in 1889, while the decennial average, after due correction for increase of population, would have been only 1647.

We are therefore face to face with a recent steadily increasing diphtheria mortality, and this especially in towns; and at the same time we are conscious of the fact that our knowledge of the natural history of the disease does not enable us either properly to explain this increase or efficiently to deal with it. In view of these circumstances it has appeared to me that we have reached a position in which there would be advantage in taking stock of such knowledge as we have acquired as to the causation and prevention of diphtheria; and whilst tracing the stages by which such knowledge has been obtained, to emphasise those points which stand out prominently as affording an indication of the lines of research which, if followed out, may be expected to clear up some of the obscurity in which the etiology of diphtheria is still involved.

It may be asserted with some degree of certainty that a malignant form of throat disease which in its various phases cannot well be differentiated from typical forms of diphtheria as now met with has prevailed in different parts of the world from a remote period of antiquity; and it is significant that amongst the later Greek

physicians Aetius, in describing a pestilential throat inflammation, refers to paralysis of deglutition as one result of the attack. Oertel speaks of diphtheria as "one of the oldest epidemic diseases of the human race," and he regards it as being unquestionably the same disease as that which Aretæus described towards the close of the first century after Christ as *Malum Ægyptiacum*, in which the tonsils are referred to as covered with "quodam concreto humore albo." Under a variety of names the fatal throat diseases of the past can, by the aid of history, be traced through successive periods until, between the sixteenth and eighteenth centuries of the present era, nearly every European State and many portions of the continent of America had been seats of epidemic diphtheria. Up to this date there are but few records of epidemic throat disease in so far as this country is concerned. Indeed, the earliest with which I am acquainted is that referred to by Noah Webster in his *History of Epidemic and Pestilential Diseases*, published in 1800. Recalling the fact that, "in 1389 appeared a singular meteor, or light in the heavens," he adds that the year was also "remarkable for the death of children in all parts of England," the cause being "a species of angina."

I find no records bearing upon diphtheria in this country between that date and the last century; indeed, according to Hirsch, the first appearance in England of the angina maligna which prevailed so widely in continental Europe and neighbouring countries during the eighteenth century, took place between 1745 and 1793;

during which period places in Cornwall and Buckinghamshire, as also the Metropolis, were attacked. And the late Dr. Greenhow states, in his work on diphtheria, that "the earliest notice of the disease in this country is that contained in Dr. Fothergill's *Account of the Sore-Throat attended with Ulcers*, published in 1848"; but he adds that "a disease, supposed to be the *morbus strangulatorius*, had been observed in London or the neighbourhood in the year 1739." But there is at least one record of a similar disease at an earlier date. Thus, Noah Webster refers to the "rage of ulcerous sore-throat" which prevailed simultaneously in America and in England in 1736; and he gives a description of the epidemic, which is the more significant because "scarlatina" and "scarlatina anginosa" are referred to in his work as distinct from the throat disease in question. Of this throat disease Webster writes:—"Very few children escaped . . . although the disease was very infectious, yet its propagation depended very little on that circumstance. It attacked the young in the most sequestered situations, and without a possible communication with the sick. It was literally the plague among children. Many families lost three and four children—many lost all." He goes on to explain that country places suffered more "than populous cities," and adds that the "virulence of the disease seems to be greatly augmented by cold and wet weather." "In some families it was comparatively mild—in others it was malignant, like a plague." "Few adults," says he, "were afflicted; its principal ravages were among per-

sons under age, or rather under puberty. For many years after it was epidemic it frequently broke out in different places without a cause, but it did not spread. A striking proof," he adds, "that such diseases will not become epidemic by the sole power of *infection*; but that some general cause must aid its propagation, or it will perish in its cradle." Again, he adds:—"It was not always attended with great prostration of strength—for persons were often walking an hour or two before their death."

This description must vividly recall to our minds the salient features of many diphtheria prevalences in our own day. The special incidence of the disease on children, the havoc it occasions in individual families, the difficulty to account for many outbreaks by means of personal infection, the differing characters of the same specific disease in point of mildness and of fatal virulence, the preference of the disease for rural as opposed to city areas, the tendency to recrudescence apart from newly-imported infection, and the sudden and unexpected fatality owing to paralytic sequelæ, are all indicated in language so forcible as to call for no interpretation.

Webster further records the appearance in England in 1742 of "an ulcerous sore-throat of a malignant kind," which continued for some years, "becoming very infectious in 1745"; and, adverting to the circumstances of the 1736 epidemic, he says, "the same happened in the angina of 1794." He also reports a prevalence of "angina" in 1797. To the account he gives of this

prevalence I shall have occasion to refer later on, affording as it does another instance of the keen insight of this worthy of well-nigh a century ago. His powers of observation were in many respects remarkable. They lacked the basis of a preliminary medical training, and were always clouded by the conviction that epidemic occurrences of disease had some obscure connection with comets, meteors, earthquakes, and what he styled the "principal phenomena of the physical world." But they were so far precise as to place him at that date in touch with questions of etiology which we have been prone to regard as the outcome of researches made solely in our own day.

During the first half of the present century occurrences of sore-throat and angina in epidemic form appear to have been somewhat in abeyance in England, but a diffusion of sporadic attacks of definite diphtheria is known to have set in about 1845, and Sir John Simon, writing in March 1860, states that "from the summer of 1855 to the present time diphtheria has again been continuously prevalent in England." And even before 1837, according to the investigations of Dr. W. N. Thursfield, an infective form of angina, which went under such names as *cynanche maligna*, *angina membranacea*, etc., prevailed sporadically in certain districts of England.¹ It has been held by some that the English epidemic referred to was primarily due to importation from Boulogne, and it is certain that the disease was prevalent there under the name of Boulogne

¹ Dr. Thursfield on Diphtheria, *Lancet*, August 3d-17th, 1878.

sore-throat, and that it had for many years been prevalent in other portions of France ; but when it is remembered that "diphtheria" had been prevalent in England for two years before there was any public knowledge of the fact,¹ and that there had been sporadic occurrences of this disease for some years antecedent to the epidemic,² it becomes difficult, in view of recent knowledge as to the behaviour of diphtheria epidemics in their early stages, to assert with any degree of confidence that we were then suffering from other than a home-bred infection.

Special interest attaches to this epidemic because, under the auspices of the newly-organised Medical Department of the State, it gave occasion for the first systematic investigation into the causation of diphtheria ever undertaken in this country ; the main inquiry being carried out by Dr. Burdon Sanderson and the late Dr. Greenhow. In addition to much information which was obtained by means of correspondence, no less than seventy principal seats of the epidemic, situated in seventeen different counties, were personally visited for the purposes of minute inquiry ; and I can pay no greater tribute to the perspicuity of my former official chief, Sir

¹ Second Report of the Medical Officer of the Privy Council, 1859.

² Dr. Burdon Sanderson, in his report to the Medical Officer of the Privy Council, 1859, mentions the occurrence of "an epidemic of malignant sore-throat which proved extensively fatal to children, was never accompanied with any eruption, and differed from scarlatina," at Ashford in 1817 ; and also a similar occurrence at Lifton on the Tamar in 1852.

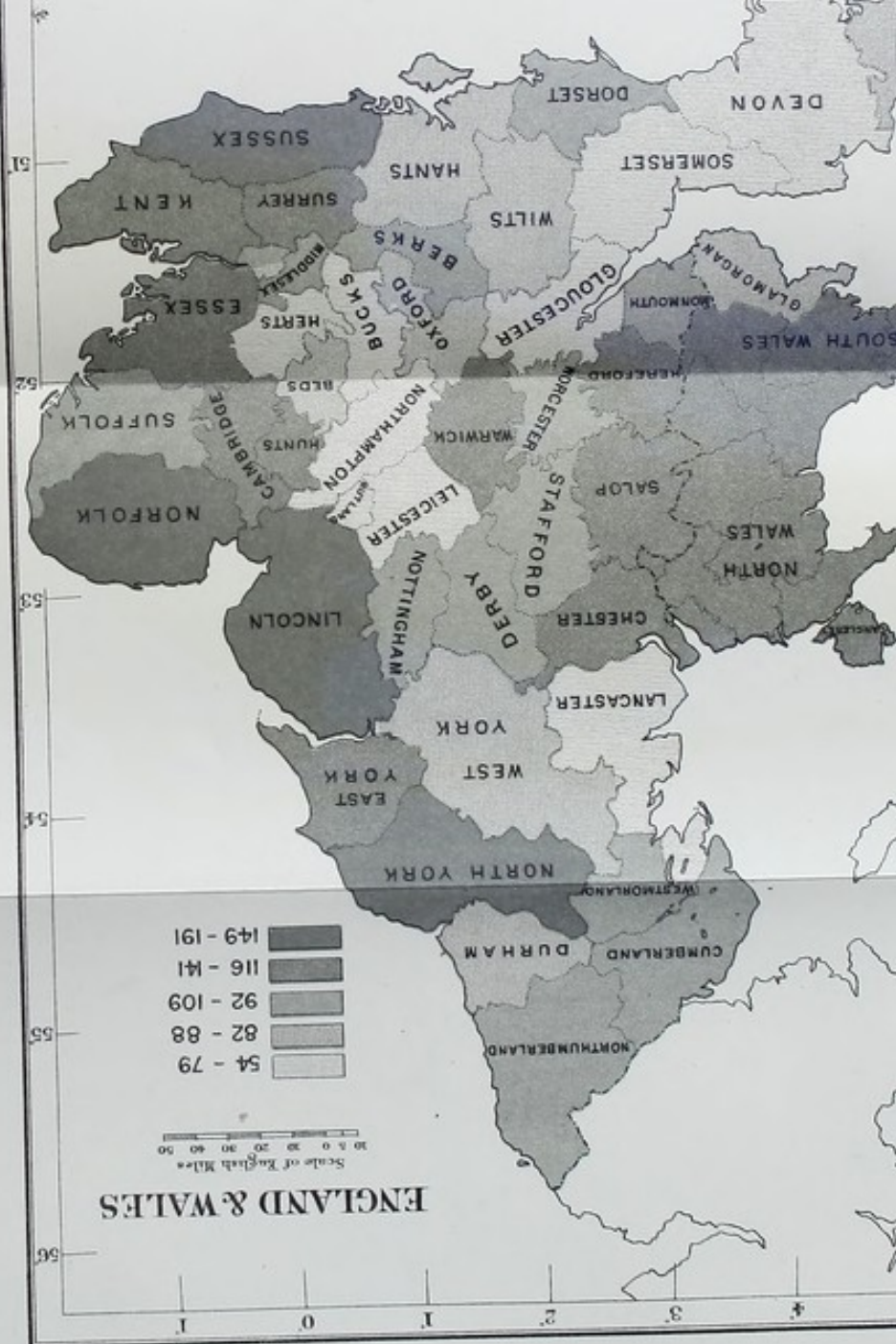
John Simon, than to direct attention to those "Heads for Local Inquiry," as to the etiology of this disease, which he compiled for the guidance of those engaged in the inquiry.¹ Were they issued anew with the knowledge of to-day, there would be nothing to amend, and but little to add.

Since that date there have been many valuable contributions to the etiology of diphtheria in England. The majority of these have been concerned with separate localised occurrences of the disease, and the information which has been obtained as the result of them is widely scattered. I would therefore propose to trace the various stages by which, as the result of skilled inquiry, our present knowledge as to the conditions under which the development and spread of diphtheria take place has been acquired ; to point, as far as I may be able, to the degree of importance attaching to these several conditions ; to indicate the lines for future research which appear to promise most ; and to suggest such measures as may usefully be resorted to with a view to the prevention of the disease.

And it may be convenient to state at once, that such information as we possess on these points is largely based on our knowledge of the behaviour of fatal diphtheria only ; for, except in regard of isolated inquiries, no systematic attempt had been made until quite recently to ascertain the extent to which diphtheria as a disease, and apart from its fatality, had prevailed in our midst.

¹ These heads of inquiry are reproduced in Appendix No. I.





It has been very generally held, and I believe with truth, that the broad geological features of a district have no known influence on the development or the diffusion of diphtheria. Any one who will recall the main features of England and Wales as ordinarily shown on a geological map, will find in the chart prepared by Dr. Longstaff,¹ and which shows by different degrees of shading the average diphtheria death-rates in the registration counties of England and Wales for the twenty-six years 1855-80, abundant material in support of this view. Dr. Longstaff takes 100 as representing the average diphtheria death-rate for England and Wales as a whole, and he then proceeds to divide the counties into five groups according as they fall short of or exceed that average rate. We thus learn that during the period in question the greatest excess of fatal diphtheria took place in Lincolnshire, Norfolk, Sussex, and North Yorks, the rates ranging from 149 to 191.

In Lincolnshire (rate 191), where the geological conditions are by no means uniform, the upper and lower cretaceous, with thick drift covering of boulder clay, and the oolitic beds, together with the great level of the fen, practically make up the county. Cambridgeshire and Huntingdonshire taken together (rate 119) may be regarded as affording sufficient geological comparison with Lincolnshire, and yet the difference between their respective rates amounted to no less than 72. There is

¹ Chart from *Studies in Statistics*, by G. B. Longstaff, M.A., M.B., Oxon. London, Edward Stanford, 1891—reproduced by the author's permission.

excess of death in Norfolk (rate 164), where the chalk formation largely predominates; whereas Hertfordshire (rate 70) and Buckinghamshire (rate 54), which also lie largely on chalk, present diphtheria death-rates which are amongst the lowest in the kingdom. North Yorks, with its large excess (rate 149), lies partly on carboniferous rocks, partly on the oolites and lias of the oolitic epoch; whereas Lancashire (rate 79), with its wide extent of carboniferous rocks, as also Bucks (rate 54), Gloucestershire (rate 79), and Oxfordshire (rate 82), which lie largely on the oolite beds, have comparatively small diphtheria death-rates.

And, if the various strata be examined more in detail as regards incidence of diphtheria, even greater differences than those indicated may be shown in respect of communities living on the same geological formations.

But, whilst I thus far concur in the view which has been commonly held on this point, I can hardly agree with Hirsch when he declares, and this largely on experience stated to be derived from this country, that "altitude and soil [are] irrelevant," and that "the assumption that *conditions of soil* have some influence in the development of diphtheria, or on its epidemic diffusion, is one that has no warrant."

Soil, and especially *surface soil*, when considered in connection with relative altitude, slope aspect, and prevailing rainfall, has, I believe, concern in the maintenance and diffusion of diphtheria, and has very possibly some relation with its beginnings. Speaking generally, I think that the experience of careful investigations extending

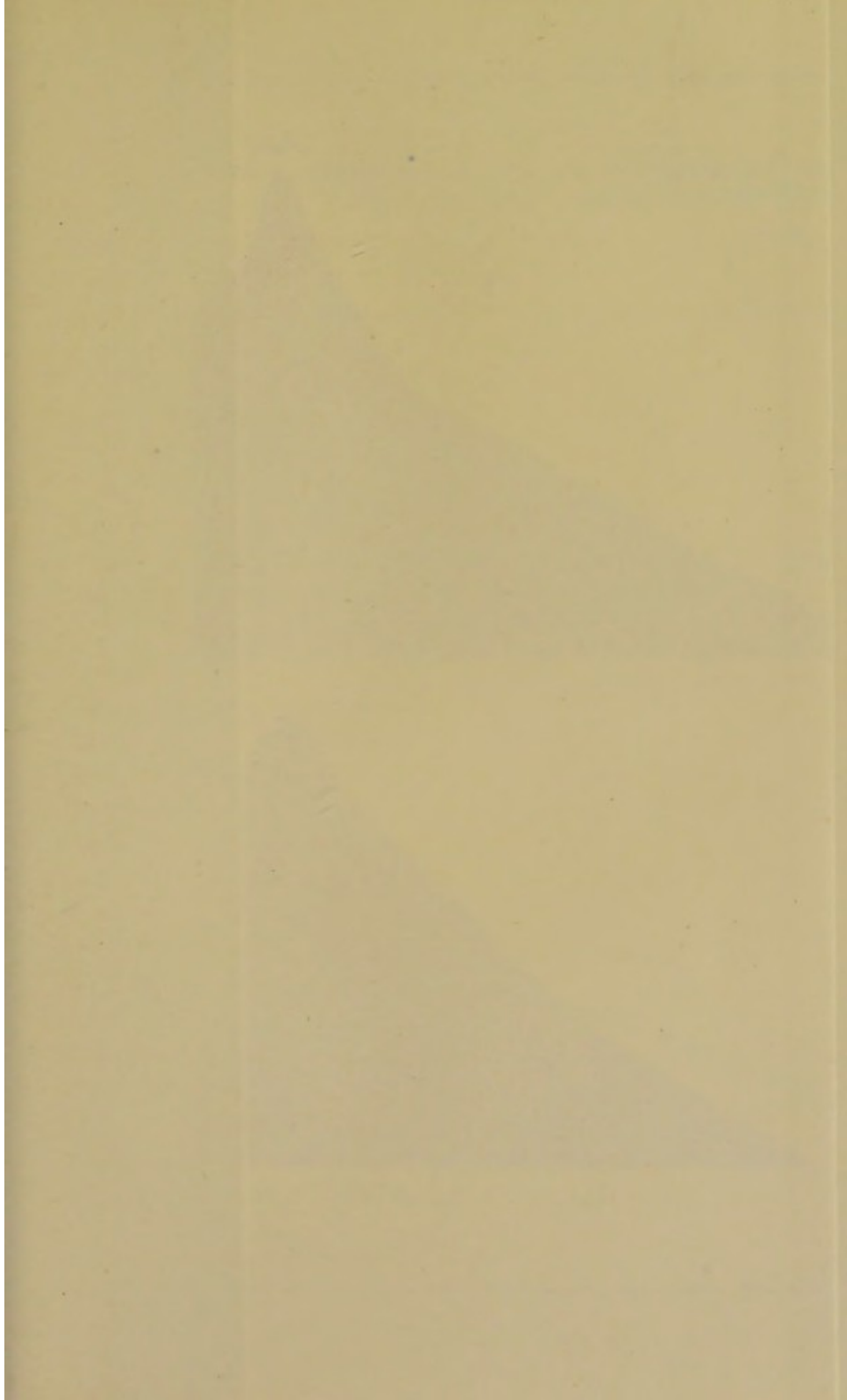
over a number of years is to the effect that where a surface soil is, by reason of its physical constitution and topographical relations, such as to facilitate the retention of moisture and of organic refuse; and where a site of this character is, in addition, exposed to the influence of cold wet winds, there you have conditions which do tend to the fostering and fatality of diphtheria, and which also go to determine the specific quality of local sore-throat.

There are many tracts in which clayey and otherwise retentive soils abound, such as those to be found in the great stretch of the oolite from the borders of Lincolnshire to the Dorset coast, which are provided with natural means of drainage by reason of great rivers and otherwise; and these, when judged as registration counties, come within the range of England's smallest diphtheria mortality; whereas, on the other hand, areas which are largely made up of impervious rocks are found to stand second only in regard of a heavy diphtheria mortality to those counties which are scattered along our exposed north-easterly and eastern coasts. Amongst these areas few are more prominent than Wales (rates N. Wales 131, S. Wales 136), with its mountainous hard rocks, and which by reason of its configuration and meteorological conditions, presents on the one hand exposed highlands, and on the other hand damp wet valleys, in which retained moisture is associated with a surface soil often infiltrated by abundance of vegetable refuse.

Allow me to illustrate my point.

Towards the close of 1877 I was instructed to

inquire into the circumstances of a prevalence of diphtheria which had occurred in and about Llanrhaiadr in North Wales, during the months of August-October in that year. Llanrhaiadr lies in the Vale of Clwyd. The Vale, which gradually widens to the north, opens at Rhyl on the coast of Flintshire. It consists mainly of a flat level plain between two ranges of hills; it is about sixteen miles in length, and is traversed by the Clwyd and its tributaries. The Vale is entirely excavated in impermeable silurian rocks which rise to a considerable elevation on either side, and pass under the newer rocks occupying the bottom of the valley, thus forming a water-tight basin through which the river and its tributaries flow. These newer rocks are all permeable strata, and would absorb a large amount of the rainfall of the district, were it not that they are covered by a thick envelope of impervious glacial drift so distributed as to form an alluvial plain, whilst older alluvial terraces fringe the valley at successive heights. From the area occupied by the rocks flanking the sides of the Vale, and from the silurian rocks on the upland tract above, the rainfall, to no noteworthy degree lessened by absorption, is thrown off into the valley, the permanent water-level of which appears to be very little below the ordinary top-water level of the Clwyd. For a space of between two and three miles in the neighbourhood of Llanrhaiadr, the drift, which consists of loamy clay charged with stones closely packed together, is stated to be "wholly impermeable." "Flourishing oak-trees, the growth of rushes, dark-coloured grass, deep and full ditches, all at-



SECTIONS ACROSS THE VALE OF CLWYD

Blue lines are underground Water-levels

2 Miles

1 Mile

Horizontal Scale

The Vertical Scale is six times exaggerated

S. W.

Rhewl

SILURIAN

Llan.

Alluvium

R. Clywedog R. Clwyd

Glacial Drift

Glacial Drift

WATER LEVEL IN ROCK

Sea level

W. S. W.

NEW RED SANDSTONE

MOUNTAIN

LIMESTONE

SILURIAN (DENBIGHSHIRE) GRI

Foelas

Pentre

R. Clywedog

R. Clwyd

Glacial Drift

Glacial Drift

WATER LEVEL IN ROCK

SILURIAN

test the clayey nature of the soil and its non-absorbent qualities." A large portion of this area is also beneath the level of the floods, which often cover the fields and roads around. The average rainfall for this part of the Vale for the months of July and August had for a series of years been 2·3 in. and 2·2 in. respectively. In July 1877 it was 2·9 in., and in August it reached 5·2 in. In the month of July nearly 2 in. of rain fell on the three days, 13th to 15th, and somewhat over an inch fell again on the 24th and 25th; and, under the peculiar physical conditions named, this led, just before the commencement of the diphtheria, to flooding of the Vale in the vicinity of Llanrhaiadr. This was again followed by the exceptional rainfall which was maintained throughout the greater part of the month of August.

The wetness thus induced was moreover a foul wetness, for the sewage of Llan is held back for many months in the year in streamlets, the level of which is below the ordinary level of the river Clwydog, a tributary of the Clwyd; but when these rivers overflow their banks, as they frequently do on heavy rainfall, the accumulated sewage mingles with the flood waters spread over the valley. And this circumstance, together with the large amount of decomposing vegetation in the valley, leads to a pervading offensiveness during and subject to periods of flood.

Such were found to be the special characteristics of this portion of the Vale of Clwyd. They are to my mind typical of conditions, topographical, physical, and meteorological, which are favourable to diphtheria; and

they are also, I believe, such as tend to maintain persistent throat-disease, and to impart to a local throat affection a specific and infective quality. In this latter connection I shall again refer to the Vale of Clwyd.

Once more: in 1885 Dr. Simpson, now medical officer of health for the city of Calcutta, made inquiry for the Local Government Board as to a prevalence of diphtheria in and about Shaftesbury. Part of the implicated area occupied a space of high table-land some 700 feet above the level of the sea, and overlooking a vale about 200 feet below. The higher-lying district consisted of a gravelly loam over green sandstone, chalk elsewhere taking the place of the sandstone. The vale is stated to consist for the most part of tenacious blue clay. The winds from the north-east are very keen, climatic changes are rapid, the houses are largely built of an absorbent local stone which soon becomes covered with mosses and lichen, and "quinsy," so called, was frequently prevalent. This general description sufficiently characterises a locality in which sore-throat, and later on admitted diphtheria, had for a number of years somewhat persistently occurred.

One locality in the village of Melbury called for especial attention as a probable centre of mischief, and Dr. Simpson describes it as follows :—

It is "situate at the bottom of a deep ravine beside a mill pond, the water of which is used for the mill that adjoins and forms part of the house. Hills of chalk and of green sandstone are on three sides, and a small brook rising in the green sandstone hills passes just in front of

the house, and supplies the occupants of the mill with drinking water which is not always very clear. The little valley through which the brook runs contains a bed of alluvial soil, an intermixture of green sandstone, chalk, and vegetable earth, deposited on clay. Other small streams run towards the house and join the main brook quite close by. In flood times the site on which the house stands is practically an island, and if there were not certain drains under the house to carry away the water when it recedes, the house itself would have been often waterlogged. Within the last few years, however, everything has been allowed to fall out of gear, and the house has not been repaired, as a new mill was to have been built and the old one pulled down. From some delay in building the new, the people still dwell in the old, which is in a very dilapidated state ; the soil on which it stands is waterlogged, the walls of the ground-floor, and indeed of the upper apartments, are wet and covered with moulds, and the woodwork is in a state of rotten decay. It is impossible for the inmates, except it be a few months in the summer time, to live on the ground-floor. There could scarcely be a more favourable soil for the growth of lower forms of vegetable life."

Following on a somewhat prolonged absence of throat affection, it is stated that "in three consecutive Novembers the family have suffered from sore-throat. In the autumn of 1882 a flood came on and invaded the lower part of the house, and compelled the inmates to take refuge upstairs. The water soon receded, but the soil was left waterlogged. In about a fortnight's time several of the

family suffered from sore-throat. In February 1883 there was a spring flood, and about a fortnight after sore-throats affected the family. After the spring flood in 1883, first one member of the family, then another, was affected with sore-throat, and so on during the year. In the autumn of 1883 the same flooding occurred with more sore-throats. In the autumn of 1884 there was a recurrence of the sore-throat, but not of the flood."

"The doctor says that on each occasion the throat affection was of a scarlatinal nature, but without any rash; if there had been the slightest rash accompanying the affection, the illness would have been designated by him scarlet fever. The throat was ragged, and the margin of the palate and surface of the tonsils were covered with a brown creamy coating."

In this case, too, other circumstances of interest in relation to diphtheria also transpired. Amongst these, I would allude to the simultaneous occurrence, on a number of occasions, of "sore-throat" amongst occupants of, and visitors to, the mill, and disease amongst lower animals, and this in nearly every case on the occasion of floods. These are points to which I shall refer again at a later stage; but I may here say that, according to the testimony of a veterinary surgeon in the locality, a so-called "laryngitis with sore-throat" had been by no means uncommon during the diphtheria prevalence of 1885, and that this disease, which had occurred amongst horses, was known to attack animals, both old and young, and to be infectious in its nature.

Once more I would call attention to certain con-

ditions under which an epidemic numbering no less than 170 cases of diphtheria and "sore-throat" occurred in 1875-76 at Great Coggeshall—Essex. I there found a small town of some 3300 inhabitants occupying a low site on the north bank of the river Blackwater. The entire district is situated on the London Clay, which comes to the surface in a considerable portion of the town. With the exception of a few dwellings lying between the Blackwater and an adjoining brook, on alluvial clay, the remainder of the town is situated on a water-bearing bed of sand and gravel, or on Boulder Clay. In this instance I was able to procure some accurate records as to rainfall and temperature, and deferring for the moment any consideration of the influence of season as such, I may explain that from the commencement of 1876, when there were numerous centres of infection in the town, the spread of the disease had been greatest during the months of excessive rainfall and of comparatively low temperature; whereas, with a rising thermometer and diminished rainfall, the number of fresh attacks became smaller. A sudden spread of the disease in March, and again in the last four months of the year, was particularly noteworthy, as being associated with periods of unusually large rainfall, and this especially since the marked subsidence of the epidemic during the five months, April-August, coincided with a rainfall of 3 inches below the average. The sudden onset of this epidemic in November 1875 was also associated with heavy rainfall, nearly four inches of rain having fallen that month.

This is one of the most sustained epidemics which I ever met with. The disease, especially when mild, was put down under different names, but well-marked and fatal attacks of diphtheria were constantly recognised during a period extending from November 1875 to December 1876. Beyond that date I have no accurate records of its incidence, but fatal attacks were still in progress up to and beyond the close of the year. But I may add that diphtheria again assumed considerable proportions at Coggeshall in 1882, and that Dr. Airy then found that in the two months, October and November of that year, no less than 58 attacks had occurred.

Dr. Airy, when discussing the question of the origin of the disease in a general report to the Local Government Board of December 1880, refers to "appearances of *de novo* origin" of diphtheria, "in its more favourite haunts on clayey soil." He also says that in the majority of cases to which his inquiry related, "the regions affected, and especially the points at which the disease broke out, were high and exposed to the wind;" and he adds, "in almost every case the soil was more or less clayey and wet." Mere "epidemic extension" of the disease did not, however, then appear to him as depending much on any such features.

Dr. Charles Kelly, working mainly in his district of West Sussex, finds that the mortality from diphtheria is much higher on wet and retentive soils than on dry and pervious ones; and Mr. W. Topley, F.R.S., of H.M. Geological Survey, traversing the same ground, states

that "Dr. Kelly brings out most clearly the prevalence of diphtheria upon damp soils, especially upon the Weald Clay."¹ According to Dr. Longstaff's chart, Sussex stands high in regard of diphtheria mortality, the rate being 163; see p. 17.

I have incidentally called attention to the fact that excess of diphtheria mortality in this country is to be found along our north-eastern and eastern coasts, as also in Wales. The vicissitudes of climate attaching to the former area are well known; and as regards Wales, I may call to mind that it constitutes one of the areas of greatest rainfall experienced in our country.

I could multiply such instances from my own experience, from that of my colleagues in the Medical Department of the Local Government Board, and from that of Local Health Officers. But I am desirous to avoid attaching too much importance to the influence of site, soil, and climate, apart from other considerations. Indeed, I would at once say that in each of the instances which I have recorded, other conditions favourable to diphtheria came into play, and exerted a not unimportant influence on the course of the epidemics.

I am also fully aware of the fact that diphtheria, in epidemic and sporadic form, has often occurred in localities where conditions obtained which are the reverse of those to which I have thus given some prominence. But this in no way disproves my con-

¹ "Geology in its relation to Hygiene," by W. Topley, F.R.S., F.G.S., *Transactions of the Sanitary Institute* for 1890.

tention that topographical and meteorological conditions leading to a cold and wet soil and atmosphere are predisposing causes of diphtheria. Study of such cases, however, reveals that there are other causes productive of diphtheria and of its spread, which at times altogether outweigh considerations of soil and climate.

I have found it necessary to insist on these facts in view of such general statements as those made by Hirsch, that "the idea of a damp soil being conducive to the development of diphtheria is contradicted;" that the malady has been found "much less prevalent" in valleys, and along the course of certain rivers, "than at elevated places and in a dry situation;" and that, in England for example, "the sickness was met with under no special conditions of locality, it occurred equally on sand or loam, on high ground as well as on low moors."

In dealing with this subject I have referred especially to the influence of clayey soils, but I would add that clays of such configuration as to admit of natural drainage are not unlikely to be associated with comparative immunity from diphtheria in one district, whereas sands and gravels which fill up basins in underlying impervious strata, and thus become charged with water, may have a share in bringing about an opposite result.¹ And even wetness of soil may not,

¹ In his paper on diphtheria in the *Lancet*, August 1878, Dr. Thursfield says: "I can point to diphtheria fields in low localities on alluvial gravel, shut in by hills, in which the water is held up by the clay beneath and the hills on the side; and to others on elevated localities, where a flat table-land and a stiff clay equally prevent the water running off."

apart from other conditions to which I shall have occasion to refer, operate in this direction; indeed, at this stage I would say that I am inclined to regard a moving body of water, as in the alluvial beds of flowing rivers, as much less likely to act as a predisposing cause of diphtheria, than are stagnant sheets lying in "pockets" and hollows of gravel or sand.

Season is generally admitted to have an influence in the diffusion of diphtheria, and some observers hold the same view as to its causation. Hirsch has collected certain data which deal at times with deaths, and at others with attacks, which go to show that under climatic conditions, corresponding fairly with those of Central and Western Europe, the proportions per cent of diphtheria occurrences, according to season, during a term of some 14 years, were as follows:—January-March 27·8, April-June 21·9, July-September 19·6, October-December 30·7; and whilst he admits the influence of cold and damp in favouring the disease, he would regard these circumstances as predisposing causes only.

In Dr. Airy's summary report of 1880, attention is drawn to the great excess of diphtheria mortality, which the fourth quarter of the year constantly shows over the third quarter, and this circumstance is referred to as lending "support to the theory that the morbid agent is an organism with seasonal development, attaining its chief reproductive power in the autumn, the very season when the air is known to be especially charged with fungoid germs."

Examination of the Quarterly Returns of the Registrar-General of England shows that during the twenty years 1870-89, the deaths registered as due to diphtheria were 67,676, and that they were distributed as follows :—

TABLE No. V.

	1st Quarter.	2d Quarter.	3d Quarter.	4th Quarter.
1870-79	7,501	6,047	5,613	7,829
1880-89	10,669	8,308	9,031	12,678
Totals	18,170	14,355	14,644	20,507
Annual Average 1870-89	903	713	732	1,025

These figures show that in this country diphtheria is most fatal during the last quarter of the year, that the first quarter stands next in point of mortality, and that there is no substantial difference in the amount of fatal diphtheria occurring in the second and the third quarters of the year, a period when the mortality is at its lowest.

As yet but little information is available as to the influence of season upon attack from diphtheria apart from mortality, although this defect is now in process of removal by reason of the great stimulus given to the notification of cases of diphtheria, amongst other infectious diseases, by the passing of the Infectious Disease (Notification) Act, 1889. But owing to the initiative of Dr. John Tatham, Medical Officer of Health to the City of Manchester, a compilation of notified cases of infectious diseases in a number of the large towns of

England has been in operation since the beginning of 1888.

For fifteen of these towns the diphtheria deaths registered month by month can be obtained from the returns of the Registrar-General, and hence I am able to place side by side the notified attacks and the registered deaths from this disease for the several months of the year. A striking rise in the diphtheria mortality during the first month of the fourth quarter of the year is thus shown; this excess of mortality only exhibiting slight diminution during the two closing months of the year. There is also distinct indication of an increase in attacks at an earlier date, namely, during the month of September. And further, there is also evidence that it is during certain summer months that diphtheria is at its lowest ebb. Each of these indications receives confirmation from the experience derived from investigations made into diphtheria occurrences in the country generally; but these particular statistics do not point to another fact which has been observed in more sparsely populated parts of the country, namely, that a not unimportant share of the January diphtheria death is due rather to sickness commencing in December than to any fully sustained incidence of the disease after the close of the year. Nor do they suggest a recognised tendency of diphtheria to exhibit some exacerbation in the spring, and notably in March and April. How far the failure of these selected statistics, in these respects, may be due to the fact that the period to which they apply is an extremely limited one, or to a somewhat different be-

haviour of diphtheria in large urban centres as opposed to the more rural areas, or again, to the circumstance that the data relate only to such throat disease as has been recognised to be unmistakable diphtheria, I am, as yet, not prepared to say.

TABLE No. VI.¹

DIPHTHERIA.

NOTIFIED ATTACKS AND REGISTERED DEATHS IN 15 LARGE TOWNS AND CITIES OF ENGLAND. 1888-90.

MONTHS.	1888.		1889.		1890.		TOTAL.	
	Attacks.	Deaths.	Attacks.	Deaths.	Attacks.	Deaths.	Attacks.	Deaths.
January .	94	34	191	65	163	54	448	153
February .	93	31	164	59	147	48	404	138
March .	103	34	152	52	151	46	406	132
April .	85	23	93	37	159	44	337	104
May .	89	21	151	34	152	48	392	103
June .	74	13	75	26	127	31	276	70
July .	51	21	165	56	172	47	388	124
August .	95	26	121	27	101	33	317	86
September	92	21	167	37	176	42	435	100
October .	125	56	229	56	207	57	561	169
November	161	52	143	42	176	42	480	136
December .	134	51	145	52	122	40	401	143
Total .	1196	383	1796	543	1853	532	4845	1458

¹ Diphtheria: Attacks and Deaths during the three years 1888, 1889, and 1890, in the following 15 towns:—

Birkenhead.	Halifax.	Nottingham.
Blackburn.	Huddersfield.	Oldham.
Bolton.	Leicester.	Preston.
Bradford (Yorks).	Manchester.	Salford.
Derby.	Newcastle-on-Tyne.	Sunderland.

[Attacks taken from Weekly "Notification" Returns.

Deaths from the Registrar-General's Weekly Returns].

With respect to the special incidence on the earlier months of the fourth quarter, I would quote the following extract from Dr. Buchanan's report on the proceedings of the Medical Department of the Local Government Board during the year 1883.¹ "In several of the reports [on diphtheria] that have been made to me during recent years, inspectors have recorded an increase of its activity manifested about the end of the month of October; apparently independent of, and sometimes even overshadowing, other influences concerned with the disease. Mr. Power, in his Tichmarsh report, has occasion to direct especial attention to this circumstance." In the Tichmarsh report¹ Mr. Power records that suddenly, towards the end of October, "diphtheria and fatal diphtheria raged in the village," that the facts of this sudden exacerbation were not consistent with the belief that it was due to any such influence as school attendance, which, in so far as it operated, was an influence "largely subordinate to some other and essential factor of diphtheria," and he refers to October and November as constituting "the well-known season of normal extra activity of diphtheria."

Sex.—On the influence of sex as a predisposing cause of diphtheria, not much accurate information is available. In some of my own investigations I have found some preponderance of attacks amongst females. This was the case, for example, at Great Coggeshall in 1876, but the excess had essentially to do with females

¹ *Annual Report of the Medical Officer of the Local Government Board for 1883* [C—4220]. 1884.

above the age of twelve years ; and this led me at the time to suggest that the difference of incidence on sex which I had noted might be due to the circumstance that females in youth and adult age spend more of their time in infected houses and in attendance on the sick, than is the case with males, the matter being simply a question of more or less exposure to infection.

My colleague, Dr. Arthur Downes, then one of the leading provincial health officers, wrote some years afterwards a series of articles on the Causes of Epidemic Diphtheria,¹ and adverting to theories I had expressed, he stated : "This explanation covers much, it may be all, of the preponderance of attacks in adolescent females, but it is not so certain that it could be similarly applied to any excess among girls of more tender age."

In so far as diphtheria deaths at all ages are concerned, I find that in England and Wales during the decennium 1861-70, males died at the rate of 0·17 per thousand, whereas the rate for females was 0·19 ; and that during the decennium 1871-80, the male and female rates were equal, namely 0·12.

But Dr. Downes has studied the incidence of diphtheria death in the two sexes at different age periods, and he finds that for ages 5-10 years the female death-rate is about 30 per cent, and for the ages 10-15 years not less than 50 per cent greater than the death-rate at these respective age-groups for males. In regard to this

¹ "Contributions to a Study of the Causes of Epidemic Diphtheria," by Arthur Downes, M.D. *Practitioner*, vol. xxxi. pp. 394, 465 ; vol. xxxii. p. 67.

he urges that if it be sought to explain that girls of the ages in question contracted more diphtheria than boys in consequence of "a greater domesticity already manifesting itself in their characters," and by reason of more constant association with the sick, it is difficult to understand why a similar result should not be found in the case of scarlatina. And he finally arrives at the conclusion that this excess of mortality from diphtheria amongst females "is probably due to their greater physiological proclivity to take the infection." In this connection I would observe that something may depend on the full significance of the term "domesticity," and upon its taking account of those acts of affection and tenderness which, in their relation to the sick, characterise females during the period of girlhood as well as in mature womanhood. I shall have occasion to revert to this subject in referring to the exceptional risk which attaches to action involving intimate contact between the sick and the healthy in the case of diphtheria, as contrasted with other infectious diseases. And, even now, I would point out that the excess of diphtheria death which attaches to females over males from 3 to 15 years of age, increases precisely as the age advances which fits them more and more to take some share in the care of home and of relatives during periods of sickness.

In the meantime I append Dr. Downes's instructive statistics, merely adding that the "diphtheria" in the period 1851-60, during one-half of which diphtheria and scarlatina fever were grouped together as one dis-

ease for the statistical purposes of the Registrar-General, is, like the "scarlatina 1861-70" period, inserted essentially for purposes of comparison.

TABLE No. VII.

PERCENTAGE EXCESS OR DEFICIENCY IN FEMALE DEATH-RATES FROM DIPHTHERIA AND SCARLATINA AT CERTAIN AGES AS COMPARED WITH THE CORRESPONDING DEATH-RATES OF MALES.

Age in years.	-1	-2	-3	-4	-5	5-10	10-15
"Diphtheria," 1851-60	-10	-5	+5	+13	+18	+27	+50
Diphtheria, 1861-70	-24	-3	+10	+10	+24	+33	+60
Scarlatina, 1861-70	-16	-8	-2	-3	-2	-3	+15

I would also draw attention to Table No. VIII., which gives the mean of the annual number of diphtheria deaths, at certain ages and in each sex, to 100,000 living in each class at those ages, for the two decennia 1861-70 and 1871-80. The table shows that the rate for males in the first two years of life was greater than that for females, whereas the rate for females was higher than that for males from the beginning of the third year up to the close of the fifteenth year. In short, there is, I believe, for girlhood as for early womanhood, a greater danger of fatal diphtheria than during the corresponding periods of life in males; the difference being very probably one of greater and more sustained exposure to direct infection.

Age is universally admitted to have an important influence on diphtheria, in so far, at least, as mortality is

concerned. According to the returns of the Registrar-General for the periods 1861-70 and 1871-80, the average annual number of deaths registered as due to "diphtheria" in England and Wales was as under :—

[TABLE No. VIII.

TABLE No. VIII.

ENGLAND AND WALES, 1861-70 AND 1871-80. AVERAGE ANNUAL NUMBER OF DEATHS FROM
DIPHTHERIA AT CERTAIN AGES TO 100,000 LIVING AT THOSE AGES.

PERSONS.

Decennia.	All ages.	0-1	1-2	2-3	3-4	4-5	5-10	10-15	15-20	20-25	25-35	35-45	45-55	55-65	65-75	75+
1861-70	18	58	91	80	83	73	39	14	6	4	3	2	2	3	3	2
1871-80	12	29	49	48	58	55	29	9	3	2	2	2	1	2	2	1
				+												
Mean .	15	43	70	64	70	64	34	11	4	3	2	2	1	2	2	1

MALES.

Decennia.	All ages.	0-1	1-2	2-3	3-4	4-5	5-10	10-15	15-20	20-25	25-35	35-45	45-55	55-65	65-75	75+
1861-70	18	66	92	76	79	65	34	11	6	3	2	2	2	3	3	3
1871-80	12	32	52	47	54	52	26	7	3	2	1	2	2	2	2	1
				+												
Mean .	15	49	72	61	66	58	30	9	4	2	1	2	2	2	2	2

FEMALES.

Decennia.	All ages.	0-1	1-2	2-3	3-4	4-5	5-10	10-15	15-20	20-25	25-35	35-45	45-55	55-65	65-75	75+
1861-70	19	50	89	84	87	81	45	17	6	4	3	2	2	2	2	2
1871-80	12	25	46	49	63	57	32	10	4	2	2	2	1	2	2	1
Mean .	15	37	67	66	75	69	38	13	5	3	2	2	1	2	2	1

Note.—The figures for 1861-70 are based on 39,454 deaths, and those for 1871-80 on 29,426. The all-age rates, and the rates from the age 5-10 onwards for both decennia are taken from p. cxiii. of Registrar-General's Decennial vol. for 1871-80. The rates given there, being per 1,000,000 living, are divided by 10 to give the rate per 100,000.

* Calculated from figures on pp. 2 and 3 of Registrar-General's Decennial vol. for 1861-70.

† Calculated from p. 4 of Registrar-General's 1871-80 Decennial vol.

‡ Calculated from p. 2 of Registrar-General's 1871-80 Decennial vol.

§ Calculated from p. 3 of Registrar-General's 1871-80 Decennial vol.

From this table it will be seen that by far the largest mortality in any age-group is that which takes place in the first five years of life, that the period 5-10 years takes second rank in this respect, and that after the age of 15 years a marked diminution sets in and is maintained for the remainder of life. But there is no uniformity in the incidence of diphtheria death on the several years included in the first group. The average annual number of deaths in the first year of life falls far short of that which attaches to the period 1-4 years, and some lessening of mortality is already evident in the 4-5th year, the largest proportion of total death falling on the central three years of the first quinquennium of life.

The comparative scarcity of diphtheria death during the first year is probably to be, in part, accounted for by the fact that there is less risk of exposure to direct infection at that age than at any subsequent one until adolescence is passed; the question of nomenclature may also have to be considered; and I am also of opinion that the circumstance of infants being so largely fed either at the breast, or by means of milk-preparations which have been more or less sterilised during the process of their manufacture, must be taken into account in this connection.

But when question of attack, apart from death, is considered, certain unpublished experience of some of my colleagues, and notably that of Dr. D. A. Gresswell, now chief health officer to the Government of Victoria, becomes of importance. On numerous occasions, when

investigating the causes and incidence of diphtheria, careful examination of the fauces of infants in houses where diphtheria was present has revealed the fact that an inflammatory condition of the tonsils, with sub-maxillary enlargement, was present, and this apparently without obvious inconvenience to those attacked. The point may possibly have some physiological interest, in view of the somewhat rudimentary character of the tonsils at a period of life associated with the functional obliteration of the thymus gland.

And, with regard to the whole period 1-15 years, it has been very properly pointed out by Dr. Downes that it would be difficult to deduce from such statistics alone the conclusion that there is an age-predisposition to attack from diphtheria. The figures quoted may only mean a greater tendency to fatal result at certain ages, or their interpretation may lie in a greater risk of exposure to infection at certain periods of life. But, whilst admitting that the returns referred to are not in themselves conclusive, I certainly express the view of nearly all skilled investigators of diphtheria when I say that, from one cause or another, the first fifteen years of life are those during which diphtheria is most commonly recognised, and that there is a special incidence of the disease, fatal and non-fatal, on the period 3-12 years.

In many epidemics the malady is almost entirely limited to children of the age-period specified, and so far as recognised diphtheria is concerned, no noteworthy difference can be shown between the incidence of attack

and of death at different ages from 3 to 12 years of life.

Referring to this question of age in a report on diphtheria at Brailes, Warwickshire, in 1876, Mr. W. H. Power, having tabulated both the attacks and deaths according to certain age-groups up to fifteen years, writes as follows :—"There is here seen a special incidence of diphtheria on children above three years and under twelve years of age, and the question now arises to what extent this was an affair of mere age as affecting personal susceptibility, or was an affair of different exposure to the cause of diphtheria. It is requisite to consider this question in some detail, for, though the results will be negative, there will be advantage in indicating some of the sources of fallacy surrounding such inquiries. Age by itself can be supposed to have determined this special incidence on children in either of two ways ; either through the circumstance of their seniors being protected by reason of having already passed through an attack of the disease, or through children having, by the mere circumstance of their being children, some greater proclivity to receive the infection of the disease. Now in the case of diphtheria there is no reason for believing that any notable degree of protection is given by an antecedent attack, and certainly at Brailes there had been for years no means of such a protection being acquired. The mere fact of childhood undoubtedly goes for something as predisposing to attack, especially to fatal attack, and the question is what degree of influence ought to be assigned to the

mere fact of age as determining attack. This question is mixed up with the question of different opportunity of exposure in children and in their elders."

But this question of opportunity of exposure to the infection of diphtheria amongst children at once opens up others. The age 3-12 years is essentially the age of attendance at elementary schools; and the influence of school attendance on the causation, intensity, and diffusion of diphtheria involves a number of important considerations. These considerations, too, in turn, owe their right interpretation very largely to the meaning which should properly be assigned to the term "diphtheria" as used in returns both of mortality and of sickness. To such points I would therefore now direct attention.

CHAPTER II

WHAT is diphtheria as it is met with in this country, both in its sporadic and epidemic form? It is certainly not limited to that disease to which alone the term "diphtheria" has hitherto been assigned, whether in records of sickness or of death.

Inquiry into the causes of diphtheria prevalences elicits few things more striking than the ever-recurring need of an attempt to disentangle the beginnings of an epidemic from out of the midst of a group of affections which, in so far as nomenclature is concerned, have but little in common. And, to some extent at least, the difficulty lies in the character of the disease itself.

The experience which I met with at Great Coggeshall in 1876 is fairly typical of the point involved. Several rapidly fatal attacks of diphtheria had occurred towards the close of January and the beginning of February of that year, and official inquiry into the circumstances was instituted. It was then found that during the months of November and December of the preceding year there had been 11 attacks of so-called "croup," of which no less than 7 had terminated fatally; that, with the exception of one non-fatal attack in an

adult female, these cases had all occurred amongst children ; and that in some houses there had been multiple attacks, second, and even third ones succeeding each other at intervals of a few days.

Following on this series of "croup" attacks, a second group of somewhat similar sort had commenced during the second week of January, but in 2 out of the 3 later fatal attacks the diagnosis was "diphtheria and croup." And lastly, simple "diphtheria," or that disease associated with paralysis, was recognised both in the fatal and non-fatal form. Seven more deaths took place before the middle of March. Then ensued a large number of attacks which were in the main regarded as "sore-throat" only, and this although an infectious quality in the disease seemed indicated by the number of instances in which attack succeeded attack in the same household. Two fatal attacks in this group were registered as having been due to "diphtheria." Between the beginning of May and the end of August the disease greatly abated, only 18 mild cases of throat illness being recorded. But a rapid spread commenced in September, although between the 1st of that month and October 30th only 2 deaths occurred out of 54 attacks that were heard of. These 2 deaths were admittedly due to well-marked diphtheria, whereas many of the other cases would have passed all but unnoticed had it not been for the sustained inquiry that had been set on foot. Between the beginning of November and the end of the third week of December fatal attacks were more largely interspersed with the milder cases of throat disease ;

and the outbreak appeared to come to a close with three fatal diphtheria attacks in the last ten days of December, when a serious milk-epidemic of enteric fever set in. The total attacks of throat disease in a population of some 3300 had been 170, and of these 25 terminated fatally.

The story, in short, is one in which fatal diphtheria was first registered as due to "croup"; an infectious quality apparently attaching to the disease next led to its being styled "diphtheria and croup"; and lastly, diphtheria, as such, was recognised, the diagnosis being facilitated by the onset of paralytic sequelæ. But with the advent of spring weather the more typical signs of diphtheria either disappeared or were no longer sought for amongst a group of "sore-throat" attacks of but little gravity, and this although it was evident that these very cases became, by direct infection, the precursors of a number of well-marked and even fatal attacks of diphtheria later on. Those patients whose attacks were mild had had "sore-throat," those who died had suffered from "diphtheria."

This outbreak, which hardly differs from many others, unless it be in respect of its long continuance under local circumstances, to which I have already referred, suffices to indicate that, concurrently with diphtheria, there often exists a large amount of throat sickness, much of it never coming under medical observation, but which, under one and another name, serves as the connecting link between groups of typical diphtheria attacks. But these undefined or ill-defined sore-throats do not only

occur synchronously with recognised diphtheria; they also claim our consideration as occurring both antecedently to and subsequently to diphtheria prevalences.

In the epidemic just referred to the group of deaths from so-called "croup" did not constitute the beginnings of the outbreak. The death-registers of the period preceding it contained entries of "croup," of "tonsillitis and croup," of "laryngitis" involving "tracheotomy," together with other similar returns; and examination of such local records of sickness as were available revealed the existence, during the same time, of an excess of "cynanche," "quinsy," "tonsillitis," and even "diphtheritic inflammation of the nares." Indeed, there was a unanimity of medical and other testimony to the effect that sore-throat, often of a low type, was a matter of common local experience, and that there had been an excess of such mischief for some few weeks preceding the five fatal "croup" attacks with which the epidemic had seemed to open towards the close of the year.

With regard to this antecedent sore-throat the experience related is by no means exceptional. The same has been met with again and again by my colleagues in the Medical Department of the Local Government Board, and by medical officers of health in different parts of the country.

In 1884 Mr. W. H. Power reported on a lingering prevalence of diphtheria in the village of Tichmarsh, Northamptonshire.

"Nothing," he writes, "can with certainty be learned

respecting the origin of the diphtheria in this village, nor can precise information now be got as to its subsequent behaviour there, and for the following reasons :—In Tichmarsh, as indeed has been observed elsewhere in diphtheria epidemics, occurrence of cases of unmistakeable diphtheria has been preceded and associated with prevalence of comparatively trifling sore-throat, much of which has not come under medical observation. Of such diphtheria and throat illness as did come under medical treatment, much occurred in club practice, and the dates of its occurrence did not get recorded.”

Later on he proceeds as follows :—

“It appears that about April 1883 ‘sore throats and colds’ became generally prevalent in Tichmarsh, and soon there occurred cases attended by severe indisposition. Of the first of these severe cases it was definitely affirmed on medical authority that the affection was not diphtheria; but by early May at least one attack had occurred, the diphtheritic character of which was medically recognised. In regard of these earlier cases no information was afforded the officer of health, and he did not come on the scene until 30th May, when two recent deaths from diphtheria had been reported to him. At this date he found three cases of distinct diphtheria in the village.”

Then followed a period, from June to September inclusive, in which only a few recognised attacks took place, and during which no records as to throat illness were maintained. But at the end of October, and in early November, “a great outbreak of very definite diph-

theria took place, some 25 children becoming attacked within a few days," 10 cases proving fatal. The disease still lingered in the village until Mr. Power's arrival there in February 1884; and of that time he writes:—"I saw during my inspection more than one case of recently acquired sore-throat, which though perhaps not clinically classable as diphtheria, could easily be thought of as having kinship with that disease. Probably similar cases might, if looked for, have been found in Tichmarsh at any time during the last ten months."

In 1889 Dr. Bruce Low was instructed to inquire into the circumstances of an excess of diphtheria death in the Halstead registration district in Essex, during a portion of the preceding year. As a preliminary to his inquiry, it became necessary to ascertain what had been the localities of the chief prevalence of the disease.

"For this purpose," he writes, "I made a careful examination of the death records of the registration district during the last fifteen years, and it soon became evident that 'diphtheria' as a registered cause of death was not alone in question. In these records there were, concurrently with the deaths registered as due to diphtheria, many deaths registered from croup, laryngitis, tracheitis, and the like. Not only were these deaths concurrent in point of time with the diphtheria deaths, increasing and decreasing in number throughout the fifteen years with increase or decrease of diphtheria deaths, but they were concurrent in the same localities, in town and country, and concurrent often in the same

families and houses, especially in recent years. The following are some illustrations of this :—

“In the month of January a few years ago five deaths were certified from ‘diphtheria’ in a small village. During the same month in the adjoining parish two deaths occurred within five days of each other ; both were certified as being from ‘tracheitis,’ and sixteen days later a third death took place, this being certified from ‘croup.’ In another village near, two deaths took place from ‘diphtheria,’ one in September, and the other in November of the same year. Four weeks later three deaths (two in persons of the same name) occurred in one day in this village, all three being certified as from ‘tracheitis,’ two of them having ‘collapse’ added as a secondary cause. In a different village, seven deaths from throat ailments were registered in one year, three of them from ‘laryngitis,’ two from ‘diphtheria,’ one from ‘diphtheritic laryngitis,’ and one from ‘croup.’ In another locality two deaths happened in one house, within six days of each other, the first being certified ‘membranous croup’ and the second ‘diphtheria.’ Elsewhere a child aged six died of ‘ulcerated throat, syncope.’ On the day of her death her mother was seen to kiss frequently her dying child’s lips. Three weeks later her mother died, her death being certified from ‘diphtheria.’ After her death two younger children became ill with throat ailment, as also did a relative who came to nurse the mother. The baby, aged eight months, died four weeks after its mother, the death being certified from ‘croup.’

"From a study of these death records and from other evidence, it became apparent that, in the Halstead registration district, diphtheria, and especially non-fatal diphtheria, had gone under various different names, and that the deaths registered under the heading of diphtheria by no means truthfully represented the dimensions of the mortality from what had been essentially one and the same disease."

And he adds that the result of a detailed examination of the death-returns went to show "that throughout the period under consideration, the deaths ascribed to diphtheria represented *less than one-half of the mortality* that probably may fairly be referred to that disease." Such occurrences as these go far to show how incomplete are the mortality returns which aim at showing the amount of death that is due to diphtheria in this country.

Dr. Blaxall tells an interesting story of diphtheria which took place at Midsomer Norton, in Somersetshire, in 1888. The symptoms in the first recognised case of diphtheria commenced on the 30th of April, and on tracing back its beginnings, he learnt that there had been "a good deal of sore-throat, ulcerative in character, and specially offensive during the winter months." School children were somewhat widely affected, but little notice seems to have been taken of their ailment until two sisters died of diphtheria early in May, their attacks being speedily followed by others amongst their school-fellows, of whom three more died between May 11th and 13th, and then a general alarm ensued. In all, 40 cases of "sore-throat" or diphtheria occurred in 27

households in this little town, and 6 cases terminated fatally. Here are a few of the antecedent cases to which Dr. Blaxall refers :—

“A. L., aged 5, was in attendance at the Chapel School up to April 13th, when she complained of sore-throat, and her mother kept her at home till April 30th. She did not have a medical attendant, but her mother describes her attack to me as showing burning heat, with great discharge from her nose and swelling of the glands of the neck. I saw the child myself on the 8th of June, two months after the date of attack, when I found her suffering from a paralysis, affecting voice and deglutition, characteristic of that which follows diphtheria. No other case occurred in this family. It consists of father, mother, and four other children, three of whom continued to go to the Chapel School during their sister's illness. A. L. returned to school on April 30th, and it is noteworthy that during the following five or six days six fresh cases of diphtheria occurred in the school, four of them in the infant class, to which this little girl A. L. belonged.

“S. M., aged 8, was attacked with sore-throat of a suspicious character on the 18th of April, and her mother kept her at home till the 30th April; her sister, M. M., aged 5, continued to attend school, and was attacked with diphtheria on May 3d. Whether the origin of this case was by infection from S. M., or by infection contracted at school, is not clear, seeing that this child was one of the four cases above mentioned as occurring in the infant class to which A. L. returned on

the 30th April. I saw the child M. M. on the 24th of May, and again on the 18th of June, when she was a pitiable object from diphtheritic paralysis, head bowed down, voice so much affected as to be scarcely intelligible, hands tremulous, and gait very tottering. Prior to S. M.'s attack of sore-throat on the 18th of April, her married brother and his wife, living in another part of the village, had both suffered from sore-throat, to which the man was subject.

"T. G., aged 8, was absent from the Chapel School from the 9th to the 17th of April, and his sister from the 17th to the 29th of April, both suffering from sore-throat.

"A. H., aged 8, was absent from the 30th of March to the 8th of April, suffering from an illness that was said to be 'like mumps.' At the same time his sister, aged $3\frac{1}{2}$, was very ill with vomiting, headache, and slight sore-throat."

Much the same point was referred to by Dr. Franklin Parsons, in a report on diphtheria which occurred in 1887 in the parishes of Roche and St. Stephens, near St. Austell. After referring to the uncertainty which attached to the origin of the disease, and to the local use of the term "throat fever," in cases where throat symptoms were prominent, he next discussed the question of the propagation of the disease.

"As regards the means by which the disease was spread, I am of opinion that, in most instances, its occurrence may be accounted for by infection contracted from a previous case, more especially if we may allow

that the known cases of diphtheria were accompanied by a number of mild unrecognised ones. I learnt from more than one source that sore-throats were very prevalent in Roche last autumn. Thus the schoolmaster at the Roche Board School states that at the time when diphtheria was prevalent, and to a less degree before and afterwards, many of the school children had sore-throats, and used to come to school with their necks tied up in flannel. Experience gained elsewhere has shown that outbreaks of diphtheria are frequently accompanied by a similar prevalence of sore-throats not distinctly diphtheritic in character, and has shown it to be probable that though such cases may not, from a clinical point of view, come within the definition of diphtheria, they are essentially of the same nature, and that a susceptible person coming in contact with one of them may contract the disease from it in a severe form."

I take it, indeed, that there is practical unanimity of opinion amongst skilled observers as to the association with diphtheria of certain throat affections which, if met with apart from cases of the recognised disease, would certainly not be regarded as having any definite relation with it.

It may be suggested that many of these mild and ill-defined attacks are but cases of ordinary catarrhal sore-throat such as is met with everywhere, and this quite irrespective of diphtheria. Or again, it may be assumed that they are cases of true but mild diphtheria in which the more typical symptoms have been so evanescent as to have escaped detection. There is some

truth in both these contentions. On the one hand, sore-throat of apparently innocent type is often exceptionally prevalent in localities that are especially prone to diphtheria; and, on the other hand, some of the mildest of these throat ailments which have been associated with diphtheria occurrences, have been followed by those secondary paralyses which are, I believe, peculiar to diphtheria amongst throat affections. But I feel convinced that neither of these views fully explains the true relation of the throat-sickness in question to diphtheria occurrences.

I have taken some pains in following out diphtheria prevalences which I have had under investigation, to examine in considerable detail the condition of the fauces of those who were classed amongst the healthy both in households, families, and localities where the diphtheria had prevailed, and also, when occasion permitted, of many persons in households lying around and beyond the area immediately under consideration. And, on a number of occasions when any such detailed investigation was practicable, I have been much struck with the evidence which was forthcoming as to a general diffusion and habitual prevalence of sore-throat mischief, such as was indicated by the existence of enlarged and hypertrophied tonsils, chronic engorgement of the fauces, and more or less deep-seated tonsillar scars. And these evidences of a general prevalence of sore-throat have usually been most marked in districts, the physical features of which I have referred to as favouring diphtheria. Such experience, taken together with that of Dr.

Airy, who found that diphtheria had a preferential incidence on families that had shown liability to throat affections, leads us to inquire into the true significance of these throat ailments. Is it, for example, that affections of this sort are capable of passing by a process of development, from an innocent to a specific form of throat disease; or is it that the local mischief they occasion provides a soil favourable to the reception and multiplication of the contagium of diphtheria?

The former view has, on several occasions, been strongly forced upon me by the circumstances with which I have met. The experience which I gained by visiting the scattered population living mostly in minor valleys in the hills which flank the Vale of Clwyd, on the occasion of the Llanrhaiadr outbreak in 1877, was very marked in his respect, and I was largely influenced by it, when, in discussing the question of the "Origin of Infection," shortly after that date I wrote as follows:—¹

"In isolated districts, and in houses situated at times miles away from other habitations, and in some instances lying in lonely spots among mountain ranges, where a visit to or a visit from the nearest town or village would be a circumstance too important to be forgotten, I have met with instances of what appeared to me to be nothing

¹ *Transactions of the Epidemiological Society of London.* Vol. iv. Sessions 1875-80. The main suggestion embodied in this extract was afterwards amplified in an interesting and closely reasoned paper by Dr. Hubert Airy, M.A., entitled, "Infection considered from a Darwinian point of view," in the same volume of the *Transactions of the Epidemiological Society of London.*

more than a simple inflammation of the throat, at times so trivial that it has passed all but unnoticed, and yet it has led by transmission through other persons to cases of well-marked and severe diphtheria. The first attacks have often happened in children whose former movements could apparently be traced with the strictest accuracy ; they have occurred under circumstances which did not appear to admit of previous infection ; and it has been difficult to interpret their occurrence except on the supposition that in some way they have arisen independently of prior cases. With regard also to the well-marked attacks of diphtheria to which they seemed to give rise, all other sources of infection could be excluded with a degree of certainty rarely to be met with. And as to those first affected, whose cases appeared to be earliest in a series which led up to attacks of well-marked diphtheria, it has more than once happened that they were children in whom so-called 'sore-throat' was a common affection, and whose fauces when examined exhibited a loss of tissue indicative of former throat attacks.

"I have stated that instances such as these have been met with in connection with outbreaks of diphtheria, and it may therefore be inferred that the early cases were merely mild attacks of that disease, the poison of which had been received in some unascertained method ; but every one of these instances occurred in persons living miles away from the apparently very limited infected localities, which in some cases were mere hamlets, and this source of error seemed to be one

which could unquestionably be excluded. And during the same investigations I have noticed the fact that over an area of some miles around the district in which genuine diphtheria was prevailing, there existed prior to as well as during the diphtheria epidemic numerous instances of sore-throats which, so far as examination of the patients was concerned, in every way resembled the early cases above referred to, and yet which gave no indication of being infectious ; sore-throat being in fact in the surrounding district a prevailing ailment. And I have hardly been able to refrain from drawing the conclusion that conditions very similar to those under which genuine diphtheria was epidemic in a limited district obtained, and had obtained before genuine diphtheria was anywhere seen, over a wide area around the immediately infected locality, and that these conditions, leading to a somewhat general predisposition to simple and apparently non-infectious inflammatory sore-throat, had further, probably under somewhat modified circumstances, tended at certain points to produce an affection capable of putting on the property of infectiveness, which thus led to the transmission of the disease in a distinctly communicable form to others.

“If this be a correct interpretation of the circumstances related, it would appear to indicate the possible occurrence of what may perhaps be looked upon as *the progressive development of the property of infectiveness*. And if the contagia of the acute specific diseases do, as has been suggested by more than one observer, belong to the vegetable world, I know no grounds for refusing to

believe that organisms capable of producing a minor and an uncommunicable disease in particular stages of their growth, may in other stages of their growth, or in the course of their subsequent development, become capable of producing a major disease communicable from person to person, the affair being essentially one of soil. This is not at all a question of the development of a living organism out of matter independently of antecedent life, but merely the production by means of a process of evolution of that which gives to an already existing organism that property by which it becomes infective, a property which it may perhaps lose directly it is deprived of the circumstances which favoured its development in much the same way as special characteristics may be artificially developed in higher plant life, and be as easily lost again."

Some trustworthy observers have on occasion failed, as the result of their investigations, to find confirmation of this view. On the other hand, I have from time to time come across observations by others tending to support it.

Dr. David Page, when medical officer of health to the Ulverstone district, referred in 1881 to certain forms of throat mischief as affecting the "throat and larynx" in diphtheria, and he added, "I have frequently found as a precedent to actual diphtheria . . . a well-marked tendency to catarrhal and inflammatory affections of the same regions." Mr. Jacob, medical officer of health for Mid-Surrey, forwarded me about the same date a report on a diphtheria prevalence which he had

investigated, and which he said embodied "an account of an outbreak of diphtheria which was preceded for a month by a series of *ordinary sore-throats*, and gradually worked up (so to say) to the genuine characteristic form of the disease." And Mr. Fosbroke, now health-officer to the county of Worcester, having more than once adverted to this subject, wrote in 1889 quoting my experience in detail, and then added that he had "spoken of this connection between sore-throat and diphtheria on very many occasions, and frequently attributed different outbreaks to 'progressive development' of throat affections. This theory as to the spread of diphtheria," he goes on to say, "is becoming more generally accepted from day to day."

But I attach special value in this connection to a passage which occurs in a report by my colleague, Mr. W. H. Power, on an epidemic of diphtheria at Pirbright in 1882, and this the more, because, as I shall have occasion to show hereafter, he definitely states as regards one of the most interesting phases of that outbreak that, viewing the epidemic as a whole, there was no evidence of progressively increasing gravity; but the matter was otherwise when certain household attacks were considered.

The passage in question is as follows:—"In our investigation of the incidence of throat-illness on families, Mr. Smith (the local health-officer) and I were struck, and independently of one another, by the apparently different ability of the disease in one and another instance to extend itself in families invaded. Not unfre-

quently severe and fatal diphtheria appeared destitute or wellnigh destitute of power to infect other children living along with it, while on the other hand cases of very trivial sore-throat or 'colds' that were not perhaps heard of (except by close questioning) often preceded, and were seemingly responsible for, after-occurrences of true and fatal diphtheria in the family. Especially was this apparent capacity of mere sore-throat for breeding malignant diphtheria noticeable in regard of families comprising many young children. In such families severe or fatal cases of diphtheria tended to occupy a position midway in a series of attacks that began as sore-throat and ended in similar fashion. And further, we got a suspicion, though the instances were too few to justify any conclusion thereon, that, given the occurrence about the same time of two or more cases of trivial sore-throat among children of a large family, such occurrence was likely to be quickly followed by severe diphtheria attack in one or more children of that family."

I am thus confirmed in the view which I expressed in 1878, but there remains the question as to the extent of the operation of any such process of progressive development of infection as an initiating cause of diphtheria.

During the thirteen years which have elapsed since I wrote the passage I have quoted, some of the more obscure occurrences of diphtheria have found their explanation in circumstances then but little suspected, and notably by reason of the communication of the poison through the medium of milk either as vehicle of

an extraneous infection, or as being itself the secretion of a diseased animal. And yet, I am unable to regard any modern research as having sufficed to set aside the views which I have formulated, to the effect that the progressive development of the property of infectiveness, and of the specificity of the contagium of this disease, is a not uncommon process by which a prevalence of diphtheria is brought about.

But whilst this is the case, I am inclined to attach increasing importance to the view, that much of the prevailing diphtheria is due to the circumstance that there exist a number of non-specific conditions of the fauces—inflammatory and otherwise—which constitute a favourable soil for the reception and growth of a wandering diphtheria contagium.

Oertel puts it that “the presence of a catarrhal affection of the mucous membrane, as one often has opportunity of seeing, seems to predispose to diphtheritic infection”; and I would venture to go so far in affirming my belief in the existence of an important relationship between diphtheria and a morbid condition of the mucous membrane of the fauces, as to intimate some doubt whether the contagium with which diphtheria is associated ever finds in a throat, the mucous surface of which remains unabraded and unaltered by reason of local disease or otherwise, the soil necessary either to its progressive maturation, or to the production of those specific changes which follow on its reception and multiplication. Indeed, I would suggest that in this respect throat-diphtheria essentially resembles the same disease when it affects

other lesions of the surface.¹ Herein lies, I believe, the explanation of that conflict of opinion which has surrounded two interesting questions affecting the natural history of this disease. I refer first, to the identity or otherwise of scarlatina and diphtheria; and second, to the relation of faulty sanitary circumstances to the causation of diphtheria.

Scarlet Fever and Diphtheria.—Amongst English medical officers of health, Dr. Francis T. Bond, of the combined Gloucestershire Sanitary District, is prominent as a believer in the identity of scarlatina and diphtheria. Writing in his Ninth Annual Report in 1881, as to deaths from scarlatina, croup, and diphtheria, under the heading of "Scarlatinoid Disease," he says: "I group these three affections together under the head scarlatinoid, because I know of no line of demarcation by which they can be theoretically separated from one another; because it is often impracticable to say whether a case is one of genuine diphtheria or merely scarlatina sore-throat." He admits freely that there are cases of diphtheria which are unconnected "in any way with suspicion of scarlatinoid infection," but he holds that scarlatina "shades off into the diphtheritic group of affections," and he adds that it tends also "to pass insensibly into measles."

In a paper read before the Epidemiological Society

¹ Dr. Thursfield in his Brighton address of 1890 says—"The experiments on animals by Dr. Roux at the Paris Pasteur Institute afford strong presumptive evidence that, on a healthy and unabraded mucous membrane, the diphtheritic germ would, as a rule, fall harmless, and that some abrasion is necessary for successful inoculation."

of London in June 1884,¹ Dr. Franklin Parsons discussed this question somewhat exhaustively. He set out, in the first instance, certain points in which scarlet fever and diphtheria exhibited resemblances. Thus he noted: That the registered mortality from diphtheria, as from scarlet fever, is highest in the fourth quarter of the year. That the mortality from both diseases is comparatively small during the first year of life, but increases rapidly, being more than double in the second year; it attains its maximum in the fourth year of life, but continues at nearly the same high level from the second to the fifth year, after which it rapidly declines. But, on the other hand, he indicated that diphtheria, unlike scarlet fever, is more fatal to females than to males;² and also—a point that is much less striking now than at the date when the paper was written—that “diphtheria contrasts markedly with scarlet fever in that the former is, in this country at least, a disease specially of rural districts.”

He proceeds, however, to give prominence to the view that “there is a very close resemblance in many respects between scarlet fever and diphtheria,” that the two diseases are often prevalent together in the same locality, and even concur or closely follow each other in the same individual; and that usually in this country scarlet fever is entered as the primary disease, and diphtheria as the secondary. He next quotes Dr. Ballard’s experience as to a number of cases in which, there being

¹ *Transactions of the Epidemiological Society of London*. New Series. Vol. iii. 1883-84.

² This point I have already discussed. See pp. 33-36.

satisfactory evidence of "diphtheritic exudation," the diphtheria was associated with recent scarlet fever, and he adds: "In only two of these did the rash appear in the course of the throat affection. Of the remainder, in all but one case the rash had left the skin before the diphtheritic exudation appeared." And, reverting to his own experiences, he says that of death-returns which had come under his notice, in which the two diseases had been conjointly certified, diphtheria had generally been secondary to scarlet fever, and rarely scarlet fever to diphtheria.

Dr. Parsons then proceeds to give the following somewhat typical instances of the association of the two diseases:—

"In 1882-83 an epidemic of scarlet fever, associated with diphtheria, prevailed in the Thorne Union, on the borders of Yorkshire and Lincolnshire, a level fenny tract with low islands of new red sandstone and marl, on which the larger villages stand. The neighbourhood suffered severely from diphtheria in 1858-59 (reported on by Dr. Sanderson in the Second Report of the Medical Officer to the Privy Council), and diphtheria, associated with scarlet fever, was also prevalent in 1874 in some closely adjoining and similarly situated places in another Union.

"Throughout the epidemic of scarlet fever in 1882-83 the type of the disease appears to have tended towards throat complications: thus, of 82 fatal cases, 12 were certified as 'scarlatina anginosa,' 4 as 'scarlatina and diphtheria,' 3 as 'scarlatina maligna and croup,' and 1

'scarlatina anginosa six days, laryngitis one day.' Thus, in 20 cases throat symptoms were so prominent as to be specially noted on the certificates of death, while in only 7 were renal symptoms so noted. Besides the above, there were 5 deaths from 'croup' associated with scarlatina in other members of the family, and 14 deaths from diphtheria. These cases occurred in different places, and in the practice of various medical men. There appears to be no room to doubt that the cases recorded as 'diphtheria' were, as a rule, correctly so described. A thick false membrane covering the fauces, and on removal often leaving an ulcerated surface beneath, appears to have been a prominent symptom, and many cases were followed by the partial paralyses characteristic of diphtheria. On the other hand, there were repeated instances in which the two diseases seemed to concur, or even to be interchangeable. What was called diphtheria appeared to have been contracted from a case called scarlet fever; members of the same family suffer together, one from the one disease, others from the other, and in 4 of the fatal cases the same individual is certified to have suffered from both.

"In one family there were 5 cases of diphtheria, and 2 of them were accompanied by scarlet fever. The first, a girl of sixteen, suffered from diphtheria in November, but recovered in about five weeks. She had no rash nor desquamation, but remained deaf for some time after her illness. In January, a boy of six, and two or three days later a girl of two and a half, had diphtheria and scarlet fever together; the girl had subse-

quent dropsy. Two other children afterwards had diphtheria. There were nuisances in the neighbourhood of the house from pools of sewage and an open middenstead.

"In another family there were 3 cases of diphtheria, and 1 of scarlet fever. The first case (diphtheria) was in a lad of sixteen; the second in a girl of two, who died of 'diphtheria'; the third, a girl of twelve, died three weeks later of 'scarlet fever'; the fourth, a girl of fourteen, recovered from diphtheria, but her sight a month later was still dim, so that she could not read.

"A little girl had, in the latter part of September, a typical attack of scarlet fever. She had, a few days before her illness, associated with another girl, who was then sickening with what proved to be an attack of scarlet fever. An apprentice, aged seventeen, worked in a room into which the little girl first mentioned, after her recovery, used to come. He was taken ill on November 6th with diphtheria, of which he died on November 13th. His mother, with whom he lived, subsequently suffered from diphtheria, followed by paralysis of the legs and pharynx. . . ."

And in conclusion, Dr. Parsons, having expressed the view that there is often an apparent connection between diphtheria and scarlet fever, and having explained that, according to his experience, "scarlet fever has tended more to assume a diphtheritic character in houses where there were local insanitary conditions," propounds the following hypothesis in explanation of the association referred to:—

"(1) That the connection is apparent only, and due

to mistakes in diagnosis;¹ cases of scarlet fever with exceptionally severe throat symptoms being called diphtheria, and cases of diphtheria, with the rash which occasionally occurs, being called scarlet fever.

“That this is not a complete explanation is shown by the occurrence in some instances of the sequelæ respectively characteristic of the two diseases, some cases of scarlet fever, as at Thorne, being followed by renal dropsy, while cases of diphtheria associated with them have been followed by local paralytic symptoms.

“(2) That the two diseases are distinct but concurrent;² the one rendering the individual more susceptible to the other, either by lowering the general vitality and power of resistance, or by denuding the fauces of epithelium, and thus rendering the mucous membrane more suited for the reception of the contagium of the other disease.

“It has been noticed that persons who suffer from chronic sore-throats are more liable than others to contract diphtheria. Doubtless an enlarged tonsil or an ulcerated pharynx offers a more favourable soil than a healthy mucous membrane for the development and growth of the diphtheritic contagium, and the sore-throat of scarlet fever may do the same.³

¹ Semple, *Diphtheria*, p. 19. ² Greenhow, *Diphtheria*, p. 105.

³ Much the same view was set out by Dr. Parsons in 1882. In recording certain experiences at Devonport, he wrote: “It seems reasonable to suppose that a chronic ulceration of the throat, a ragged tonsil, or an enlarged mucous follicle, would afford more lodgment to infective material, and a fitter soil for its development, than a healthy and unbroken mucous membrane.”

“(3) That scarlet fever and diphtheria are merely two different forms of one and the same disease, the essence being the same, and the differences being explicable by differences of age and constitution and surroundings of the patients.¹

“Against this view is the undoubted fact that an attack of one disease does not protect against an attack of the other,² as it should do if they were merely modifications, like smallpox and cow-pox, of one thing. Nor, indeed, does one attack of diphtheria offer anything like the same degree of protection against a second attack that is afforded by an attack of scarlet fever or smallpox.³ Moreover, it is not only scarlet fever which may be complicated with diphtheria ; so also may measles, erysipelas, etc. . . .

“(4) On the other hand, it has been contended by Dr. Walker of Spilsby⁴ that such cases show that diphtheria is not a distinct and autonomous disease, but that the formation of a false membrane is a pathological process, which, like suppuration or dropsy, may occur in the course of various diseases.

“Even then, however, we should still have to recognise that there is an infectious throat disease which occurs as an epidemic often uncomplicated with scarlet

¹ *Zum Sande (loc. cit.)*

² Greenhow, *Diphtheria*, p. 107. One-half of the cases of Diphtheria reported by Coll. Invest. Committee had previously had scarlet fever.

³ Oertel, Art. “Diphtheria” in Ziemssen’s *Cyclopædia* ; Sander-son, Report of the Medical Officer to Privy Council ; Gull, *ibidem*.

⁴ *Diphtheria* (Churchill, London).

fever or other similar disease, which runs as definite a course as most other diseases of the class, and which is followed by peculiar and characteristic nervous sequelæ.

“On the whole it would seem that in this aspect diphtheria occupies a position similar to erysipelas and puerperal fever, diseases which, we know, may arise otherwise than by specific infection from a previous case, but which, when once called into existence, propagate themselves among susceptible persons with great energy, and the contagium of which, like that of diphtheria, may attach itself with persistence to places and persons.”

One thing at once strikes the reader, and that is the marked sequence of the events narrated. Whether the story of the attacks or the terms of the death certificates be considered, and whether account is taken of Dr. Parsons's own experience or of that of other authorities, it is clear that in these cases of associated disease it is the scarlet fever that almost always takes precedence of the diphtheria. The few instances in which the reverse apparently takes place may easily be accounted for by the well-known circumstance that two different infectious fevers may run their course synchronously in the same person, the more characteristic features of both undergoing some modifications. But in those cases in which the identity of scarlet fever and diphtheria is in question, the throat mischief and other typical features of the diphtheria come rather as complications of scarlet fever than otherwise. And I would submit that just as is the case as regards the non-specific forms of sore-throat to which I have referred, so also in the case of scarlet fever

does the morbid condition of the fauces supply the soil favourable to the reception of the diphtheria contagium,¹ the scarlatinal throat thus acting as a predisposing cause to diphtheria.

I thus incline to the proposition laid down in the latter part of Dr. Parsons's second hypothesis. Were it otherwise diphtheria would frequently be met with in the scarlet fever wards of infectious hospitals; and the paralytic sequelæ of diphtheria would be manifesting themselves amongst the scarlet fever convalescents. But, with one notable exception to be referred to, neither of these experiences is met with in such hospitals as are adapted in point of construction and administration to isolation purposes, and where ordinary professional skill is exercised in allotting the different specific fevers to their respective pavilions. My own experience at the London Fever Hospital is entirely opposed to any such association of these two diseases as has been suggested by some observers.

At that hospital record is kept, with an amount of detail and precision that leaves nothing to be desired, of all the complications with which the several cases of fever received there are associated; and during the ten

¹ It may be noted in this connection that Dr. W. N. Thursfield, in his Brighton *Address on Diphtheria*, has suggested that the predisposing influence of dampness may perhaps be explained by the condition of the fauces which that condition tends to bring about. Thus he writes: "A congested condition of throat and tonsils, akin to what is known as rheumatic laryngitis, is probably one of the reasons why a damp condition of dwelling is such a powerful predisposing cause of diphtheria."

years 1871-80, a period in which 3623 cases of scarlet fever were admitted, there does not occur, amongst several hundred instances of recorded complications, a single case in which there is so much as suggestion of diphtheria in any phase. During that period only occasional cases of diphtheria were received into the hospital, and thus the scarlet fever patients were placed under conditions tending to protect them against accidental infection from diphtheria. During the next ten years, 1881-90, the admissions from scarlet fever amounted to 5023, and there were 9 instances in which diphtheria or one of its sequelæ is noted as a complication, 6 of these occurring in one year. During this latter period the number of diphtheria patients admitted had undergone a somewhat marked increase, and the contagium of the disease was more commonly within the hospital walls than was formerly the case. But the fact remains that amongst no less than a total of 6973 scarlet fever patients admitted in 17 out of the 20 years referred to no diphtheria complication arose.

This experience would at first sight seem contradicted by that derived from the hospitals of the Metropolitan Asylums Board. It was in October 1888 that arrangements were first made for the reception into those hospitals of cases of diphtheria. Separate detached pavilions in four hospitals were set apart for acute attacks, the number of beds in each hospital varying from twenty to fifty; and convalescent cases were transferred to a fifth hospital. The reports of the several medical superintendents of these hospitals differ

very much as regards the details given as to the results of this new departure, but the following points may be gathered from them. In 1888 diphtheria, acute or convalescent, was received into five out of seven hospitals. Into one of four of the hospitals in which acute cases of diphtheria were received 1632 cases of scarlet fever were admitted, and amongst these cases complications of a diphtheritic¹ character occurred in 14 instances; so also in the hospital set apart for convalescents from diphtheria and other diseases there occurred amongst 3041 scarlet fever patients 27 cases exhibiting diphtheritic complications. As regards the remaining three hospitals receiving acute diphtheria, in one no such complication occurred, in the second there were three cases of "croup," and in the third there were eight cases of "croup" and of diphtheria. In 1889 765 cases of diphtheria were under treatment in four hospitals. As regards one into which 371 acute cases were admitted, 10 cases of diphtheritic complication occurred amongst 1423 scarlet fever patients. The second hospital received 144 cases of diphtheria and 790 of scarlet fever, and 11 of the latter are recorded as having suffered from either diphtheria or membranous croup. In the third there were 146 cases of diphtheria and 985 of scarlet fever, and 27 of the scarlet fever patients suffered from diphtheritic complications. The diphtheria patients under treatment in the fourth hospital

¹ The term "diphtheritic" covers affections recorded as diphtheria, diphtheritic croup, membranous laryngitis, croup, and croupous laryngitis.

numbered 105, the scarlet fever cases numbering 1599, and of the latter 26 exhibited diphtheritic complications. Lastly, there is the hospital for convalescents. Into this institution 60 diphtheria patients and 1352 scarlet fever patients were received, and 20 of the scarlet fever cases suffered from complications of a diphtheritic character.

These results are in more than one sense very remarkable. In the first place, it is to be noted that during 1887, the first year as to which any report was issued by the Statistical Committee, and before any arrangements had been made for the admission of diphtheria patients, there is mention by the medical superintendents of only 15 diphtheritic complications in seven hospitals which contained 6392 scarlet fever patients. Then again it is to be noted that as regards the remarkable change in the amount of such complications which characterised the year 1888, no diphtheritic complication took place in one hospital where 1800 cases of scarlet fever and 37 of diphtheria were under treatment, nor in another where 426 cases of scarlet fever, to the exclusion of other diseases, were received. And the possibility of the change which took place in 1888 being due to aerial infection owing to the new circumstances of diphtheria aggregation is set aside by the fact that, of the diphtheritic complications which supervened in that year by far the majority occurred during the nine months before the regular reception of diphtheria patients commenced. Then, again, during the year 1889 no case of diphtheritic complication took place in one hospital where 240 cases of scarlet fever, to the exclusion of

other diseases, were received. And lastly, I would note that Dr. Gresswell, in recording his experience as to this latter hospital during the period September 1887–February 1888, when the scarlet fever patients were under his “constant and immediate care,” states that there were three instances only that “would, perhaps, be spoken of by some as cases of diphtheria after scarlet fever,” and even these he subsequently refers to as “doubtfully diphtheritic.”

The difficulty in explaining the experience of the Metropolitan Asylum’s Board Hospitals in this respect is greater because metropolitan experience in the opposite sense is by no means confined to the London Fever Hospital. Thus, Dr. H. P. Hawkins, who during the three years 1888–90 acted as resident physician to St. Thomas’s Hospital, has supplied me with the following information. At that hospital diphtheria is not isolated in a separate pavilion, as is the case in the Asylum’s Board Hospitals; but the diphtheria patients occupy one of two wards on the third floor of a pavilion, of which the floor immediately above is devoted to scarlet fever patients. During the three years referred to 383 cases of diphtheria, 134 cases of scarlet fever, and 1173 patients suffering from other diseases¹ were admitted into the pavilion, and yet in only one single instance did any disease of a diphtheritic character spread to any patient; the exception being due to the transference to the scarlet fever wards of a diphtheria patient who, after admission, developed scarlet fever.

¹ *i.e.* Syphilis, erysipelas, enteric fever, measles, and influenza.

And it may be further noted that the results observed in the hospitals of the Metropolitan Asylum's Board cannot be regarded as having been brought about by any peculiar seasonal influences, for the period in which the diphtheritic complications amongst the scarlet fever patients occurred was the very period in which similar complications were markedly absent both at the London Fever Hospital and at St. Thomas's Hospital.¹

In reporting generally on this subject the Statistical Committee of the Asylum's Board draw especial attention to the statement made early in 1889 by Mr. R. D. R. Sweeting, then medical superintendent of their Western Hospital, to the effect that "the whole question of this close inter-relation of scarlet fever and diphtheria would seem to be one calling for immediate skilled scientific inquiry."

Before leaving this subject I would note that in all the cases in which dates are given as to the occurrence of these diphtheritic symptoms in connection with scarlet fever, the diphtheria has always been a sequel to attack from scarlet fever. And having regard to the view

¹ It is quite possible that bacteriology may come to show that the connection between some of these post-scarlatinal throat attacks and diphtheria is more apparent than real. Dr. Mitchell Pruden in 1889 recorded his failure to discover the bacillus of Löffler as the result of bacteriological examination of membrane in 24 cases, whereas he has recently discovered it in 11 out of 12 cases. He now explains that whereas his recent 12 cases were attacks of uncomplicated diphtheria, the first group of 24 cases were, with one exception, all drawn from two asylums in which measles and scarlatina were prevalent at the time. — *British Medical Journal* (Supplement), June 6th, 1891.

expressed to the effect that the scarlatina throat affords, in all probability, a diseased and abraded surface favourable to the reception of the diphtheria contagium, I would further suggest in connection with the alleged identity of the two diseases that the occurrence of diphtheria on abrasions of the skin, on wounds, or on the pudenda, must be regarded as without parallel in the case of scarlet fever.

Diphtheria in occasional association with measles has also been referred to by some of the observers whom I have quoted. The explanation is doubtless the same. The inflammatory condition of the tonsils and mucous membrane of the pharynx, and later on the laryngitis with hoarse voice—features admittedly attaching to measles as such—provide the morbid mucous surfaces so congenial to the diphtheria contagium.¹

I come next to consider the relation between faulty sanitary circumstances and occurrences of diphtheria.

Nothing is more common than to read of diphtheria, whether in its sporadic or epidemic form, being ascribed to unwholesome water supplies, to defective conditions of drainage and sewerage, or to various forms of offensive emanations. The mere co-existence of one or

¹ Since writing the above passages I have referred in another connection to a report by Mr. Matthew Algernon Adams, F.R.C.S., medical officer of health for Maidstone, on diphtheria in 1888-89, and I find that much the same views have been set out by him. In referring to an observed "association between diphtheria, scarlet fever, and measles," he says:—"I can only imagine that the diseased condition of the faucial mucous membrane brought about by scarlet fever or measles may provide the pabulum on which the diphtheria microbe can flourish."

other of these conditions with an occurrence of diphtheria suffices with many to determine the whole question of cause and effect ; and this without regard to the fact that diphtheria in its worst form is by no means unfrequent where there is complete absence of any such faulty circumstances. With observers of this class I do not propose to discuss the point. But there are others who, after careful and exhaustive investigation in which they have sought to eliminate sources of error, have arrived at the conclusion that the frequent association of diphtheria with faulty sanitary circumstances is no mere matter of coincidence ; their facts are unquestioned and their views call for consideration. Indeed, I would at once express partial concurrence in these views, adding, however, that I do not believe the relation between the two to be one of direct cause and effect, neither do I regard it as being so common in its operation as is often contended for. And further, I would also admit that increased fatality may be the result of attack in the case of diphtheria patients who have been living and, when sick, are still exposed to conditions such as those referred to.

Dealing in the first instance with the influence of individual faulty circumstances, I would at once say that no trustworthy evidence is forthcoming to show that polluted water supplies have ever caused diphtheria ; whereas, on the other hand, there is an abundance of negative evidence in the opposite direction. Some observers, whose investigations merit every consideration, have held that the use of pond water and other stagnant

waters which have contained a large amount of various fungoid growths has favoured diphtheria ; but Dr. Airy, after considering the whole subject in his summary report of 1880, came to the conclusion that the disease "did not appear to have any concern with the nature of the supply of drinking water," and I may add to this the statement that in no single instance, out of the many investigations into the causes of diphtheria that have been made by the medical department of the Local Government Board since that date, has there been reason to believe that water-supplies polluted in one or another way have been concerned with disease. The same view is held by Professor Fodor of Buda Pesth, who has devoted much attention to this subject.¹

In his Brighton *Address on Diphtheria*, already referred to, Dr. Thursfield, in speaking of the connection of diphtheria with contaminated water, says: "I do not wish to dogmatise on this point, but, speaking solely from my own personal investigations, I have never yet been able to satisfy myself or to obtain any good evidence that diphtheria has been spread by drinking contaminated water or has arisen from it, and except as a debilitating agent predisposing to severe attacks, I have not been able to establish any connection between diphtheria and contaminated water. This result of practical observation in diphtheria outbreaks is so far confirmed by the result of some experiments at the Paris Pasteur Institute, where animals have been caused to take into the stomach, without any bad results following,

¹ *Luft, Boden, und Wasser*, by Prof. Fodor, p. 371.

an amount of diphtheria poison, which, if introduced into the system by inoculation, would infallibly have produced the disease in a serious if not fatal form."

And, as regards water generally, and apart from the question of its contamination, as a vehicle of the diphtheria contagium, it was stated by Dr. Klein, F.R.S., in an address delivered at the Royal Institution on February 20th, 1891, on "Infectious Diseases, their Nature, Cause, and Mode of Spread,"¹ that "the bacillus of diphtheria . . . is killed when kept for a few days in pure water, on account of not finding sufficient nutriment."²

But diphtheria has very commonly been held to be due to faulty conditions of sewerage and drainage, such as have led to the contamination of air and of soil about dwellings. Indeed, the disease has in consequence been classed by some amongst the so-called "filth-diseases," and hence its etiological connection with the various forms of filth merits serious consideration.

On the general question of the influence of the defective sanitary circumstances indicated, I would, at the outset, observe that there never was a time in the modern history of this country when its sanitary state was better than it is at present. Sanitary progress has been universal, it has on the whole been well sustained, and its operations have especially tended to the removal from our midst of those conditions which tend to the fouling of air and soil. Enteric fever has always been

¹ See *Nature*, March 5th, 1891.

² See also p. 78.

regarded as standing foremost in this country amongst those diseases which were classed by Sir John Simon as forming the specific filth-infections, and it has also been recognised as typical of that class of diseases which is most amenable to such preventive action as is involved in the construction of proper works of sewerage and drainage, and in the adoption of adequate systems of refuse disposal, and which tends to free the air and soil from filth. And, as a matter of fact, it has been one of our national boasts that with advance of knowledge in the principles of health, and with the resulting intelligent administration of our sanitary laws, the rate of mortality from this form of continued fever has steadily diminished. And yet, concurrently with this diminution we find that the diphtheria death-rate is increasing in our midst.

But it is, above all, in our large towns and cities that this enlightened sanitary policy has been most marked during the past twenty years, and we can point to this group of sanitary areas as exhibiting, by means of their vital statistics, a story of success attained. And yet, whereas when, in the past, sanitary defects abounded in our large centres of population diphtheria was essentially a disease of rural districts, that disease is now invading our more cleanly towns and cities to an extent unknown in the annals of their more faulty past.¹

¹ Dr. Thursfield, in his paper on "Diphtheria" in the *Lancet*, August 10th, 1878, whilst expressing the opinion that faulty sanitary circumstances influence the severity and fatality of diphtheria, says: "I know of no fact so striking, from a preventive-medicine point of view, as the comparative rarity of diphtheria in urban as compared

The various points to which I have adverted in this connection are set out in the annexed table, from which the following points may be deduced: 1st, That, as regards England and Wales, whilst during the period 1871-89, the death-rate from all causes, from the group of "zymotic diseases," including diphtheria, and from enteric fever, has been slowly but somewhat steadily decreasing, that from diphtheria has on the contrary distinctly increased. 2d, That, as regards London, whilst the contrast between the several death-rates has been much the same, the increase in the diphtheria death-rate has been even more marked. 3d, That the group of "large towns" of England, as to which the needed statistics are only available since 1882, and in which the continued fevers are not differentiated in the only available return of the Registrar-General, the story is much the same; that is to say, whilst the death-rates from all causes, from the seven zymotic diseases and from "fever," have been almost continually decreasing, the death-rate from diphtheria has as continually been increasing.

with rural districts; or, considered in another way, in unhealthy as compared with healthy districts. The frequency of the occurrence of diphtheria is inverse, not only to the general death rate, but also directly and invariably to the frequency of typhoid fever."

[TABLE No. IX.

ANNUAL MORTALITY PER 1000 PERSONS LIVING

Years.	ENGLAND AND WALES. ¹				LONDON. ²				LARGE TOWNS. ³			
	All causes.	Seven Zymotic Diseases.	Enteric Fever.	Diphtheria.	All causes.	Seven Zymotic Diseases.	Enteric Fever.	Diphtheria.	All causes.	Seven Zymotic Diseases.	Enteric Fever.	Diphtheria.
1871	22.6	5.4	0.37	0.11	24.7	6.0	0.27	0.10	26.5	6.5	...	...17 tns.
1872	21.2	4.8	0.38	0.09	21.4	3.8	0.24	0.08	23.7	4.8	...	...18 tns.
1873	21.0	3.8	0.38	0.11	22.5	3.3	0.27	0.09	24.1	3.9	...	...
1874	22.2	4.7	0.37	0.15	22.5	3.3	0.26	0.12	25.0	4.5	...	...
1875	22.7	4.4	0.37	0.14	23.7	3.9	0.23	0.17	25.2	4.4	...	...
1876	20.8	4.0	0.31	0.13	22.3	3.6	0.22	0.11	23.6	4.1	...	...
1877	20.3	3.5	0.28	0.11	21.9	3.5	0.25	0.08	22.7	3.5	...	...
1878	21.5	4.2	0.31	0.14	23.5	4.1	0.28	0.15	24.2	4.4	...	...
1879	20.7	3.2	0.23	0.12	23.3	3.3	0.23	0.15	23.2	3.2	...	...
1880	20.5	4.1	0.26	0.11	22.2	3.7	0.19	0.14	22.7	4.0	...	...
1881	18.9	2.6	0.21	0.12	21.2	3.6	0.25	0.17	21.7	3.4	...	...
1882	19.6	3.1	0.23	0.15	21.4	3.49	0.25	0.22	22.3	3.59	0.37	0.16
1883	19.5	2.6	0.23	0.16	20.4	2.74	0.24	0.24	21.6	2.86	0.35	0.16
1884	19.5	3.1	0.23	0.18	20.3	3.34	0.23	0.24	21.6	3.50	0.29	0.17
1885	19.0	2.5	0.17	0.16	19.7	2.77	0.15	0.22	20.5	2.71	0.20	0.17
1886	19.3	2.6	0.18	0.15	19.9	2.69	0.15	0.20	20.9	2.88	0.23	0.16
1887	18.8	2.7	0.18	0.16	19.6	3.02	0.14	0.23	20.8	3.21	0.22	0.18
1888	18.0	2.1	0.17	0.17	18.5	2.53	0.16	0.30	19.2	2.41	0.20	0.21
1889	17.8	2.4	0.17	0.18	17.4	2.24	0.12	0.37	19.3	2.73	0.20	0.26

¹ The "all causes" figures are taken from p. xlii, R. G.'s 52d (1889) Annual Report. The "seven zymotic diseases" figures for 1871-80 are taken from p. lxxiv of R. G.'s 43d (1880) Annual Report; those for 1881-89 are taken from p. x of R. G.'s 52d (1889) Annual Report. The "enteric fever" and "diphtheria" figures are taken from p. xlvii, R. G.'s 52d (1889) Annual Report.

² The "all causes" and "seven zymotic diseases" figures are taken from R. G.'s Annual Summaries. Those for "enteric fever" and "diphtheria" are taken from p. xlvii, R. G.'s 52d (1889) Annual Report.

³ Figures given for all four causes are taken from R. G.'s Annual Summaries. Those for "enteric fever" and "diphtheria" from 1871-81 are not obtainable.

But whilst these statistics force on us the general conclusion that, synchronously with a marked improvement in the sanitary circumstances under which our population is living, there has been a marked increase in the diphtheria death-rate, yet there remain certain instances in which the occurrence of diphtheria has been in such association with sanitary defects of special gravity that the contention as to the existence of a definite relation between the two sets of circumstances cannot be lightly set aside.

One of the most painstaking reports dealing with this aspect of the question is that which Mr. John Spear submitted to the Local Government Board in December 1888 on a prevalence of diphtheria in Aylesbury.

The small county town of Aylesbury (pop. 7795 in 1881) was, during the three years 1885-87, the seat of a prevalence of diphtheria. A first portion of the epidemic, from October 1885 to June 1886, was reported on by Dr. Astley Gresswell, who found that together with recurring but not excessive fatality from diphtheria there was, antecedently to an outburst in 1885, history of a large amount of so-called "croup" and "various fatal throat maladies;" that the three public elementary schools had been largely concerned in the spread, if not in the development of the disease in 1885-86; and that "ulcerative sore-throat," to which he was disposed to attribute a part in the elaboration of the diphtheria, had prevailed amongst the children attending one of these schools before the diphtheria was recognised.

Between the middle of July 1886 and the month of

April 1887, no diphtheria death was registered in Aylesbury, and only three non-fatal attacks were heard of in widely-separated houses. In short, there was an intermission in so far as recognised diphtheria is concerned. But in the spring of 1887 the disease recurred, and Mr. Spear was instructed to report on the occurrence.

At one stage of his report, Mr. Spear deals with the possibility of the operation of a "potential and gradually developing specificity attaching to an apparently benign disease," such as that suggested in 1878; but in reviewing the circumstances of the epidemic at a later stage, and in speaking of its gradual growth as "strongly indicative of some slowly progressive mischief," he evidently inclines to the opinion that any such progress was essentially a matter of "the multiplication of foci of personal infection." He next considers how far mild and hidden cases could have maintained a continuous chain of infection during the apparent intermission of July 1886–April 1887, and as to this he says: "It is certainly true that 'simple sore-throat' had prevailed throughout the winter of 1886-1887; catarrhal rhinitis, likewise, with some offensive discharge, has been spoken of to me as common during this period. But as to the diphtheritic nature of the catarrhal affections that were thus interposed, the absence throughout a long series of cases of the distinctive appearances of diphtheria, the freedom from fatality and from characteristic sequelæ, must be allowed weight. On the other hand, when diphtheria prevalence was again established, although that of 'sore-throat' had been diminished, several cases

of illness had occurred not distinguishable, it is said, from the apparently simple affection, except for characteristic sequelæ; and here and there unequivocal cases of diphtheria were associated, apparently casually, with attacks that from a clinical standpoint alone would be considered non-specific."

He next gives the following account, which was supplied to him, of the clinical features of the "sore-throat" which had been observed antecedently to the epidemic of 1887-88—an epidemic which resulted in 149 attacks in 89 households, with 31 deaths.

"In recognisable features the affection does not appear to differ from that of an erythematous or follicular tonsillitis. The small white or yellowish specks on the swollen and hyperæmic mucous membrane of one or both tonsils, common to that affection, never, it is said, assumed the appearance of the thick continuous membrane of developed diphtheria, and disappeared after one or two days' duration. Slight follicular erosions of the tonsils were frequently seen. The lymphatic glands were often enlarged and tender; and for a day or two constitutional disturbance was present. Albuminuria, in the few cases in which it was looked for, was never observed. General debility of some duration frequently followed these attacks, but distinct paralyses were absent. Children and young adults were attacked in largest proportion, and occasionally, it is said, several members of a family suffered simultaneously, or more often in rapid succession. Dr. Eagles, who tells me he has seen perhaps 200 of these cases, speaks of them as generally

multiple, and is convinced of their infectiousness. Dr. Hilliard likewise holds this view."

Following on this and other historical matter, Mr. Spear proceeds to devote a considerable portion of his report to the consideration of the influence of sanitary circumstances on the diphtheria epidemic which had followed this prevalence of throat mischief. And in so doing he refers prominently to certain marked localisations of the disease, to the recurrence of the diphtheria in 1887-88 in the same spots and in the same houses as those in which it prevailed in 1885-86; and having next described the sanitary circumstances of the town in much detail, he arrived at the conclusion that "these localisations have been, in almost every case, associated with grave defects of sewers and drains,—defects which have led to the contamination of the atmosphere in and about houses with sewage effluvia and to sewage contamination of the foundations of houses."

Amongst the many sanitary defects which were discovered, reference is made to the retention all over the town of old tributary sewers containing sewage matters excessively foul from long retention, and yet ventilating themselves through a new system of sewers; to the fact that the old sewers were constructed of loose brickwork admitting freely of percolation into the surrounding soil, whilst a thick black sludge was retained within; to private drains which not unfrequently passed beneath houses, being so faulty as to admit of the impregnation of the foundations of dwellings with sewage effluvia; and by way of summary he lays it down that "endemic pre-

valence of diphtheria in Aylesbury co-exists with a condition of sewers and drains that is productive of excessive filth-contamination of soil and air." In conclusion, he expresses the opinion that whilst the general sanitary circumstances of Aylesbury remained during the later prevalence of diphtheria much the same as they did when the same disease invaded the town in 1885, there was "this important difference, that whereas before that date the half-blocked sewers and sewage-sodden soil were for the most part a source of insidious mischief to general health only, there exists now a probability that they have become the breeding-ground of a specific contagion capable of rapidly destroying human life."

Mr. Spear, as I gather it, would differentiate between the effect produced by the faulty sanitary circumstances prior to and subsequently to 1885, and he would thus draw a line between the early general prevalence of sore-throats referred to and the subsequent attacks of diphtheria in so far as their specific character is concerned. And he would appear to have adopted this view after freely admitting that an infectious quality often attached to the various forms of "sore-throat," and after including amongst diphtheria attacks those cases of nasal diphtheria which are but too frequently regarded as "bad colds" only, and of which the true character not uncommonly remains unrecognised unless the attack be followed by paralytic and other sequelæ.

I take it then that the contention is that filth conditions which, at one stage, only produced sore-throat and

other comparatively trivial affections, are held later on to have caused diphtheria owing to their having acquired a specific character. How the specificity was acquired is not explained in this case, but I may state that it has been held by some observers that as the result of casting sputa and other ejecta of diphtheria patients into drains and sewers, the poison at times attaches itself to the culverts, and at others finds a nidus and breeding-ground in the soil around.

The Aylesbury story is one concerning which it would be imprudent to dogmatise, and this the more, because of the mass of involved detail which was elicited as the result of an exceptionally careful inquiry. We have first a past history of much "sore-throat" and of occasional diphtheria; then comes the diphtheria epidemic of 1885, the diffusion of which was favoured by the occurrence of "various throat maladies" amongst school children; this is followed by an enormous accession of similar ailments amongst children and young adults, one medical practitioner having himself seen some 200 cases; and finally comes the diphtheria burst of 1887-1888, which was again associated with a large amount of throat disease, which clinically could not be distinguished from throat disease generally regarded as benign in type. It may well have been that more than one cause was in operation in the production of these recurring accessions of diphtheria, and I am inclined very largely to limit the operation of the faulty sanitary circumstances to the production of a morbid state of the fauces which induced a local condition favourable to the

reception of the specific organism of diphtheria. Much of the prevailing "sore-throat," "rhinitis," "laryngitis," etc., I regard as having been manifestations of the diphtheria poison ; and that form of sore-throat often identified with drain effluvia being common in the town, it needed but a resuscitation of the diphtheria infection in order to the specific inoculation of such throats. In short, I am inclined to regard the influence of a sewage-polluted air as operating in much the same way as the scarlet fever poison, in so far as predisposition to diphtheria is concerned.

In a recent contribution by Dr. Klein, F.R.S., to the report of the Medical Officer of the Local Government Board for 1889, "On Concurrent Inoculation of Different Infections in the same Animal Body," it is shown that whilst two organisms in their growth on the same soil may be mutually inhibitive, the effect may, on the other hand, be quite different. Thus, in the case of life-processes within the animal body, a given bacterium may, as the result of the processes attendant on its growth, actually enhance for another bacterium the nourishing quality of the tissues in question. And, according to Achille Monti,¹ there are instances in which specific cultures having, in one way or another, lost their virulence for certain animals, that virulence may be restored to the bacteria of such cultures by previous injection, into the animal to be inoculated with them, of the chemical products of a certain bacillus. Possibly qualities occasionally attaching to drain-air may in much

¹ *Rend. d. R. Acad. dei Lincei.* Ottobre 6, 1889.

the same way prepare the human system for the reception of specific infections such as diphtheria.

It will be convenient at this stage to refer to the relation of so-called "croup" to diphtheria in its bearing on the etiology and natural history of the latter disease. That diphtheria is constantly masked under the term "croup" must already be abundantly obvious; so much so indeed is this the case, that the question has been raised whether "croup," other than the purely spasmodic croup of infants, is ever anything but diphtheria. There can be but little doubt that there are other causes of "membranous croup" than the diphtheritic infection; thus, there would appear to be sufficient evidence that a membranous inflammation of the larynx and trachea may be brought about by direct action upon those organs of such substances as hot water, acids, etc. And in 1879 it was reported by the Committee on Membranous Croup and Diphtheria, appointed by the Royal Medical and Chirurgical Society, that agents such as are commonly concerned in the "generation or transmission of zymotic disease," might cause a membranous inflammation of the larynx and trachea, and that the same condition was at times an accompaniment of measles, scarlatina,¹ etc. But on the other hand, it was admitted that this "membranous croup . . . may be imparted by an influence, epidemic or of other sort, which in other persons has produced pharyngeal diphtheria;" and, in the end, the Committee, with a view

¹ On the relation of scarlatina and measles to diphtheria, see also pp. 63-77.

to the avoidance of the then existing confusion, suggested "that the term *croup* be henceforth used wholly as a clinical definition implying laryngeal obstruction occurring with febrile symptoms in children. Thus, croup may be membranous or not membranous, due to diphtheria or not so." This suggestion has, I would venture to submit, not been helpful in so far as the prevention of diphtheria is concerned; it leaves the main difficulty unsolved; indeed, the use of the term "croup" for fatal as well as for non-fatal diphtheria, which latter disease is, after all, essentially a disease met with "in children," has again and again served to mask the beginnings of diphtheria epidemics, and so to spread and maintain the infection. Taking, at haphazard, twelve reports of sanitary districts where croup and diphtheria had prevailed simultaneously in a given year, I find that whereas the death certificates record 65 fatal attacks of diphtheria, no less than 156 fatal attacks of "croup" were registered during the same period. In one district, where diphtheria was ultimately found to be the prevailing disease, 15 deaths from "non-spasmodic croup" were registered, whilst there was no record of a single diphtheria death. In another, where 4 deaths from diphtheria and 14 deaths from "croup" without mention of diphtheria, had been recorded, the medical practitioners signing the certificates admitted either that they "made no distinction" between the two terms, or that they used them "indifferently," the result being that so far as the prevention and arrest of the disease were concerned, it "would appear to have been left

pretty much to go its own way.”¹ And, when it is remembered that whilst “diphtheria” is classed by the Registrar-General as one of the “Miasmatic Diseases,” whereas “croup” is placed under the heading of “Diseases of the Respiratory System,” it will at once be seen how grave a source of error underlies our vital statistics as to diphtheria.

Intimately allied to the question which has been under discussion in connection with the Aylesbury epidemic, is the relation of diphtheria to the inhalation of effluvia other than those due to such contamination of air as is brought about by defects of sewerage and drainage; and amongst these effluvia those which are the result of the decomposition of certain forms of animal refuse deserve consideration.

Of recent years many allegations have been made in certain counties in the neighbourhood of the Metropolis, to the effect that diphtheria has been brought about by exposure to the emanations which result from the traffic in “London manure,” a material which is largely despatched down the Thames in barges, to be used for agricultural purposes. This form of manure often contains a large amount of animal matter. Dr. Downes, when health officer in Essex, described a sample which he examined as consisting of, amongst other things, litter, sawdust, blood, paunches, and foetal calves; and Dr. Thresh, his successor, in a paper on “London

¹ Dr. Ballard's report to the Local Government Board on a prevalence of diphtheria in the Camelford rural sanitary district. Feb. 1889.

Manure and Diphtheria,"¹ adds that "it frequently contains putrid fish, dogs, cats, and a black slimy matter which looks as though it had been raked out of gully-holes and blocked drains." Dr. Thresh has put on record the main body of the evidence hitherto available bearing upon the influence of this stuff on diphtheria. He points out that there is a very general concurrence of medical opinion to the effect that sore-throat and diphtheria are induced by exposure to emanations from this refuse, and he then gives instances of the circumstances which have come under his notice. Thus, he cites cases in which, after other causes of diphtheria have, to the best of his ability, been excluded, there remains only the evidence pointing to the manure and the diphtheria as being in some way related to each other. In another set of instances it is evident that he finds difficulty in eliminating all sources of error. And lastly, he records attacks of diphtheria which have locally been assigned to London manure, but which, on further investigation, have obviously been due to other causes. The latter class seem to be the most numerous, and the following are stories fairly typical of the two previous classes:—As to the first of these, Dr. Thresh summarises the details which he records as follows:—"The . . . outbreak I mention is one, during the course of which several cases proved rapidly fatal. School attendance, milk supplies, disease amongst infected animals, etc., were all investigated during the course of the epidemic,

¹ *London Manure and Diphtheria*, by John C. Thresh, D.Sc. Lond., M.B., etc.

but all with negative results. The disease first appeared in the family of a man who had been carting London manure, and next attacked the children in a house directly opposite where a portion of the manure was heaped, afterwards attacked the bailiff and family of the farmer who had imported the manure, and, finally, other families near the fields on which the manure was spread. The village in which the outbreak occurred, Tolleshunt D'Arcy, stands on a patch of gravel overlying the London Clay. . . . For several years past Tolleshunt D'Arcy has been singularly free from diphtheria." As regards the other class of cases Dr. Thresh writes:—"It was at Burnham that I first made acquaintance with this special manure, and for the better elucidation of the statements which follow, I should say that this village has a population of some 2300, and that it stands upon the north bank of the tidal river Crouch, and that coals, manure, etc., are or were unloaded chiefly at the Malting Wharf near the middle of the village. On November 24th, 1889, I received a letter from Dr. Downman, who practises there, saying: 'On Saturday evening I was called to a case of diphtheria at the Maltings. Cause, undoubtedly, a barge of London filth unloaded . . . at the malting landing stage.' I immediately went over and found that manure was being unloaded on the 21st and 22d, that the child attacked had played around and with the filth during unloading. He appeared quite well on the morning of the 22d, when he went to school, but at night complained of his throat and head. Dr. Downman was sent for, but the

lad died on the 24th. Diphtheria had been smouldering in the village for two years previously, but for some months I was told that no cases had occurred, neither could I hear of any suspicious cases of sore-throat. No other cause than the London manure could be traced."

As yet, there is certainly an absence of evidence sufficient in amount and precision to determine what is the relation, if any, between such effluvia and diphtheria. And even where the facts point strongly to the existence of some relation, it is impossible to suggest whether this "manure" forms a specially favourable breeding ground for specific organisms already existing in it, or whether, in localities where "sore-throat" allied to diphtheria already prevails, the inhalation of the manure effluvia imparts to a comparatively mild affection a more definitely specific and severe character.

More than once there have appeared grounds for believing that slaughter-house refuse has acted in a somewhat similar way to that alleged with regard to London manure. An instance in which there arose suspicion as to this is recorded by Dr. Bruce Low in connection with an inquiry which he made as to a prevalence of diphtheria at Ashbourne in Derbyshire.¹ At first there were grounds for believing that the prevalence was, in the main, due to the dissemination of infection through the Infant National School, but this view was "very soon met by a statistical consideration entirely in opposition to a hypothesis of the school being the

¹ Report to the Local Government Board on Diphtheria in Ashbourne. Eyre & Spottiswoode. London, 1888.

chief agency in the causation of the outbreak." A stream divides the town of Ashbourne into two parts. The Ashbourne part to the north of the stream lies mainly on rising ground formed of new red sandstone, whereas the Compton portion is situated on low-lying gravel or alluvium, and is liable to flooding in rainy seasons. The infant school is situated in the Ashbourne division, in a somewhat crowded locality close behind the market-place, but the children attending it come from both divisions, the proportion of attendants from the two localities being approximately, Ashbourne 70, Compton 40. "But the diphtheria had been limited to such of the children as resided north of the river in Ashbourne proper"; the sufferers are stated to have resided, for the most part, at or near the market-place; and the circumstances with which the occurrence seemed to be associated included "general prevalence of dirt, overcrowding of dwellings, foul privies emptied or not emptied, pig-keeping, emanations from slaughter-houses (establishments especially abundant in the neighbourhood of the market-place), slaughter-house blood in the sewers, congregation of human beings and animals, along with a haunting by strangers to the town, of public-houses in the market-place, and the promiscuous use by all-comers of the back-yard open privies attached to these houses." In view of this description it would obviously be wrong to attach too much importance to the influence of such animal refuse as is connected with the process of slaughtering in the limitation of this incidence of diphtheria; and there also remains, as pointed out by Dr.

Low, the possibility that the Compton children, whilst escaping grave or fatal diphtheria, may have had some share of the malady. But after weighing the several circumstances connected with this occurrence, Dr. Low reminds his readers that the incident points to the need of giving attention "in future investigations as to the apparent origin of special diphtheria outbreaks," to the question of "slaughter-houses and their sewer connections." This view is shared by others.

One other case deserves record before I quit this subject. A maintained prevalence of diphtheria occurred in Maidstone during 1888 and 1889, and the occurrence was very carefully investigated by Mr. Matthew A. Adams, F.R.C.S., the borough health officer. In all, the number of attacks heard of up to the end of 1889 amounted to 99, on a population which numbered 29,620 in 1881. Maidstone lies at the foot of the chalk escarpment in the valley of the Medway, and, speaking generally, the soil on which the town stands may be said to be porous, well aerated, to be subject to saturation by water, and to become quickly dry again by natural drainage, the subsoil water-level being thus liable to considerable fluctuation. Previous to 1879 the drainage of the borough was effected either by means of cesspools soaking into the surrounding soil, or by old imperfect brick sewers, of which a number were retained when a new system was constructed later on. These latter remain a source of nuisance ; and owing mainly to deficient means of flushing, house drains become blocked by pent-up sewage which is described as becoming

decomposed and "unutterably foul, so that when by one means or another the abominable stuff is forced forward into the main sewer vile stench proceed from the ventilators." In parts, and especially in a locality known as Tovil, where the diphtheria was most persistent, such nuisances, together with others tending to the soakage of the soil about houses with filth, were more than usually abundant.

During the eleven years 1878-1889, 72 diphtheria deaths were registered in Maidstone, but Mr. Adams significantly adds that during the same period there were 67 fatal attacks of "croup." Of the 72 diphtheria deaths only 1 occurred in 1887, whereas no less than 41 took place in 1888-1889.

After eliminating a number of the more common causes of diphtheria, and after showing that school attendance could not, to any material extent, have conduced to the spread of the disease, Mr. Adams proceeds to show that the diphtheria was to a great degree localised in areas where defective sanitary circumstances such as those described mostly prevailed; and to give certain instances in which an attack of well-marked diphtheria followed promptly on exposure to the emanations of recently disturbed soil that had been impregnated with filth. He then discusses the influence of subsoil water in relation to the epidemic.

For three years antecedent to 1888, the subsoil water began its rise towards the close of one year and reached its maximum height in the early part of the following year, a steady and practically continuous fall setting in

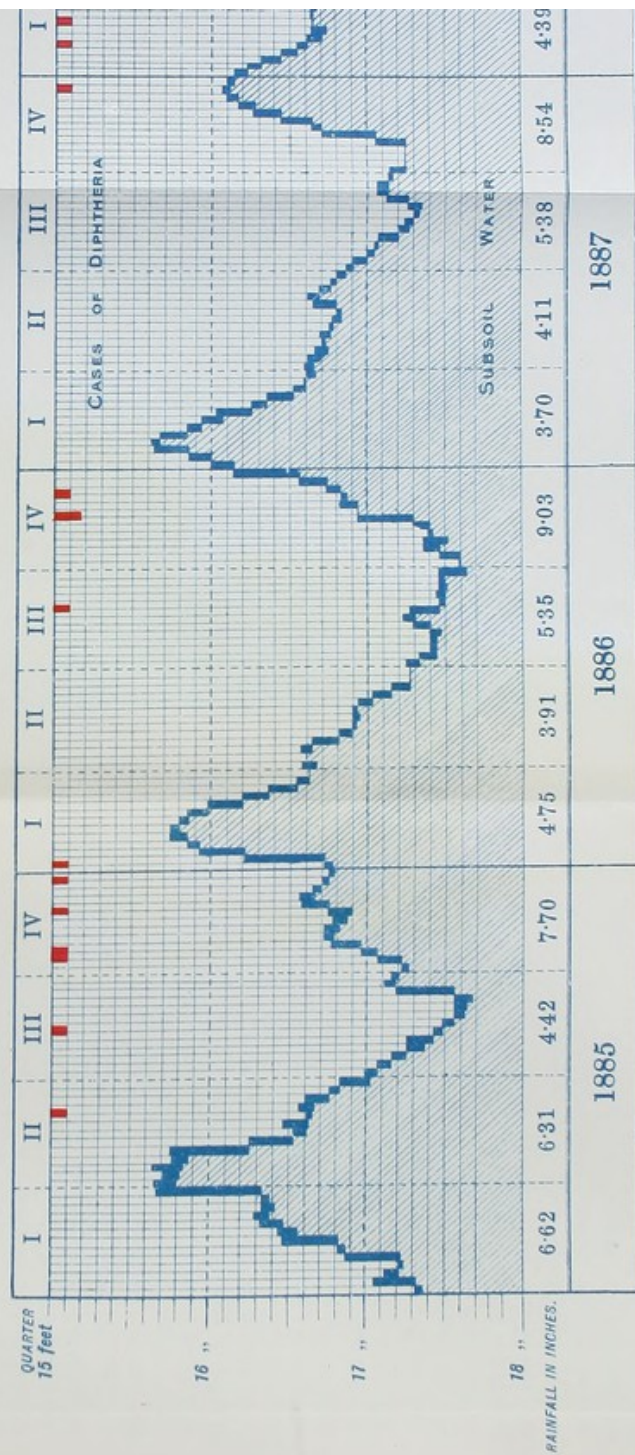
during the first or early portion of the second quarter, and being maintained until about the fourth quarter. Whilst these "single high and low tides," corresponding to the cold and warm seasons, were maintained, diphtheria is stated to have been comparatively scarce. But this uniformity of rise and fall was interrupted during 1888-1889; the ebb and flow recurred at irregular intervals, the level of the subsoil water oscillating to and fro with unwonted frequency. It was during this period that a prevalence of diphtheria, exceptional in the recent history of Maidstone, occurred; and during this prevalence, it is reported by Mr. Adams, that every departure from the one annual rise and fall was attended by an increase of diphtheria.

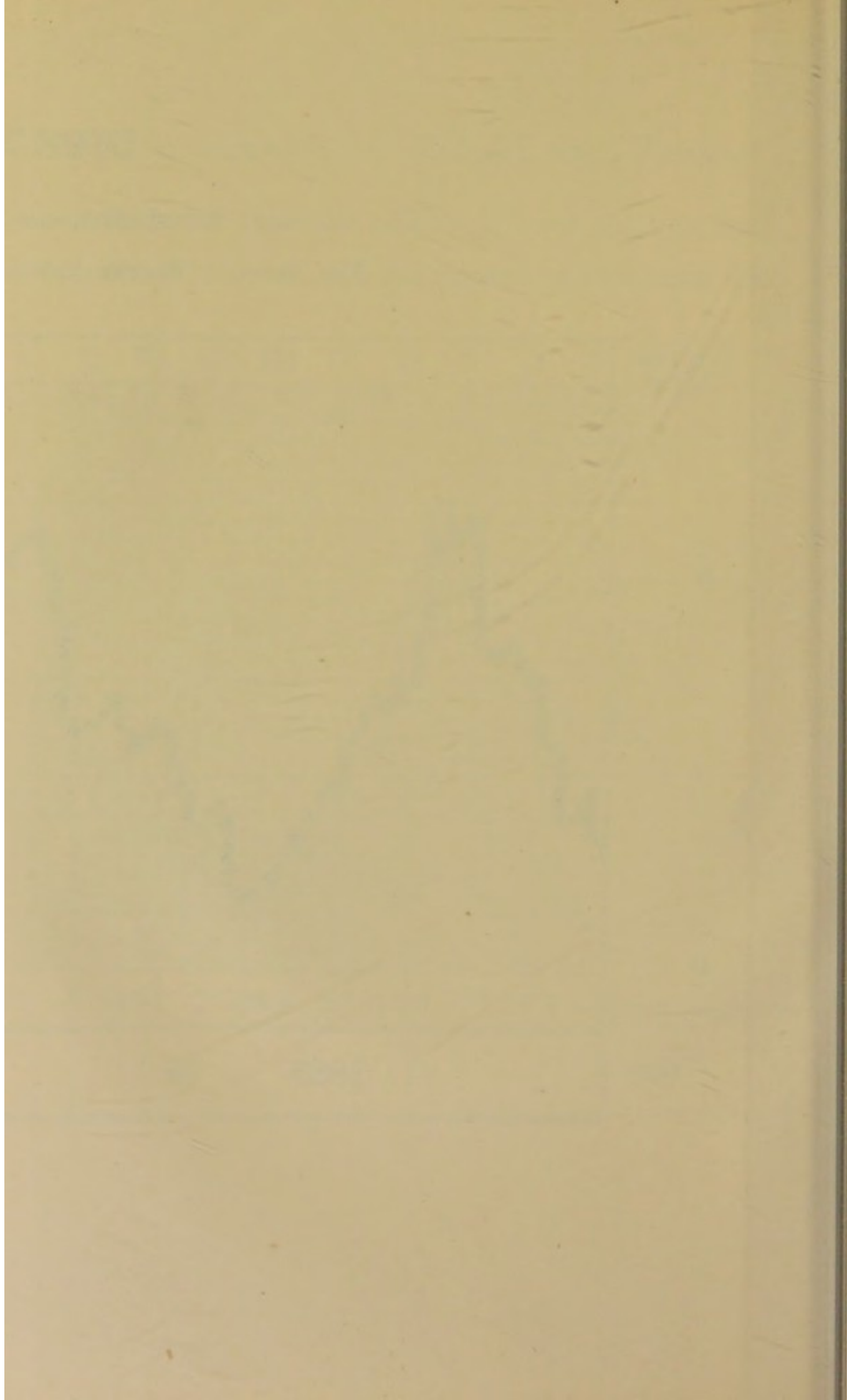
After recalling the fact that "dampness of soil, defects of sewerage, and other grave sanitary faults" are so often "found cropping up in reports of outbreaks of diphtheria," Mr. Adams indicates by means of diagrams and meteorological records the fluctuations of subsoil water referred to in their relation to diphtheria occurrences; and he explains that whereas, under the conditions of 1885-1887, which he regards as normal, the soil "must have been more thoroughly washed during the colder seasons, and better drained and dried and aerated during the hotter seasons," this coincidence of tide and season was practically reversed in the two following years, and he points out how these irregular oscillations tended to the production of such dampness of soil as may be regarded as favourable to the development of the diphtheria organism, and to the periodically recurring expulsion of

DIPHTHERIA in relation to Height and Fluctuation of SUBSOIL WATER

The CASES OF DIPHTHERIA are represented in RED, and the number of cases that originated in the respective quarters are given in the following table.

The SUBSOIL WATER LEVEL is represented in BLUE, and the amount of fluctuation for the respective quarters is given in the following table.





ground air into the atmosphere around the dwellings. He subsequently proceeds as follows :—

“How can the behaviour of the subsoil water-level be supposed to act? Is it mechanically, by forcing the germ-charged air out of the soil into the air which we breathe, or is there some more intimate biological connection between the two things promoting the activity of the germ? Probably both ideas are correct. There can be little doubt that a damp condition of the soil favours the development of the microbe; in all probability it cannot live actually submerged in water, immersion would drown it, for it does not appear that there is a tittle of evidence to indicate that diphtheria is ever water-borne; we must therefore believe that if it exists in the soil it lives somewhere above the water-level. It is equally probable that much drought will kill it, and there can be no doubt that decaying albuminous matter is absolutely necessary for its existence. In short, it is aerobic, requiring its just proportion of moisture, heat, air, and albuminous food, and it seems to me that at or near the surface of polluted soil is the most likely place to find these conditions best fulfilled, and when these conditions are conjoined with the fluttering fluctuation of subsoil water that we found to occur in 1888-89, the soil must have been in a condition peculiarly favourable to the vigorous development and rapid multiplication of the microbe. In this way we can imagine the interstices of the soil, at or near the surface, thronged by colonies of spore-bearing microbes, ready at any moment for distribution in the atmosphere, by any dis-

turbance of the soil or other mechanical means whereby they could be driven out of the soil-air to mingle with the atmosphere we breathe, such for instance as must necessarily attend the sudden fall of the barometer, which in effect causes the germ-charged air to be aspirated out of the soil and sewers. As a proof that this does take place, we need only be reminded of the common enough forecast, one so often hears, that because of the stinks from the drains, rain may be expected. For the same reason a sudden fall of rain is an effective cause in producing a like result, and many observant persons no doubt have had evidence through the sense of smell of the truth of this. Among others, Dr. Gresswell has noticed the association between throat disorders and increase "of rainfall and certain other meteorological changes;" and lastly, there is the rise of the level of the subsoil water, which of necessity pushes the air out of the soil, and if the air is germ-charged, the germ may go with it. . . ."

With regard to the diphtheria organism in question, Mr. Adams inclines strongly to the view that it is one "which neither air nor water appears to cherish," which tends at times to make the soil, and especially a polluted soil, its habitat; and, given this organism in the soil of Maidstone, he would attribute the specialities of the Maidstone diphtheria prevalence to conditions affecting the barometer, the rainfall, and the subsoil water-level.¹

¹ Adverting to the opinions expressed by a number of observers as to the absence of evidence that the diphtheria poison is ever conveyed by water, I would recall the address delivered by Dr. Klein, F.R.S., at the Royal Institution, Feb. 20th, 1891 (see p. 80).

The views which Mr. Adams propounds are of extreme interest, and they point very distinctly to a set of circumstances under which a polluted soil may take an important part in the diffusion of diphtheria. True, such views are by no means new in so far as epidemic disease as such is concerned. Thus, in 1887, Mr. W. H. Power, in reporting an epidemic diarrhœa in Winchester,¹ dealt with much the same subject, and he arrived at the conclusion that—"By oscillations of its level, however brought about, soil water is capable at one time of allowing collection in, at another of forcing out from, the soil, air charged with excremental impurities—operations largely influenced by the circumstances affecting the flow of streams, and probably also by meteorological conditions;"—and to such influences he regarded the "specific diarrhœa" in question as being in all probability related. As is well known, these views have since been put to exhaustive test, and confirmed; the results being embodied in Dr. Ballard's official report on the "Causation of Summer Diarrhœa."² In a somewhat similar way certain experiences of the behaviour of enteric fever have been explained.³

As regards diphtheria, the Maidstone experience

¹ *Report of the Medical Officer of the Local Government Board for the year 1877* [C—2130.—I.] 1878.

² *Report to the Local Government Board upon the Causation of the Annual Mortality from Diarrhœa, which is observed principally in the Summer Season of the year*, by Dr. Ballard, F.R.S. [C—5638]. 1889.

³ *Report on Enteric Fever in Kendal*, by Charles E. Paget, Medical Officer of Health. April 1884.

stands practically alone,¹ and it is to be hoped that similar research will, if the occasion offer, be repeated elsewhere. This is the more desirable because it was not practicable to carry out the observations as to the level of the subsoil water at the actual spots where the diphtheria prevailed, and because the amount of diphtheria and allied throat disease on which Mr. Adams's views were based was comparatively small.

Where definite diphtheria is in question, the theory as to soil influence proceeds largely on the assumption that the specific organism of that disease is present in the soil before the mischief is induced. But Mr. Adams goes farther than this. He evidently inclines to the view which I have already referred to as to diphtheria being practically the result of the inoculation of a mucous surface in a morbid but probably non-specific condition by a specific material. Thus, he writes: "Again and again it has been observed that diphtheria epidemics arise as it were out of a cloud of ordinary and apparently non-specific sore-throat. Is it not possible that even an ordinary catarrh may in some way render the mucous surface receptive? possibly by some chemical or biological change. My idea is that

¹ Since writing this I find that the same question has been discussed in Dr. Henry H. Vernon's report on the health of Southport, issued in 1889. Dr. Vernon expresses the opinion that "there is a connection between outbreaks of diphtheria and the emission of ground air from the soil"; he is doubtful whether the result is due to a "chemical poison or an organised germ"; but he is convinced that occurrences of diphtheria have coincided with "rise of level of subsoil water and extrusion of ground air."

the microbe lives a very precarious life, and the least thing is sufficient to turn the tide for or against its existence—a trifle too much acidity or alkalinity, the presence or absence of a few benign micro-organisms may be all that is necessary to attract or repel the invasion and determine the result.” Here we have then faulty sanitary circumstances inducing a generally prevailing morbid condition of the faucial mucous membrane, and at the same time the expulsion by the aid of peculiar local, physical, and meteorological conditions of the specific organism of diphtheria from the soil and its conveyance by means of air breathed to the morbid surface prepared for its reception.

If this view be correct, we are forced to the conclusion that diphtheria is, primarily at least, a local disease. Oertel says: “Diphtheria makes its appearance under two different series of symptoms—as a *local* and as a *general* disease”; and he obviously holds the opinion that the general is secondary to the local. The local affection varies according to the point of inoculation. The contagion is mostly conveyed aurally to the mucous membrane of the mouth, pharynx, nose, larynx, and air-passages generally; but it may be conveyed by contact or otherwise to the conjunctivæ, the prepuce, anus, labia, the inner surface of the puerperal uterus, and other parts. On whatever surface the poison is received, there the characteristic inflammatory process and the false membranous deposit will be found; and it is in this sense that the disease differs from other specific infections which always produce their chief characteristic

pathological changes in certain definite organs. Thus, as Oertel points out, though the poison of glanders may be inoculated at any point beneath the skin in a horse, its local manifestation is always upon the nasal mucous membrane.

CHAPTER III

I HAVE from time to time adverted to the influence of school attendance in connection with prevalences of diphtheria. That some such influence obtained was one of the earliest observations following on inquiry into the etiology of the disease in this country. It had long been noticed that there was a special incidence of diphtheria on children attending schools, and it was assumed that this was essentially an affair of personal infection under circumstances of community and prolonged exposure that were inseparable from school attendance. But, as already explained, it became evident later on that the question was complicated by age-susceptibility ; and that, whilst the age 3-12 years, which essentially constitutes the age for attendance at elementary schools, also gave the largest number of diphtheria cases, the incidence of the disease varied, both as regards fatality and attack, at different periods during this school age.

In Mr. W. H. Power's report of October 1876, to the Local Government Board, on diphtheria at Brailes this question of age in connection with school attendance is discussed at length, and though, owing to the

number of schools and the intermitting character of the school operations in that place, no definite conclusions could be arrived at on some of the points raised, yet a number of considerations, which it is essential to bear in mind in dealing with this aspect of diphtheria, were set out, and they have served and still serve as a guide for future observers.

Early in the following year (1877) I endeavoured to ascertain the influence of school attendance on the diphtheria prevalence at Coggeshall, and, if possible, to differentiate between such influence and any that was due merely to age. Dealing with the question of "The Influence of School and Age," I wrote as follows: "These two subjects can best be considered together. It has been incidentally noted that some of the earlier attacks in several households occurred in children attending school in Great Coggeshall, a circumstance which suggested that the spread of the disease had been favoured by school attendance. The possibility of infection being thus spread arose at the commencement of the epidemic, for a sister of the second recorded case attended one of the most frequented schools in the town during the whole of her brother's, as well as on the first day of her own illness. Indeed, in a large number of cases it was evident that the early symptoms of diphtheria were first noticed during school hours or immediately after.

"There are in Great Coggeshall eight day schools, having together an average of nearly 650 children, to say nothing of Sunday schools, concerning the attend-

ance at which no trustworthy information could be obtained. This latter circumstance, combined with the fact that inquiry as to school attendance involved a period extending over twelve months, made it impossible to obtain thoroughly reliable data as to the influence of the schools in the spread of the epidemic. At first sight it appeared as if this influence had been very considerable, for the incidence of the disease was essentially on children and young persons, as many as 99 out of a total of 126 attacks up to the end of October 1876 being in persons under 15 years of age. In 78 of these 99 cases the attacks had occurred in children from 3 to 12 years of age, a period of life on which, according to the previous experience, the incidence of diphtheria appears to be greatest; in 11 cases the affected persons were under 3 years of age, and in 10 between 12 and 15 years. With a view of noting the effect of school attendance on the spread of the disease, I, with the aid of the census returns, prepared the following table, the numbers in which are, I am satisfied, fairly approximate to the facts:—

[TABLE

TABLE No. X.

Probable numbers of Children in Great Coggeshall.	Age in Years.				Of whom had Diphtheria.			
	0-3.	3-12.	12-15.	Total, 0-15.	0-3 Years.	3-12 Years.	12-15 Years.	Total, 0-15.
Known to be at school	18	620	49	687	1 (5.5 per cent)	59 (9.5 per cent)	5 (10.2 per cent)	65 (9.4 per cent)
Remainder ¹	254	308	161	723	10 (3.9 per cent)	19 (6.2 per cent)	5 (3.1 per cent)	34 (4.7 per cent)
Total number	272	928	210	1410	11 (4.0 per cent)	78 (8.4 per cent)	10 (4.8 per cent)	99 (7.1 per cent)

“From this table it will be seen: 1st, That, as regards children under 3 years of age, school attendance did not materially influence the number of attacks—the numbers here dealt with are, however, but small; 2d, that the incidence of the disease upon children from 3 to 12 years was not far from 50 per cent greater upon those who are known to have attended school than it was upon the remainder; 3d, that the number of attacks between 12 and 15 years of age was amongst school attendants nearly three times as great as it was amongst those at that age not known to attend school. This circumstance may, however, probably be to some extent accounted for by the fact that 3 out of the 5 who were attacked were pupil-teachers, who as a class were known to visit the houses of the sick pupils. 4th,

¹ This will probably include a few who attended Sunday school only.

That the total number of attacks upon all children under 15 years of age was twice as great upon those known to attend school as it was upon the remainder. Indeed, from these statistics it would appear that school attendance did materially aid in the spread of infection, and this view is confirmed by the circumstance that out of 21 first attacks in families where there was more than one case, and where information as to school attendance was procurable, 14 occurred amongst the 687 children known to have attended school, and only 7 amongst the 723 constituting the remainder."

In August of the same year Mr. Power presented to the Local Government Board another report on a "Prevalence of Diphtheria and other Throat Illnesses at Radwinter" in Essex, and it was again found that school attendance exercised an important influence on the diffusion of the infection, and this notably by children either incubating the disease or suffering from comparatively trivial attacks of "sore-throat."

In discussing the question of opportunity afforded at school for contracting the disease, the report states: "It is certain that for many weeks after the first appearance in the parish of throat illness, children from infected households freely attended schools of all sorts. But soon after the reassembly of the day school at the conclusion of harvest, restriction respecting such attendance was undertaken, and has been exercised up to the present time. It has not, however, been complete, and does not appear to have extended to minor cases of sore-throat, for again and again in the course of house-

to-house inquiry has information been obtained respecting the attendance at school of children incubating diphtheria or recovering from throat illness that cannot be dissociated from it. Often, too, have children with slight sore-throat continued their school attendance throughout the whole period of their ailment. Clearly, then, the day-school in Radwinter has afforded to healthy children at a particular age special opportunity of coming in contact with other children capable of transmitting throat infection."

Mr. Power having, at an earlier stage of his report, pointed out that in a total of 98 attacks, 42 were primary ones in households, the remaining 56 occurring amongst persons other than those originally attacked, proceeds as follows :

"Now, upon investigation of the daily doings of the persons who were attacked by throat disease *the first of* their respective households, it was found that, out of the 42 such persons, 26 were in attendance at the day-school of the village during some part of the week immediately preceding illness, and five of the 26 had only been back at school for a few days before their attack after a previous absence of several weeks. In none of these cases could any communication with infected persons, unless it were at school, be traced. Then there were four other persons of the 42 who had been in attendance at night or Sunday school in the week preceding attack. As regards the 12 persons remaining out of the 42—the 12 who had not been to any school in the week before their illness—five are

known to have been in personal communication with already infected families, and three others are believed to have been in similar communication. There remain but four persons who got throat illness without (so far as can be learnt) having been in relation with antecedent cases, or without having been in attendance at any school.

"There is another piece of evidence, however, that points somewhat definitely towards the day school as having been concerned in the distribution of throat disease. Of the 42 persons whose attacks are now in question, most were aged between 3 and 12. This was to be expected if the special susceptibility of children at these ages be considered. But it would seem that there must have been some further and peculiar influence at work upon the children aged 3-12 out of these 42 beyond that which was at work upon the children of the same ages out of the 56" [secondary attacks in households]. "The incidence of the disease according to age, within each group of cases, is shown below.

TABLE No. XI.

At Ages (in years)	Of the 42 first persons attacked in their respective households there were	Of the 56 persons subsequently attacked there were
0-3 . . .	1, or 2 per cent of the 42	5, or 9 per cent of the 56
3-12 . . .	32, or 76 per cent of the 42	27, or 48 per cent of the 56
12-15 . . .	3, or 7 per cent of the 42	5, or 9 per cent of the 56
15 and upwards	6, or 14 per cent of the 42	19, or 34 per cent of the 56

“This incidence upon age within the 56 cases is the incidence under conditions of exposure alike in people of all ages; and the proportionate incidence on each age of this group may be taken as a standard for examining the incidence according to age in any other group where the conditions of exposure are unknown. Now, in the other group of 42 persons, those who were first to fall ill in their respective families, there is a noteworthy excess beyond the standard in the case of children aged between 3 and 12 years; and it cannot be doubted, I think (though I admit the inference would be more certain if the actual figures were larger), that this excess shows the children of these ages to have been specially exposed to infection. In the known circumstances of the village, such special exposure cannot have been anywhere but at the day-school, and accordingly I judge that that school was in effect a means of distributing the infection of diphtheria from one family to another.”

I am not aware that any material addition was made to our knowledge as to the precise relations of school operations on diphtheria between 1877 and 1883. The conclusions already arrived at were, in the interval, found to be matters of common experience, and some information was obtained which went to show that where faulty sanitary circumstances of the school-house—and notably circumstances of overcrowding and inadequate ventilation—also came into play, the mischievous influence associated with school attendance operated with exceptional force, both in respect of numbers attacked and of

the type of the malady. In one such case a different incidence of diphtheria which varied between 34·6 and 20·6 per cent of attacks, on two schools in the same locality and having much about the same number of scholars, was held to be largely accounted for by the prevalence of such conditions as I have indicated.

But early in 1883 a very important report was issued by Mr. W. H. Power on a prevalence of diphtheria, which had been maintained throughout the preceding year, in the parish of Pirbright in Surrey, a parish in which the houses were largely disposed of in small groups scattered over several miles of country. Out of a total of 106 attacks, on a population hardly exceeding 700, 75 had either been recognised as diphtheria at the outset, or had shown themselves to be such by their sequelæ; the remainder were attacks of "sore-throat" such as are now known to be so common during diphtheria outbreaks; and the whole are for the purposes of the report included under the term "throat illness."

In the course of the report the incidence of this throat illness on households and on persons at different ages is discussed in connection with nine alternating periods of school work and school closure. "Passing over the first period during which diphtheria was acquiring a hold on the parish, we come," writes Mr. Power, "to compare the seven weeks ending May 20, during which the school was open, with the following period of six weeks (ending July 1) during which it was closed. The weekly number of attacks declined between the two

periods, and declined only among children under 15 years old. The school was now reopened for three weeks, and in that period the weekly attacks became again more numerous, becoming so solely among children under 15. The school being again closed for six weeks, the weekly attacks among children fell almost to the point of disappearance of the disease among them, but new cases occurred among older persons. During the last four months of the year, the school had been twice again opened and twice again closed, with some corresponding fluctuations (smaller in actual amounts) in the appearance of the disease, suggesting a relation between the work of the school and the occurrence of the throat illness, and between the suspension of the school work and the disappearance of the throat illness."

It having next been ascertained that the special incidence of the throat illness on children at the more susceptible ages 3-15 years had obtained uniformly throughout the scattered parish, much time was spent in attempting to differentiate between mere age-influence and any influence that might have been special to the school; and the question at once arose as to how far the incidence of the disease on children had "been due to mere age as conducing to attack, and how far to difference of exposure, whether at school or elsewhere." With a view of answering this question, Mr. Power takes as a standard sufficient for comparison "the behaviour of the throat illness towards *persons of various ages in the families that had become invaded*," and he found that under such circumstances of equal exposure as are

involved in living on the same premises and under the same influences as surrounded the original sufferer in living by day in the same room, in sleeping in the same or the next room, parents nursing children, children tending one another, and the like, there were attacked of those living at ages 0-3 years 9 per cent, at 3-12 years 38 per cent, at 12-15 years 31·8 per cent, and over 15 years 13·5 per cent. This result is then compared with the relative incidences on the same groups of ages under circumstances of life in non-infected houses; *first attacks in families* alone being taken into account for this purpose; and it was found that the corresponding percentages were: at 0-3 years 1·8, at 3-12 years 25·0, at 12-15 years 10·8, and over 15 years 2·0. "Thus, while throat illness was but seldom introduced into the family by the baby or by the grown-up members of the family, it was brought by the child of 3-12 not very much less often than it would have been brought if the child had been living in an atmosphere of persons infected by throat illness. And this difference between the child of 3-12 and other persons is found, after all due allowance has been made for the differing susceptibility of various ages, to contract the illness. The child of 3-12 years, therefore, has for some reason or other, apart from its age, been the child to get the disease and to take it home to the family that has hitherto been free from it."

Other influences having been considered and eliminated, school-going was obviously indicated as the reason sought for.

The data for the comparison made by Mr. Power may be thus tabulated—

TABLE No. XII.

Age-periods.	In Families already invaded.			First Attacks in Families.		
	Persons living at Age-periods.	Numbers attacked.	Attacks per cent.	Persons living at Age-periods.	Numbers attacked.	Attacks per cent.
0-3 yrs.	22	2	9.0	52	1	1.8
3-12 yrs.	59	23	38.0	148	37	25.0
12-15 yrs.	22	7	31.8	46	5	10.8
over 15 yrs.	148	20	13.5	444	9	2.0

But, with a view of determining the influence of school attendance more in detail, the influence of throat illness on children 3-12 years, both at school and not at school, and on other persons, was studied for each period of school work. And, similarly, the facts of the incidence of throat illness were studied for each period of school closure. Distinction was, for these purposes, made between first sufferers and subsequent attacks in households, and the periods were somewhat modified so as to avoid crediting the school with cases that might have got their infection just before the school reopened. And, in the end, it turned out that school influence had seemingly a larger share in the prevailing illness than had at first been apparent. Thus, in uninfected families, children at ages 3-12 years "who at a given period were attending school, became affected by

throat illness five or six times as numerous as children of the same age who at the same period were not attending school. And this was observed on every occasion when the school was open and the opportunity for comparing the two existed. While the school remained open in the early months of the year, the rate of attack in children 3-12, presumably susceptible of diphtheria but not having the disease at home, was 16·6 per cent of those who were at school, 3·8 per cent of those who were not. The next time the school was open, the respective rates were 4·8 and 0·0; the third time, 7·1 and 2·5; and, on the November occasion, 4·1 and 0·0. The numbers upon which these percentages are based are indeed small, but on the other hand the indication which they furnish is too uniform to be mistaken." These points may be tabulated as under :—

TABLE No. XIII.

Periods in which school was open.	Percentage of attacks on children 3-12 years living in houses not infected.	
	Attending school.	Not attending school.
1st period.	16·6	3·8
2d period.	4·8	0·0
3d period.	7·1	2·5
4th period.	4·1	0·0

It was next sought to ascertain what was the incidence

of throat illness, subsequent to the culmination of the outbreak, among children 3-12 years who had no infection at their own homes during periods of school-closure and school-work respectively, and it was found that on four occasions between May 17th and December 20th, a period during which the school was closed for, in all, 166 days, there were three periods, covering in all 125 days, during which no single attack occurred, whilst in the remaining one, namely the first period in which closure was attempted, five cases, mostly slight, occurred; whereas on the other hand, during the three intervening periods, covering in all only 63 days, in which the school was open there were 14 attacks of which no less than 5 terminated fatally.

And, without intending to imply that school influence was the only factor of throat illness amongst children of the ages specified, Mr. Power, in view of the facts elicited, naturally came to the conclusion that "no doubt" could "be entertained that the conditions of school attendance [had] played an important part in the speciality of the incidence of grave illness on children 3-12 in Pirbright," and this although it could not be ascertained that anything in the sanitary circumstances of the school could have had any essential part in the production and maintenance of the disease amongst the scholars.

It will be noted that a new point was indicated as the result of the last observation, and this is considered in connection with the experience afforded at Pirbright as to the recurrence of diphtheria on each resumption of

school operations. I refer to the gravity attaching to the type of the disease induced.

The persistent character of the outbreak had caused much anxiety to the able medical officer of health for the district, Mr. Joseph Smith, D.P.H. Cantab.; and both during the periods of school closure, as also immediately antecedent to its reopenings and during school attendance, exceptional care had been taken, under his advice, towards effectually getting rid of the infection. "Not only was the school building with its contents thoroughly cleansed and fumigated, but disinfection of dwellings and clothing of persons that had been attacked was diligently practised in all instances. And on each occasion of reassembly of the school (and reassembly of the school was not permitted until no diphtheria had for several weeks occurred in the parish), children that had suffered were excluded until they could be pronounced completely recovered from their throat affection." Indeed, as regards diphtheria or recognisable throat illness Mr. Power believes that it "could hardly have escaped notice."

Evidence as to the possible introduction of infection on each occasion into the school was on the whole negative, and the diphtheria seizures that did follow on occasions of reassembly of school occurred so nearly together as to indicate the operation of a common cause, rather than that one attack had been derived from another. But "no sooner does school reassemble than diphtheria, and commonly fatal diphtheria, reappears amongst the school-children." How did this come about?

In discussing this question, Mr. Power explains that he could find no history of even trivial sore-throats amongst the children on their reassembly at school; unless, indeed, a few cases of "cold" so called were of that character. And even if they were such, he explains that the operation of the process of "progressive infectiveness" in this case offered no sufficient explanation, for there was "no evidence of progressively increasing gravity of the earlier cases, if indeed there was time for the process. On the contrary, with startling suddenness, multiple cases of diphtheria, and fatal diphtheria, promptly occurred on each occasion of re-opening the school; and cases intermediate in gravity between these diphtheria cases and the 'colds' that on the above hypothesis gave rise to them, are not, except perhaps in the July period, to be found. No satisfactory explanation," adds Mr. Power, "of this behaviour of the diphtheria is forthcoming."

A newly-ascertained phase of school operations seemed here to be at work, and it naturally attracted attention. Referring to the subject in his official report to the Local Government Board,¹ Dr. Buchanan, F.R.S., writes as follows: "A very remarkable experience of diphtheria is recorded by Mr. Power from the parish of Pirbright near Guildford. On four successive occasions, while the village school was open, well-marked diphtheria appeared among the scholars, who carried the disease home to their respective families; and this although the

¹ *Report of the Medical Officer of the Local Government Board for 1882*, p. vi [C—3778—I.], 1883.

school was free from recognisable sanitary defect, and although the school was not, after its first closure, reopened until the disease had seemed extinct in the parish, and careful measures of disinfection had been used. There did indeed appear indications that the actual bringing together of children was responsible for a serious specific quality attaching to throat ailments which otherwise would have been trivial."

Reviewing this together with subsequent experiences as to the effect of school attendances, it soon became evident that the aggregation together of children at the ages 3-12 years under conditions such as attach to elementary schools, was one of the most potent means for the elaboration and diffusion of diphtheria, and this often in a specially dangerous form. The suddenness which marked the Pirbright occurrences found a parallel in the case of an outbreak at Oaksey near Malmesbury. This prevalence was reported on by Dr. Arthur Downes¹ in June 1883; the relations of the disease to school attendances were worked out with exceptional care, and reference is made in the report to an "explosion" of throat illness which occurred amongst the scholars of a day and a Sunday school, on the return of a child who had sickened with diphtheria some two months before.

The influence on diphtheria of the aggregation of children at susceptible ages, under somewhat different circumstances, is referred to in a report by Dr. Bruce Low on an outbreak of that disease at East Haddon in

¹ *Report of the Medical Officer of the Local Government Board for 1883* [C-4220], 1884.

Northamptonshire ; the outbreak having resulted in 134 attacks in 85 households, and in 20 deaths, and being almost entirely confined to the months of August and September 1889.¹ In this case the disease had been preceded by an unusual prevalence of sore-throats in two neighbouring villages, and school influence was found to have been associated with the spread of the disease ; indeed, in no less than 79·4 per cent of the attacks which occurred before the school closed for the harvest holidays on August 23d, the first sufferers in households were children attending the village school. On the 21st of August the squire gave a school treat in his private grounds. "This gathering of all the village children together afforded on a large scale means for association of a considerable number of those already sick with the healthy. The treat was fixed originally for Tuesday, August 20th, but owing to the wetness of the weather it was postponed till the following day, Wednesday, August 21st. The weather on this day also was wet, but cleared up towards the afternoon, and the evening was fine. Tea was provided in two marquees joined together, and it is stated the canvas curtain of the whole of one side and a portion of the other was removed to admit of ventilation. . . . Almost all the children in the village attended the treat, and other children who resided one or two miles outside were also present. . . . With two exceptions all the children known previously to have been attacked with the throat malady were present at this treat. Indeed

¹ *Official Report to the Local Government Board, December 2, 1889.*

two little ones, sickening with the disease, were taken from their beds, and carried to the treat by their respective mothers. After tea there were games and sports; nearly all the adult population of the place were gathered in the squire's grounds as onlookers during the evening. Scrambling for sweets took place, and an eye-witness states that he saw the children crowded close together, hot and excited, pushing up against one another in the struggle to gain the sweets. The grass and the ground were very wet owing to the recent heavy rains."

Up to the date of this treat only twelve attacks, all single ones in households, had occurred, and one single death had resulted in a period of eight weeks. But on the very night of the treat a sudden accession of diphtheria set in, fresh attacks followed day by day, and by the end of a fortnight 91 patients had been newly attacked, 17 of the cases terminating fatally.

In this case the cause of the sudden increase of diphtheria is involved in some obscurity; the circumstance was complicated by suspicion of milk-infection; and its almost instant sequence in somewhat wholesale fashion on the assembling of the children is, to say the least, an exceptional experience. Dr. Low is also inclined to regard the chills and colds contracted on the afternoon and evening of so wet a day as having in some measure acted as predisposing causes. But under any circumstances the story serves to illustrate the fact that in determining the causes of rapid and fatal developments of diphtheria other aggregations of children than those in school-houses have to be taken into consideration.

I may here conveniently recall what has previously been said as to the influence of cold and wet as a predisposing cause of diphtheria,¹ and quote in that connection a passage from Dr. Thursfield's observations as to diphtheria among school children :

"Sitting all day with wet shoes and stockings is a constant source of catarrhal sore-throat, and I have over and over again seen diphtheria select those children as its first subjects, or, in established epidemics, as its worst victims, who have had to walk long distances through country lanes where they would be pretty sure to get their feet wet. In addition to this, children who come a long distance to school are exposed to the debilitating influence of a fatiguing walk, and not being able to go home to dinner, have frequently to eat it cold, and under generally uncomfortable conditions. I have often seen the above considerations explain what otherwise would appear a most inexplicable distribution of the disease in a rural epidemic."

Before further considering the particular conditions which are responsible for that which has been termed "school influence" in connection with diphtheria, I would refer to one other experience to which prominence has been given by Dr. D. Astley Gresswell.² I refer to the recrudescence of the infective quality of throat illness in persons who have suffered from diphtheria.

¹ See p. 28, and also p. 129.

² "Diphtheria as a Chronic Malady in Particular Individuals with Liability in them to Recrudescence," by D. Astley Gresswell, B.A., M.D., Oxon. *Transactions of the Epidemiological Society of London*. Session 1885-86.

Dr. Gresswell explains that, whilst prosecuting inquiries into diphtheria in different parts of the country, he had met with "a considerable number of persons who, having been affected with diphtheria years ago, have suffered almost constantly ever since from throat affections," their throats being habitually and peculiarly sensitive to changes of weather, a very trifling exposure sufficing to produce in them acute inflammation of the tonsils. "Further," he adds, "diphtheria has occurred among persons associating with those who at the time have been suffering from this condition, and in instances where I have not been able to find satisfactory explanation for this diphtheria, I have had to ask myself whether the condition here referred to may be of a diphtheritic nature. The question put shortly stands thus. Is the chronic tonsillar inflammation which is left in particular persons after an attack of diphtheria due to a continued sojourn in them of the material cause of diphtheria? And do the violent reactions of the tonsils of these persons to weather changes involve likelihood of rendering them diphtheritically infectious?"

Dr. Gresswell holds that the facts which have come under his notice are not inconsistent with such belief, and a group of cases which he sets out as embodying these facts is of sufficient interest to deserve quotation. The histories are as follows :—

"1. A lad, R. G., twelve years of age, fell ill of diphtheria in July 1883. There is clear evidence that he had associated but a few days previously with a diphtheritic patient. His father, his mother, and the

three others (children) of the family all fell ill of diphtheria in quick succession after him. Two of the children, aged respectively fourteen and twelve years, have suffered ever since from tonsillar trouble, and the tonsils of each have ever since been prone to swell largely on exposure to either cold or wet.

“Late in April 1885 a woman who had visited this family fell ill of diphtheria. I took some considerable trouble in attempting to solve the origin of her case ; and the only fact that I felt worthy of consideration was that she had associated frequently for some weeks prior to her attack with the family referred to. She had, I learnt, become much attached to the children, aged fourteen and twelve years.

“The conclusion suggested itself to me that the woman contracted diphtheria either from some member of this family or from some infected thing in the house inhabited by this family.

“The latter alternative is open ; it would appear to be impossible to exclude it. But I would suggest, and I think with equal, or rather with greater, probability of truth, that she derived infection from one or other of the children. Six days prior to her attack I had seen these children. The child aged fourteen years at that time presented a strawberry tongue, an enlarged left tonsil, and hypertrophied pharyngeal follicles ; a white, sticky substance also was adherent to various parts of the throat. The child aged twelve years had at the same date large red tonsils ; the follicles were widely open, and a white substance was exuding from them. If

the view which I have taken of the origin of infection in this case be correct, a person once infected with diphtheria may remain capable of transmitting infection for a period of nearly two years.

“2. A girl, A. P., took diphtheria in December 1881. This girl has, I am told, suffered ever since from sore-throat. Whenever she has been exposed to cold, especially if the feet¹ have been wet, her tonsils have very quickly swelled, and to an extent involving, her mother has supposed, danger of suffocation. She suffered from one such attack of sore-throat in July 1883, very shortly (two weeks or so) after she had taken on duties as mistress in a school. I was not able to find any other explanation for this attack of sore-throat than the one suggested by herself and her mother, she ‘had taken cold.’ There was not apparent any evidence to show that she had within a recent period been in association with any person, or been in contact with anything infected with diphtheria.

“This girl continued her duties at school for a day or two after falling ill, and within a few days—at the most five or six—three children who were attending the school fell ill, and two of the three died, of diphtheria; while other cases and deaths occurred evidently as the result of infection contracted from the three children referred to. I made searching inquiry into the previous health of the school children and school teachers, also of the persons living in the village and in the surrounding country; but I was not able to find evidence affording any probability

¹ As to this see also p. 126.

that the three children derived their infection from any other source than the teacher, A. P.

“This case suggested to me dormancy and recrudescence in an infectious form of the material cause of diphtheria in the individual.

“3. A lad, J. W., nine years of age, suffered, it is said, from diphtheria late in 1877, and all the rest of the family (four in number) suffered about the same time. In 1878 he again, it is said, had diphtheria, and one of his brothers died of diphtheria. He was then two years of age. Ever since this second attack he has been subject to severe attacks of sore-throat, and ‘when he gets wet-shod, the tonsils quickly swell and become covered with a white coating.’ One morning in August 1884 he played truant from school; he returned to school (where he boarded) late, the same night, very wet and feeling ill, and next day he was reported by his medical attendant to be suffering from diphtheria. It is possible that while truant he came into contact, or that previously he had been in contact, with diphtheria-infected persons or things. But, though I took considerable trouble to trace the movements of the boy, I was not able to discover such contact; and the consideration arose as to whether mere exposure to wet had been in this lad a sufficient cause for revival of growth of the material cause of diphtheria lying dormant in him. The question may be raised whether the last attack was truly one of diphtheria. All I can say in answer is, that the medical attendant who pronounced the case to be one of diphtheria had had considerable experience of this

malady ; and that I have suspicion that the lad has been on several occasions, in late years, a centre for diphtheria infection.

“ I quite recently met with a very similar instance in the person of a girl.

“ 4. A family, twelve in all, with governess and four servants, living together in an isolated house, were remarkably free from illness, and no case of sore-throat, croup, laryngitis, diphtheria, mumps, or scarlet fever can be remembered to have occurred in the house for some consecutive years prior to March 1881. Between March 1881 and July 1882 seven cases of diphtheria occurred among the inmates of this house.

“ There is good reason for thinking that diphtheria was in the first instance imported in the person of a servant girl, and that all of the seven cases above spoken of were due to infection derived directly or indirectly from her.

“ Most of the patients were sent away, either very shortly after their several illnesses had been recognised, or as soon as possible during convalescence ; and attack in all but two instances was preceded by the return a few days or a week or so before of the person who had suffered last.

“ It may be noted that the first patient was, in the early days of her illness, said to be suffering from quinsy, and that her death, which took place six days after she had fallen ill, was registered as due to diphtheria. It may also be added that diphtheria occurred and caused deaths in several families among which these patients and convalescents had been sent.

“General and careful cleansing and disinfection were conducted in and about the house on several occasions during the above-mentioned period.

“Still, however, severe attacks of sore-throat continued to occur, and cases of diphtheria were recognised, viz. one in February 1883, one in July 1883, one in September 1884, three in quick succession in October 1884, one in May 1885, and finally the last case in June 1885. All but one of these were primary attacks. It is quite possible that the belongings of the house had, by virtue of the succession of cases between March 1881 and July 1882, become so far infected that fresh occurrences of sore-throat and diphtheria may be explained on this ground. But I wish to draw attention to the fact that one of the seven who suffered between March 1881 and July 1882 has suffered from throat affection ever since, and has had acute attacks of sore-throat from time to time. On one occasion, when she was suffering from an attack which she regarded as an excessive development of her ordinary attacks, she was recognised on medical authority as again suffering from diphtheria; and, ten days after this illness began, a servant, a new-comer, slept with her, and a few days later fell ill of diphtheria.

“5. A girl, E. D., aged 15 years, another monitress, was taken with diphtheria early in June 1884, and her illness is definitely traceable to personal infection. Among the children at the school where she was teaching there occurred three cases of diphtheria in November of the same year. I was able to suggest but one ex-

planation for these cases. This explanation lay in the fact that the monitress had a second severe attack of sore-throat early in November, when she was a second time disabled for a few days from work, and that she returned to school, still with some degree of tonsillar discomfort, only a few days before these three cases occurred. I was not able to trace any renewal of infection as a cause of her second illness.

"The five groups of cases above detailed serve to illustrate what I have in view when speaking of diphtheria in certain individuals as a chronic malady with liability in them to recrudescence. To these illustrations I would add yet another.

"In an asylum, in which some 150 female orphans are brought up as domestic servants, throat affections of one and another sort (variously spoken of as putrid throat, sore-throat, throat affection, strumous throat, and the like) have almost constantly been present, and diphtheria has been recognised from time to time for several years past. On turning to the fragmentary records of illness in this asylum (the sick-register, in which are entered only those patients actually under treatment on twenty-six days in the year—a fortnightly record in fact), I found the following facts recorded: A girl, then 11 years of age, was taken with diphtheria on February 23d, 1881, and she was suffering from loss of ocular accommodation on April 8th of the same year. This girl has suffered frequently from sore-throat since this attack, and on October 7th, 1883, she and four other orphans were invalided with 'sore-throat and catarrh.'

The precise order in which she and the other four fell ill cannot now be ascertained. Again, one of the four referred to has suffered on and off from sore-throat ever since October 1883, to an extent, indeed, necessitating periodic removal to hospital, and quite recently she has been recognised as suffering from diphtheria. Other similar facts were recorded, suggesting a chain-like order of succession among cases of sore-throat and diphtheria.

"It is, I think, at least open to question whether diphtheria has not been maintained in this asylum in the persons of its inmates, and in a way as suggested by the facts just mentioned."

Dr. Gresswell further explains that he has himself met with several persons who, whilst suffering from what he has termed "recrudescence diphtheria," have been apparently the starting-point of a fresh outbreak; thus he refers to instances in which so-called acute tonsillitis sequent upon diphtheria has, in the case of monitresses, appeared to be the initiating stage of diphtheria among school children. He also records cases which go to show that diphtheria convalescents who, on recovery, have exhibited healthy-looking tonsils, may be subsequently found at school and elsewhere with "creamy patches on the tonsils or pharynx," or with genuine diphtheritic patches on the fauces. In short, he holds that in particular individuals diphtheria becomes a chronic malady with liability in them to recrudescence. And he appeals to the analogy of glanders in the horse, which, though it may to all appearance have been cured, yet manifests itself afresh months afterwards, and this inde-

pendently of any renewed infection ; also to the analogy of gleet in its relation to gonorrhœa ; to our experiences in contagious ophthalmia ; and to the somewhat parallel experience as to the activity exhibited by certain parasitic organisms in which periods of rest are followed by periods of apparently renewed vitality to which the term "rejuvenescence" has been applied. "It seems," he adds, "to be justifiable analogy to regard recrudescence of a disease which is apparently referable to the life of a parasitic organism as the expression of rejuvenescence of that organism. That some such process takes place in some diseases is scarcely to be doubted ; that it takes place in diphtheria I have more than suspected."

As bearing upon what I have said in connection with the influence of faulty sanitary circumstances on diphtheria, it will be interesting to record Dr. Gresswell's experience as to the nature of the conditions under which these persons were found living, amongst whom this recurring "diphtheria-imparting sore-throat" was specially noticeable. "The conditions have been almost without exception such as would unhesitatingly be pronounced unwholesome. The dwellings inhabited by these persons have been badly ventilated, damp and mouldy, and in some instances they have had grave defects of drainage. I have been told that such conditions are amply sufficient for the maintenance, if not for the production, of the material cause of diphtheria, and that, the conditions being as represented, there is no need to go further afield and speak of recrudescence of diphtheria in the individual. It may be so, but I think

by no means necessarily so. The conditions referred to produce in particular individuals, it seems, a reduced vitality, which is largely evidenced in un-coördinated aimless development of amoeboid elements in adenoid tissue. The tonsils, with other parts of the body, suffer, and it is likely enough that in such condition they afford exceptionally suitable 'hosts' for sustained maintenance of the virus of diphtheria, and under certain conditions, such as those spoken of as 'chilling,' for a revival of it."

Dr. Gresswell's experiences have important bearings on the natural history of diphtheria. They may largely explain why it is that one attack of diphtheria does not, as is commonly the case with the ordinary specific fevers, confer immunity against a second or even a third attack; and I should perhaps point out that they tend in the direction of diminishing the number of instances in which such a process as "the progressive development of the property of infectiveness" can be put forward as the only available explanation of such occurrences of diphtheria as those in connection with which I have drawn attention to that process.

School influence¹ would appear, then, to be operative for mischief in a number of ways.

1st, It brings together those members of the community who are, by reason of age, most susceptible to diphtheria.

¹ In connection with this subject see "Memorandum by the Medical Officer of the Local Government Board on restricting school attendances in order to prevent the spread of disease," Appendix No. II.

2d, The children thus brought together are placed, and remain for many hours of the day, in exceptionally close relation with each other.

In this connection, it must be remembered that we are dealing with a disease the communication of which from person to person is largely dependent on the closeness of the mouth and nares of the recipient individual to the faucial mucous surface of the individual by whom the infection is imparted. And when it is remembered that children are so placed in elementary schools as necessarily to be for long periods inhaling the lung exhalations of their fellows, and that collective singing and a kindred form of general intoning often form part of the school programme, it will not be difficult to understand how especially favourable such circumstances are to the transmission of a specific infection which has a primary seat upon the mucous membrane and in the secretions of diseased fauces.

3d, The closer the aggregation and the greater the lack of ventilation, with corresponding hindrance to the free movement of air, the greater is the risk.

4th, Such faulty sanitary circumstances of the school-house and its surroundings, and such other conditions as tend to a condition of general ill-health, in that they induce sore-throat, favour the reception, by children so suffering, of any imported diphtheria infection.

5th, There are ample grounds for believing that the aggregation of children in elementary schools "constitutes one of the conditions under which a form of disease of

particular potency for spread and for death may be, so to speak, manufactured.”¹

6th, The danger of school aggregation is by no means limited to the period in which the throat-disease is acute.

“Recrudescence” of the throat-mischief in the individual probably tends to be favoured by conditions intimately associated with school-attendance. And similarly, even in the stage of the disease after paralytic neuroses have supervened, infection may be communicated. Thus Dr. Downes, in his Oaksey Report, tells of a child who, soon after having been sent to her grandparents to recruit, on convalescence from a mild attack of some throat disease, which raised no suspicion of diphtheria, was noticed to have a “peculiar” voice ; her sight was also defective ; and, in swallowing, “bits of food stopped in her throat.” Nineteen days after her arrival diphtheria appeared among her new associates and playmates. Indeed, Dr. Downes says that his observations go to favour a view, which has been advanced, “that in diphtheria there may be a period in the later stages, or in convalescence, when the contagion becomes more readily transferable” than even in the acute stage. How far such character of the diphtheria contagion may be due to recrudescence of the disease had, I believe, not been considered at the date of Dr. Downes’s report.

7th, The practices of kissing and of transferring

¹ Inaugural Address delivered before the Epidemiological Society of London by Dr. Thorne Thorne, F.R.S. *Transactions of the Society*, vol. v. ; session 1887-88.

sweetmeats from mouth to mouth—practices which are more common amongst girls than with boys—as also the joint use of drinking cups, etc., must, according to experience, be credited with assisting in the diffusion of diphtheria amongst schoolfellows.

This last consideration leads me to draw attention to a habit which is not uncommon, and this especially in some of our northern counties, of bringing the youthful members of a family, as well as whole classes of Sunday school children, to bid farewell to a dying relative or schoolmate, or to pay a visit to the dead ; some of them being encouraged to do this by a kiss. Again and again has this practice been followed by the communication of infectious disease, and notably of diphtheria ; and were it not that the wilful persistence in the practice is largely the outcome of ignorance, I could hardly do otherwise than characterise it as criminal.

In a recent report on epidemic diphtheria¹ Dr. Bruce Low refers to this practice as follows : “ Again, there is a custom . . . of assembling children of the family in the sick room to take their last leave of a relative, dead or dying from infectious disease ; and children have even been brought from other districts to take part in such formal leave-taking. . . . In one case, a child having been attacked by diphtheria, the rest of the children were sent off to the house of a relation to be out of danger’s way. But the case being likely to prove fatal,

¹ Dr. Bruce Low’s *Report to the Local Government Board on Epidemic Diphtheria in the Enfield Urban District*. Eyre and Spottiswoode, London, 1888.

the children were roused from their sleep at midnight to return to the infected house to bid the little sufferer a last farewell. One little child was brought in a blanket to save time. As the patient was dead on their arrival, they were each lifted up to kiss the lips of their dead brother. Whether from kissing the corpse, or from returning to the infected atmosphere of the sick-room, the other children contracted the disease, as might have been expected. . . . In several cases mothers persisted, in spite of the warnings and entreaties of their medical advisers, in kissing their children's lips, and appeared in this way to have contracted diphtheria." The attacks in the cases of these mothers occurred, according to information supplied to me by Dr. Low, within a week of the act of kissing.

I am also induced to revert in this connection to the occurrence of diphtheria in adult life, an age-period when, in so far at least as mortality is concerned, the incidence of the disease becomes so much reduced as to border on immunity.¹ In a large number of the instances in which adult diphtheria has come within my own experience there has either been some indication of pre-existing sore-throat favouring reception of the contagion, or, and this more often, there has been opportunity for some close contact between sick and healthy. I am able, in illustration of this point, to contrast certain hospitals in which diphtheria is received. In one there is a rigid rule that no diphtheria patient shall be lifted up or carried about, and in that institu-

¹ See Table No. VIII, p. 38.

tion no nurse has for a series of years contracted the disease. In the other, regulations of like stringency are not observed, and nurses tending the sick not infrequently endeavour to alleviate the distress of their little patients by fondling them and carrying them about; in that institution diphtheria amongst nurses has all but amounted to an epidemic prevalence. The risk thus involved is, owing to the age-period of those incurring it, one attaching more to health than to actual life; but it is one that cannot be justified.

There is one other class of adult sufferers, in whose case the contact I have referred to is so close as to involve urgent peril. I refer to those careful watchers who, seeking to prolong or perhaps save a life that is suddenly endangered, have not hesitated to apply their lips to the tracheotomy tube in order to clear it by suction of some fragment of diphtheria membrane that bids fair to choke their patient. And the result is, generally, that the life of the life-giver becomes forfeited. But if one and the other practice just now called for condemnation, we may well join with those who have classed amongst deeds of heroism the still more perilous practice which has so often become the last effort in a career deliberately devoted to the alleviation of human suffering and to the saving of human life.

I have addressed you at length on the subject of school influence in relation to diphtheria. And what I have said cannot but raise a question as to how far the observed increase, during recent years, of that disease in the country as a whole, and especially in the group of

large urban districts, has been related to change in the conditions of elementary education. The question is a difficult one, and I do not profess to do more than refer to some of the considerations that are involved in it. To this end it will be convenient to set out, side by side as it were, two parallel series of facts.

On the one hand, as I have shown, diphtheria has, apart from age-susceptibility, a special incidence on those attending our elementary schools. Time after time the beginnings of diphtheria epidemics have been traced to the local school as a centre. Special facilities exist at school for the dissemination of the infection by and amongst the scholars. School attendance has operated to foster and maintain those "sore-throats" which so often form the connecting links between one and another fatal prevalence of diphtheria. "Recrudescences" of the disease have been notable amongst those frequenting schools, whether as pupils or teachers; and daily aggregation within school premises of those who are at the age of greatest susceptibility to diphtheria has again and again led to sudden development of the disease, and this in a form most potent for mischief and for death.

On the other hand, is the fact that elementary education became compulsory in 1870, and that since that date the machinery for procuring and maintaining the attendance at school of *all* children at school ages has been gradually improving until now it is well-nigh perfected, with the result, that first in country districts, and later on in urban centres also, a very large proportion of that section of the population most prone to

suffer from diphtheria in its various phases has day by day been aggregated in our schools.

Having given the facts, I would willingly quit the subject. But since more may be expected of me, I can hardly refuse also to state the inference which, provisionally, I have drawn. If schools have now larger concern than heretofore in the current diphtheria of the country, and particularly in that notable increase of the malady in our great towns and cities, it is, I suspect, largely owing to the compulsion that has come to be exercised over what I will term the defaulting class of school children.

Again and again have suggestions to exclude from school children residing in infected houses or localities, been resented because the step tended to diminish the average attendance on which the financial status of the school, and at times also of the teachers, was in part dependent. It is by no means uncommon for school officials, who doubtless act in ignorance of the risk involved, to "whip-up," so to speak, absentees during prevalences of sickness; and in this way, amongst others, it comes about that "sore-throats" of a type to be regarded with suspicion may, on the occurrence of diphtheria, generally be most readily found amongst those who are at school.¹

¹ Dr. Wilfred W. E. Fletcher, medical officer of health to the Ormskirk rural sanitary district, found the school attendance officers so averse to give him information as to the existence of infectious disease in the homes of scholars that he secured the adoption of a resolution imposing upon those officers the duty of giving him that information. Referring to his later experience, which was to the

And if, as I have suggested, the specific organism of diphtheria tends to behave as do certain low forms of vegetable life, may it not be that, just as special characteristics tend to be developed by the gathering together into a hot-house of selected forms of plant life that have hitherto been struggling towards a tardy and imperfect development in the open, so the increased virulence and greater reproductiveness of the diphtheria contagion, which would appear, in point of time, to have been associated with the steady growth of a system by which the young are gathered together for educational purposes, may turn out to be dependent on the aggregation, forced or otherwise, within school premises, of children suffering from such throat ailment as I have indicated?

I have no proof of my contention. The question could only be solved as the result of such comprehensive inquiry into the natural history and behaviour of

effect that even under this instruction he failed to get the information required, he writes: "I can only conclude that teachers are unwilling to inform the attendance officers of absentees, whom they themselves know to be suffering from infectious disease, knowing they would report to me, and fearing that I would keep away from school many children who, though themselves quite healthy, might be living in infected dwellings; whereas, so long as I was kept ignorant of the cases, they could compel these children to attend school by threatening the parents if they persisted in keeping them at home. I have many times had to remonstrate with teachers for sending for children in these circumstances; sometimes they have even sent for children whom I had forbidden to attend, knowing perfectly well that I had forbidden them. . . . I have even had to threaten some of them with legal proceedings under section 126 of the Public Health Act." Public Health Section, British Medical Association Meeting, Birmingham, August 1890.

diphtheria as is called for by national interests ; but finding no other solution of my difficulty, I provisionally submit this one to your judgment.

In closing these remarks as to the bearing of school influence on diphtheria, I may conveniently record a recent experience which, besides serving to illustrate the contention that the beginnings of diphtheria may often be traced to the elementary schools, also enforces the views I have expressed with reference to certain other points involved in the natural history of this disease.

Towards the end of last January a typically severe case of diphtheria occurred, and terminated fatally after four days' illness, in the person of a male adult of twenty-four years of age who was in service in a country mansion ; and it was assumed that the attack, which was stated to have been an isolated one, had its origin in certain sanitary defects which were believed to attach to the mansion. I, in consequence, paid a visit of inquiry and inspection to the locality in company with an expert in sanitary engineering, and it soon became evident that very grave defects were associated with an antiquated system of barrel drains passing around and underneath the residential buildings. The view that the defective sanitary circumstances and the diphtheria were related to each other as cause and effect seemed, on the surface, to be fully borne out by the conditions discovered. But there were points in the history of the case which led me to regard the attack in question as being more like one of a series of other cases than a single and isolated attack ; and this suspicion was increased when I ascertained,

on further inquiry, that the only part of the mansion in which substantial and fairly successful efforts had been made to remedy the generally prevailing drain defects was precisely the one which the young man almost exclusively occupied both by day and by night. Previous inquiry of the local medical officer of health had, however, failed to ascertain the existence of any antecedent attacks in the neighbourhood ; no case of throat disease had been seen by him or reported to him, and it seemed clear that none had occurred in the mansion itself.

If any such disease had prevailed in an unrecognised form the elementary schools would, I felt convinced, give some evidence of it, and hence I suggested that the school teachers should be requested to draw up a list of all scholars who had been absent from school on any occasion between the middle of the preceding September and the end of December, together with a statement as to the cause of the alleged absence. It was soon found that no account could be taken of the statements of the scholars in the Infant School, where children at the age-period most susceptible to diphtheria—namely three to five years—were to be found. But amongst the scholars in three other schools, having collectively an average attendance of 307 pupils, there had been a considerable number of absentees during the period in question, and in no less than fifty-seven instances was some form of sore-throat assigned as the cause of the absence. In one of these three schools the convalescents were examined, and five cases of well-marked diphtheritic

paralysis were discovered ; indeed, in one case the tardy recovery of the child had led to her being taken to a metropolitan hospital, where the diagnosis was "paralysis after diphtheria."

Owing to the fact that the fatal attack which led to the investigation had commenced three days after one, and two days after a second ball for tenants and servants, at both of which the young man had been present, and which had included certain of the school teachers and monitresses amongst the guests, these school officials were also examined, and, quite apart from histories of sore-throat, which in two cases had led to a temporary absence from school, it was evident from the condition of the fauces in some of the teachers that they had recently suffered from acute throat mischief.

The second of the two balls was densely crowded ; the atmosphere, indeed, is stated to have been intensely oppressive. And it transpired further that the young man in question had habitually suffered from sore-throat ; that when in town during the preceding London season he had constantly been under treatment in consequence, and that on the evening of the second ball he was so ailing that he avoided taking part in the festivities.

Possibly some exposure to faulty sanitary circumstances may have had concern in a recurrence of the young man's habitual throat ailment ; but, however this may be, it seemed clear, as the result of my investigation, that unrecognised diphtheria had for some months been prevalent in the village ; that the guests at the entertainments included persons suffering from

trivial forms of the disease; that the atmosphere of the apartment in which the company were assembled was largely contaminated with the exhalations of those present; and it was further probable that the fauces of the patient in question were in precisely that condition which would fit them to receive the diphtheria contagion. In short, the circumstances were just such as might well have favoured the cultivation and operation of the poison in a specially virulent form.

Two other questions call for brief notice at this stage. The first has to do with the fungoid origin, so-called, of diphtheria. The association of diphtheria with dampness has often involved its association with mould and fungoid growths; and the co-existence in tissues of the human subject of low forms of vegetable life and of pathological processes, has more than once led to the belief that the development of certain forms of fungi might have causal relation to diphtheria. These views have been prominently set out by Dr. W. Michael Taylor, in a paper entitled, "Diphtheria in connection with Dampness and Mould Fungi," published in 1887,¹ in which he contends, amongst other things, that the essence of diphtheria consists in fungoid vegetation, that common moulds in a non-pathogenic condition can be made to grow in animal tissues, and that innocent forms of mould may acquire, in noxious media, toxic properties. Such investigation as has been made into the intimate pathology of diphtheria since that date, whilst

¹ *Transactions of the Epidemiological Society of London.* New Series, vol. vi. ; session 1886-1887. Shaw & Sons, E.C.

it has gone to confirm the view that the disease is due to the operation of a specific micro-organism, has, so far as I am aware, afforded no indication of any relation between this organism and fungoid growths.

The second question relates to the aerial diffusion of diphtheria. This disease, in common with the other specific fevers, is communicable from person to person through the medium of the air; but the term aerial diffusion, when applied to any infectious disease, tends to become limited to the transport for considerable distances through the atmosphere of the specific contagion in question, in much the same way as smallpox has been shown to spread from hospitals in which acute cases of that disease have been aggregated.¹ Dr. Hubert Airy, in a paper which he read before the Epidemiological Society of London in 1881,² has suggested that the infection of diphtheria may sometimes be conveyed by wind, and even by wind currents of considerable velocity. In this latter respect his observations as to diphtheria differs from those of Mr. W. H. Power as to smallpox, for, in so far as the meteorological conditions which favour the aerial diffusion of smallpox are understood, it is rather absence of wind than its obvious presence that favours any such diffusion of the infection as admits of recognition. Since the date when Dr. Airy collected the very interesting materials on which

¹ See Mr. W. H. Power's observations on this subject in the *Annual Reports of the Medical Officer of the Local Government Board for 1880* [C—3290] and for 1884 [C—4516].

² *Transactions of the Epidemiological Society of London*. New Series, vol. i.; session 1881-1882. Shaw & Sons, E.C.

his paper is so largely based, our knowledge as to the beginnings of diphtheria in and through a series of hitherto unrecognised cases of sore-throat, has been largely added to, and the remoter origin of diphtheria prevalences has been traced with much exactitude to sources which were then by no means generally apprehended. Whilst, therefore, no limit can as yet be assigned to the conditions, as to distance or otherwise, under which the diphtheria contagion can travel through the atmosphere and yet retain its potency for harm, it is pretty certain that many occurrences of diphtheria which some years ago might with plausibility have been held to be due to an aerially transmitted infection, would now admit of a different explanation. I would add that, so far as my own observations have gone, the diphtheria contagion rather resembles typhus than smallpox in regard of its little liability to produce disease after being subjected to conditions such as are involved in transmission by wind currents.

CHAPTER IV

FROM time to time I have incidentally referred to milk in connection with the causation and diffusion of diphtheria. The subject is one of the most instructive in the history of modern etiological research, and its importance is the greater, because its pursuit has afforded a leading clue to a body of valuable facts as to the relation of diseases in the lower animals to the specific fevers affecting the human subject.

In an inaugural address which I had the honour to deliver before the Epidemiological Society of London in 1887,¹ I have already traced the early history of this branch of work. I there drew attention first to a paper by Dr. Michael Taylor, which appeared in the *Edinburgh Medical Journal*, May 1858, on "The Infection of Fever by Ingesta," in which the author suggested that an outbreak of a fever, which we now know must have been enteric fever, was due to specific contamination of milk derived from a dairy where that fever prevailed. This report received but little publicity. It was followed in

¹ Inaugural address "On the Progress of Preventive Medicine during the Victorian Era." *Transactions of the Epidemiological Society of London*. Vol. vii. Session 1887-1888.

1870 by Dr. Ballard's well-known report on a prevalence of enteric fever in Islington. This report, which was, at the time, aptly characterised as "a masterpiece of medical logic," demonstrated conclusively that the diffusion of the disease was due to a special milk-service. In August of the same year Dr. Michael Taylor recorded, for the first time, an occurrence of scarlet fever in connection with a milk-service, and since that date a considerable number of outbreaks of both the diseases named have been found to be in causal relation with milk supplies.

But it was not until 1878 that proof was obtained as to the dissemination of diphtheria along with milk, and to Mr. Power belongs the credit of being the first to submit any conclusive evidence to that effect. The occasion to which I refer was a prevalence of diphtheria in North London¹ in the early half of the year 1878.

The disease had mainly prevailed in Kilburn and St. John's Wood, and it had locally been styled as either diphtheria or diphtheritic sore-throat. The area attacked was, for the purposes of the report, divided into an inner and an outer circle of nearly equal populations, and the maximum incidence of the disease was experienced in the "inner circle." During the fifteen weeks, March 9th-June 15th, 98 households were invaded within the inner circle, the attacks in individuals being 230 and the deaths 30 in number; whereas from the outer circle

¹ *Report to the Local Government Board on an Epidemic Prevalence of Diphtheria in North London*, by Mr. W. H. Power. Issued December 10th, 1878.

the only invasions that could be heard of had to do with 20 households, 34 persons, and 8 deaths. In point of time, there was also a special incidence of the disease. Thus, out of a total of 118 invaded households, no less than 78 got their first attacks in the four weeks ending May 25th; 70 of these households being within the inner circle. Indeed it became obvious, from the facts ascertained, that "in this history of the prevalence of throat illness there [was] question of some factor strongly circumscribed in area and operative during a very limited time."

In seeking for this factor it became necessary to exclude such circumstances as school influence, water supplies, the spread of infection from person to person, the faculty of development out of antecedent throat illness, and the like. An unwholesome condition of sewers did, however, at first sight, appear to be concerned in the diffusion of the disease. The area coming under any such influence was a portion of the inner circle referred to in the report as the "special sewage area," and it was ascertained that throughout the outbreak there had been a marked excess in the incidence of the throat illness on this area as compared with the remainder of the district involved in the epidemic. Indeed, if this had been all the evidence obtainable upon the facts of the outbreak, it would have looked as if there had been "a real relation between the circumstances of the special sewage area and the incidence of the throat illness"; in fact, Mr. Power would not even now deny that these circumstances may have had some

secondary and subordinate place in the causation of the disease.

During the great outburst in May, when no less than 186 fresh attacks occurred, milk came under suspicion ; and although, as Mr. Power says, he then "looked on the relation of the throat illness to milk as improbable," the matter was exhaustively inquired into, and the main facts ascertained were as follows :—

Two wholesale milk businesses came to require particular consideration ; they were both in the hands of one proprietor, referred to as Mr. X, and they consisted of cowsheds on premises at Kilburn, to be styled Dairy X¹, and of a dairy farm at Muswell Hill to be termed Dairy X². Of some 80 "barn-gallons" (about 160 ordinary gallons), daily yielded from Dairy X¹, 61 were distributed by Messrs. A and B, two independent vendors, much smaller quantities being served out by other milk vendors. Now, within the "inner circle" of the epidemic area, 473 households supplied with milk by Messrs. A and B were invaded at the rate of 143 per thousand, whereas 2227 households supplied from other dairies—including some who got milk from Dairy X¹—were only invaded at the rate of 13 per thousand. On the "outer circle" the incidence of the disease on the same two classes of households was at the rate of 60 and 5 per thousand respectively. And, on extending inquiry to the district which has been termed the "special sewage area," it was found that, whereas 430 households supplied by Messrs. A and B had been invaded at the rate of 148 per thousand, the incidence of the disease on 1870 house-

holds supplied by other milkmen—including again some who got milk from Dairy X¹—had been only at the rate of 11 per thousand. “There is now seen,” says Mr. Power, “in the facts of the milk-supply of the special sewage area a reason, apart from any question of sewer circumstances, for the special incidence of throat illness therein observed.”

The relation between the incidence of the throat illness and the milk-service, as regards time, was next investigated, and the information obtained on that point is summed up as follows:—

“It thus appears that not only have customers of Messrs. A and B suffered as has been already ascertained, relatively and actually in excess of other people, but that these persons have borne almost the whole brunt of that outburst of throat illness which first attracted attention to the district, and which has been locally referred to sewer causation. From almost complete immunity during the five weeks ending April 13, customers of Messrs. A and B commenced to suffer in rapidly increasing ratio, until in mid-May they were invaded in one week at a rate of 70 per thousand households; after that date their rate of attack declined even more rapidly than it had arisen, and by mid-June had become almost *nil*.”

But there was throat illness within the area of this diphtheria prevalence before, during, and after the outburst referred to, and this apart from that which affected the customers of Messrs. A and B; and it was further evident that the milk which these vendors delivered

could certainly be acquitted of the introduction and early maintenance of the disease. Hence it became necessary to ascertain the facts as to throat illness in households not supplied by either of these milk retailers. Out of 44 such households which were invaded 17 obtained their milk from vendors (other than Messrs. A and B) who were also in part supplied by Mr. X, the remaining 27 being served from entirely different sources. Of the 17 households referred to as running chance of using Mr. X's milk, it was ascertained that 13 derived their supply from a Mr. M, who derived such milk as came from Mr. X, not from the X¹ Dairy at Kilburn, but from the dairy farm X² at Muswell Hill; and when the period antecedent to the outburst of May was investigated, it was found that such throat illness as prevailed had fallen "with exceptionally intense incidence upon the families who consumed milk distributed by Mr. M," whose supply included nine barn gallons derived daily from X² Dairy, this milk being distributed as much in the outer as in the inner circle. Owing to the circumstance that the X² farm milk formed but a small proportion of the supply delivered by Mr. M in an extensive business, the facts hardly admit of being set out in more precise form.

But, amongst other milk vendors who procured milk from Mr. X, was Mr. N. He received from X² Dairy a large portion of his total supply, namely "nine barn gallons" daily, and delivered it in Fortis Green and the neighbourhood, a locality several miles away, which suffered a serious prevalence of throat disease in April,

and as to which it could confidently be asserted that the mischief was not connected with the public sewers or with any of the then ordinarily ascribed causes of diphtheria, including personal communication of the healthy with the sick. In the neighbourhood in question 27 households were invaded, and of these 27 households 19 obtained their milk-supply from Mr. N, and 8 from other sources. And further, "of 17 households invaded during the first three weeks of the outbreak all but 3 were so supplied. And these three exceptions are noteworthy." In one instance the disease attacked a youth who was actually employed by Mr. N in his milk business; in the second it was this youth's own brother, living next door, who was attacked; and in the third case the sufferer was a girl who also lived next door to the youth employed by Mr. N. I may add that I am not without authority in so reading between the lines of this story, as to transfer the three "exceptional" households bodily over to the group getting milk from Mr. N.

"By itself," says Mr. Power, "the evidence tending to implicate the Muswell Hill [Dairy X²] milk that is afforded by examination of the circumstances of throat illness in and about Fortis Green, is not, it may be admitted, of very great strength. But taken in conjunction with that adduced respecting similar association at the same time of throat illness with the milk-supply (partly derived from Mr. X's Muswell Hill business) of Mr. M in St. John's Wood, it acquires much additional force. The facts that need to be insisted on are as follows: In two localities so widely separated, and so

utterly differently circumstanced (except in this one matter of X² milk-service), as St. John's Wood and Fortis Green, throat illness attacked, almost simultaneously, customers of retailers supplying the particular milk; continued to attack such persons with similar but moderate force for several weeks; and then, again simultaneously in both places, ceased to attack them."

It is further stated that other milk walks in which milk from Dairy X² was derived offered a similar experience, and the main facts are summed up thus:—

"(1.) Mr. X's milk, whether from Muswell Hill or from Kilburn, and in whatever locality distributed, has conveyed to customers of retailers distributing it throat illness. (2.) In regard of each business (Muswell Hill or Kilburn) the above relation of milk-service to throat illness was observed for a limited period only, that period beginning for one business only about the time that it ceased for the other."

I have set out the leading facts relating to the use of Mr. X's milk in tabular form—

[TABLE

TABLE No. XIV.
SCHEME OF MR. X'S MILK DISTRIBUTION

Sources of Milk.	Inner Circle.		Outer Circle.		Special Sewage Area.
	House- holds.	Invasions per 1000 house- holds.	House- holds.	Invasions per 1000 house- holds.	Invasions per 1000 house- holds.
Messrs. A and B (Dairy X ¹)	473	143	100	60	148
Other dairies (includ- ing some from Dairy X ¹)	2227	13	2600	5	11

The means by which this milk-supply became infective had next to be fully considered. And, as the result, it was found possible to set aside any chance of infection after milking, whether by water or other allied agencies, or owing to absorption of any infective matter from the air, or by any process involving human infection during the process of milking. But there remained the fact that the milk of cows from two distinct dairies belonging to one and the same owner had had concern in the prevalence of the diphtheria; and in the end, so strongly did the evidence point to the cow herself as being related in some way to the epidemic, that Mr. Power was compelled to consider whether there might not have been "risk of *specific* fouling of milk by particular cows suffering, whether recognised or not, from specific disease." Indeed, he was led, by a process of exclusion,

“to the surmise that actual cow conditions capable of affecting, directly or indirectly, the milk” might have brought about the results observed.

Having regard to the fact that the use of milk from Dairy X² had been found to have a definite relation to the early portion of the outbreak, and especially to the household invasions during the first three weeks of the prevalence, and to the further fact that during the greater portion of the main outbreak, and especially during the outbreak in the month of May, the milk from X¹ Dairy was ascertained to have been in even closer association with the incidence of the throat disease, it is important to bear in mind that the common ownership of these two dairies had involved, 1st, certain community as regards the food supplies to the cows; 2d, similarity in the arrangements controlling the reception and the removal of cows into and from the two dairies; and 3d, an occasional though unrecorded transference of cows from one dairy to the other.

It so happens that no recognised infectious diseases could be heard of as having existed amongst the cows, but the affirmation to this effect was distinctly not intended to have excluded minor ailments, such as would not have affected the milking of the cows. With the information available on this point it was felt that further explanation would be speculative only, and at this stage the inquiry was closed.

But the demonstration that the throat disease was brought about by the milk derived from these two dairies, and the inference that it was probably due to the

transference of some morbid quality attaching to one or more cows located alternately at Muswell Hill and at Kilburn, is, to some extent at least, borne out by analogy. Thus, we know that the milk of cows suffering from foot-and-mouth disease often leads to fatal results when it is given to young pigs, and I have also shown that there are conditions under which the diseased milk induces a disease in the human subject which can hardly be regarded as other than specific.¹ Mr. Power also, in a paper submitted to the Pathological Society² a short time after the occurrence of the North London epidemic, has pointed out that there is a parallelism between certain diseases affecting both man and the bovine race; as, for example, is the case in vaccinia, which is *ejusdem generis* with human smallpox; in tubercle, and in anthrax.

The next occasion when diphtheria was found in association with a milk-supply was in 1882, when a sudden outbreak of that disease occurred at Devonport. The circumstances were investigated by Dr. Parsons.³ In all, 31 persons were known to have been attacked; they lived in houses of a superior class, and were scattered over widely different parts of a borough containing some 49,000 inhabitants; two of the attacks

¹ Report by Dr. Thorne Thorne into "The Effect produced on the Human Subject by the Consumption of Milk from Cows having Foot-and-Mouth Disease." *Report of the Medical Officer of the Privy Council for 1869*. [C—208] 1870.

² *Transactions of the Pathological Society of London for 1879*.

³ *Dr. Parsons's Report to the Local Government Board on an Outbreak of Diphtheria at Devonport*. Eyre & Spottiswoode, East Harding Street, E.C. 1883.

occurred in the early half of November, and these were followed, after an interval of a fortnight, by 29 others in December; the whole of the 29 persons attacked in December received their milk-supply from one particular dairy, and no circumstance, other than this milk-service, could be discovered as common to either the localities or the persons attacked. But no data were available to show definitely how the milk became infective.¹

¹ It is, however, interesting to note that in 1888 diphtheria again became epidemic in a limited portion of Devonport, the occurrence being reported on by Mr. Joseph May, Jun., the medical officer of health. He explains that the disease was sudden in its onset, and appeared simultaneously in several different places; that 61 attacks, of which 17 terminated fatally, occurred between August 5th and 17th, and that inquiry as to its cause indicated that "some morbid influence acting in a limited area and for a limited period" had been in operation. None of the conditions to which diphtheria was then commonly assigned, including infection from antecedent cases, afforded any explanation of the occurrence, but suspicion as to milk-supply was aroused. The particular supply in question was, it is true, largely resorted to in the locality under consideration, but the incidence of the disease on consumers of it went beyond anything that could be explained by reason of the area and amount of the milk business. In the case of 50 out of the 61 persons attacked detailed inquiry became possible, and 47 out of the 50 were found to take the milk in question. So also, all the 35 persons first attacked, in point of date, received this milk. In two of the 35 cases milk was also partly obtained from a second dairy to be referred to. No evidence could be found of any disease "of a diphtheritic character" amongst the employés of the dairy farm from which the milk was derived, but with the assistance of a veterinary surgeon careful examination was made on August 17th, not only of 28 cows belonging to the dairy farmer whose milk was under suspicion, but of 147 cows belonging to other owners. Of these 147, the veterinary surgeon reports that they were all found "in perfect health and presenting no indication of scars or scabs on the teats or udders"; and the same freedom from disease was found five days later as regards

In January of the following year, Dr. Cameron, medical officer of health for Hendon, reported to the Local Government Board a sudden outburst of diphtheria in the Hendon Ward of that urban district; the houses invaded were stated to be some of the best in Hendon by reason both of the social status of their occupants and of their sanitary circumstances; and, apart from a milk-service which had come under suspicion, no explanation of the occurrence appeared to be forthcoming. Mr. Power was instructed to inquire further into the circumstances.¹

The outbreak, which was spread over a period of four weeks—November 27th, 1882, to January 25th, 1883, involved some 60 attacks of diphtheria and allied throat illness in 28 households. By December 20th, 5 households had been invaded; this was followed by an interval of a fortnight; then ensued a sudden and fatal outburst 33 cows belonging to the dairy farmer whose milk was under suspicion, but located on a different farm. But on examining 28 cows on the implicated farm, the following facts were elicited: Eight cows gave indications of their having suffered from so-called “cow-pox”; and amongst the indications referred to were—“scab situated at the base of the teat, which on removal left a raw surface surrounded by a base of indurated tissue”; “ulceration of the teat . . . of a ragged character with a good deal of indurated tissue around the edges.” Sixteen cows were also found on the dairy farm referred to as the second one, from which two persons amongst those first attacked with diphtheria were in part supplied; and as to these it is stated that 6 were found giving indications of the same disease, and 1 “had an ulceration of the teat” which “corresponded in character” with the description given as regards the other cows.

¹ *Mr. W. H. Power's Report to the Local Government Board on an Outbreak of Diphtheria in the Hendon Ward of the Hendon Urban Sanitary District.* Eyre & Spottiswoode. 1883.

during the first ten days of January, and this was followed by a few later attacks. "Bringing into account all throat illness that could be heard of as having occurred in the village during the first ten days of January, which was the period dealt with by Dr. Cameron, there were 15 households invaded, all but 2 of which had obtained milk from the particular dairy that has been called in question. And in the same period it will be noted that, with the single exception of slight diphtheria occurring in the same house with enteric fever, all the definite diphtheria attacks and all the fatal cases occurred among customers of this dairy."

And, eliminating 4 household invasions which occurred after mid-January, when the infection was somewhat widely diffused in the district, only 3 households were invaded which received their milk from other sources than the particular dairy in question; and, as regards one of these exceptional houses, the throat mischief, which was mild, occurred (as was also the case in the exceptional attack earlier in January) almost simultaneously with an attack of enteric fever in another member of the family. Indeed, it is more than doubtful whether in these two exceptional instances diphtheria was in question.

"The total houses of the Hendon Ward are 905, of which number 86, or one-tenth of the whole, got their milk-supply from the particular dairy. In the complete period (end of November to end of January) dealt with, houses having this milk-service, and becoming invaded, amounted to seven-tenths of the total number invaded;

while in the limited period, 1st to 10th January, regarded as that of chief operation of a milk cause of diphtheria, such houses comprised nearly nine-tenths of the houses invaded. It will hardly be contended, I think, that an incidence on customers of the particular dairy seven to nine times greater than what under equal conditions would be the expected incidence is likely to have been the result of mere accident."

Another point deserves mention. It was noticed, and I believe for the first time as regards diphtheria, that there was a special incidence of the disease on those members of households which, whether children or adults, habitually consumed unboiled milk in large quantities, and that as regards such children the attacks were especially severe and fatal. On the other hand, it was also observed of certain families that habitually cooked this milk before consuming it, that their children wholly escaped the prevailing throat illness.

Whilst investigation was in progress concerning this diphtheria in Hendon, it was learned that milk from the implicated dairy was also supplied to a score or so of houses in Finchley; and inquiry being made of the medical officer of health for that place, it was further ascertained that amongst the consumers of this particular milk in Finchley, nearly a dozen persons had suffered from "sore-throat," all of it being of sufficient gravity to come under medical treatment, and some of it being described as either "diphtheria" or "diphtheritic." And not only so, but the Finchley cases were separated into two groups, one having occurred co-incidentally with

the November-December cases in Hendon, and the other with the January outburst in Hendon. Thus, "not only was there in this Finchley experience corroboration of the already inferred relation between the particular milk-service and diphtheria, but also there was strong suggestion that this milk had at two distinct periods, separated by an interval of several weeks, possessed the faculty alike in Hendon and Finchley of bringing about in persons consuming it throat illness of a diphtheritic sort."

Short of absolute demonstration, this milk-service must then be held to have been concerned in the prevalence of the diphtheria in Hendon. But how did it become infective? Dr. Cameron had, indeed, thought that sewage, bearing with it infective material from some antecedent case, might possibly, during a period of overflow, have got access to a pond the water from which had been used for certain of the dairy processes. This view was opposed to our experience of diphtheria production, and besides this another solution of the difficulty suggested itself. As to this Mr. Power writes :—

"Another possible explanation of infectiveness of the milk, viz. by causes operating through the cow herself, and enabling her to furnish milk capable of inducing diphtheria or throat illness in persons consuming it, seems to deserve notice for a reason that will now appear. There is abundant evidence that shortly before the outbreak of diphtheria in Hendon the milk distributed from this particular dairy was ropy or stringy. Especially was this the case on the 1st and 2d of

January, four to five days before the simultaneous occurrence of multiple cases of diphtheria among customers of the dairy. On these days several households either returned the milk to the dairy or made away with it on account of its ropiness, and some on account of its unpleasant taste or appearance. A similar condition of the milk, though much less noticeable, is believed by at least one family to have occurred towards the end of November. But at no time was this condition general, or at anyrate it was not generally noted, for I made special inquiry on this head. Seemingly, too, the ropy condition was most conspicuous in milk that had been kept over night.¹ The fact of the ropiness of the milk was early brought to the notice of Dr. Cameron by persons referring illness to it, and no doubt this abnormal condition of the milk did much to call attention to association of the milk-service with occurrence of diphtheria. It is indeed difficult to resist suspicion that ropiness of the milk and its ability to cause diphtheria may have been in some way related to each other." This "ropiness," it may be added, is generally held by persons acquainted with bovine diseases to be due to some condition of the cow herself, and even the dairyman who was in question on the occasion related, was inclined to ascribe it to improper feeding, the result of carelessness on the part of his cow-man. But on January 7th, when the cows were examined by a veterinary surgeon, they were pronounced free from disease. "Upon this evidence about the cows" Mr. Power offers

¹ See p. 173.

no comment beyond remarking that "these assurances might be entirely comforting but for a growing misgiving to the effect that ailments of animals, so trivial as to be disregarded or even unnoticed by people about them, may have larger concern with occurrence of specific disease in the human subject than has heretofore been thought likely."

Twice had a similar stage been reached. Attention was now somewhat generally drawn to the question of milk-diphtheria, and during the next few years a number of instances were reported in which milk was held to have been in causal relation to that disease. Amongst these instances few were of greater interest than an occurrence of diphtheria at York Town and Camberley in October 1886—a prevalence which was also investigated by Mr. Power.¹

York Town and Camberley had, at the date of the inquiry, a population estimated at some 3000, in which the better classes, both military and civil, were strongly represented. In the three and a half weeks, October 8th to 31st, no less than 88 attacks of diphtheria and 52² of lesser throat illness, 140 in all, occurred in 57 households; 90 per cent of the total attacks taking place in the eleven days October 8th to 18th. For the purposes of inquiry into the cause of the outbreak a defined area, involving 176 houses, and including all which were

¹ Mr. W. H. Power's *Report to the Local Government Board on Diphtheria at York Town and Camberley, in the Farnham Rural District*. Eyre and Spottiswoode, East Harding Street, E.C. April 1887.

² Five of these attacks had been regarded as scarlatina.

suspected of having suffered diphtheritic invasion, was chosen with a view to differential examination; and it soon became clear that, from amongst the three different methods of sewerage and drainage, and from amongst the varying sources of water supply which came in question, no indication as to cause could be elicited. Indeed, there was no sufficient evidence to show the dependence of the diphtheria outbreak upon any such local conditions as had heretofore been commonly regarded as concerned with the causation of the disease.

But some suspicion as to milk-service had arisen very early in the outbreak; indeed, there was a very general local belief that the epidemic was due to milk, and inquiry was extended in that direction.

The 176 households within the area referred to were found to divide into 94 taking the particular milk-service which had come under suspicion, and 82 which were otherwise supplied. Taking the whole period of the epidemic, it was found that, of the 94 households served by the particular dairy 48 were invaded with throat illness, 81 of the attacks being regarded as diphtheria and 43 as some lesser throat mischief, or 124 in all; there were also 15 deaths. Of the 82 households getting milk from other sources only 9 were invaded, there being 6 cases of diphtheria, 10 of milder throat mischief, and 1 death. There is thus a conspicuous difference in the incidence of the epidemic upon houses having the one and the other milk-service. And there was also a special incidence in point of time, for in all the 48 invaded houses receiving the special milk-supply

the diphtheria and the throat illness commenced in the ten days October 8th to 17th ; and of the 124 attacks in those 48 houses no less than 116, or 93·5 per cent, took place in the same limited period. Whereas, in so far as recognised diphtheria is concerned, in the 82 houses not taking the particular milk all the invasions but one took place at a later date, and the one exceptional attack was found to be referable to an antecedent attack.

Differential rates cannot, unfortunately, be stated ; for, as Mr. Power points out, whilst all the houses supplied by the particular dairy came under judgment, the 82 other houses within the area by no means included all those which derived their milk-supply from other sources ; and thus no valid comparison of incidence was possible. But whilst this is the case, "there is enough in the facts given about the vastly greater incidence of diphtheria upon houses getting their milk from the particular dairy to indicate a very strong probability of a causative relation between the milk and the disease ;" and it is evident that the "speciality of incidence *qua* milk" was very different from any other incidence that could be made out.

I have already pointed out, in connection with the Hendon outbreak, that a distinct relation had been found to exist between the amount and the severity of the diphtheria, and the amount of infective milk consumed ; and a somewhat similar point seemed indicated in the York Town and Camberley case when it was found that, if the customers of the suspected dairy were divided into two classes—one the "better class," consisting partly

of the military and partly of the civil community, and the other the cottagers and small tradespeople—the family invasions in each instance amounted on the better classes to 84 per cent of the total, and on the cottager classes to 22 per cent only.

In some milk-epidemics, and notably when either enteric fever or scarlet fever has been concerned, there has appeared to be a larger incidence of the disease on those who have habitually consumed cream, as compared with those using milk from which cream had been abstracted, and I have thought that this difference might possibly have been due to the circumstance that specific particles were entangled—so to speak—and then carried to the surface during the process of cream formation. But the case now under consideration suggests another explanation of the special incidence of the disease on the better classes consuming the milk under suspicion.

And it must first be observed that in York Town and Camberley not only was the milk supplied by the different cows in the particular dairy mingled so as to secure general uniformity of quality on each of the four several milk-walks, but no skim-milk was served out by the dairyman to any of his customers; and hence it became impossible to explain, by differentiation as regards quality of milk, the varying incidence of the disease on the two classes of customers. But whilst the milk delivered to the better class households had averaged somewhat over five pints per household daily, it had amounted to less than one pint amongst the other class.

And not only did children in the better class households suffer eight times as much as in the poorer households, but even adults amongst the better classes suffered five times as much as their poorer adult neighbours. So also, whilst "escapes" amongst persons of all ages in invaded households were as 3 to 1 in the better class houses, they reached 16 to 1 amongst the poorer class.

"The distinction in extent of invasion, whether in households or individuals, in children or adults, clearly has borne *some* relation to the amount of milk consumed. But what then was the *nature* of the relation between *amount* of milk and *quantity* of diphtheria? Did small consumption of milk by poorer persons involve only a swallowing by them of few and small doses of a diphtheria poison contained in the milk, whereas large consumption of milk by the better class involved swallowing of many and large doses of the same poison? Or was *quantity* as quantity a less important element in the result than some *quality* obtained by the larger quantity, and not by the smaller quantity of the milk? And if so, how far may such increased harmfulness of the larger milk-supply to a house have been obtained at a period *subsequent to the reception of the milk into the houses* of the better and poorer sorts respectively?"

Inquiry into considerations of this sort elicited the information that, whereas after babyhood the poorer class only used milk in fractional quantities, and this generally in tea or coffee, the more well-to-do were, in very numerous instances, both in childhood and during

adult life, found to consume uncooked milk both frequently and in large quantity. And, in this way, "it was seen that the differences in the amount of milk consumed involved, *inter alia*, differences of *number of opportunities* for infection in one and the other class;" but how far the special incidence of diphtheria on the better class population had to do with the greater amount consumed, or with the multiplication of milk-drinking acts, could not be measured. Neither is there any evidence to indicate to what extent the use of milk in tea and coffee only may have afforded some such immunity against infection as that which had elsewhere been associated with the use of cooked milk only.

As to the use of cream, it is true that households where milk was kept for "setting" cream were heavily smitten, but they were also, almost without exception, households where large quantities of milk were consumed. And, on the other hand, skim-milk was found to be by no means free from suspicion in regard of a heavy incidence of diphtheria. But the use of either cream or skim-milk involved *storage of milk* by householders; and there seemed reason to believe that this keeping of milk before use, a practice almost exclusively resorted to in the better class households, had more concern in the special incidence of the disease on the more well-to-do than any other circumstance. How far this result may have been due to the increased opportunity afforded by milk-storage for the development or multiplication of specific organisms of disease did not

then appear. Dr. Klein has, however, since that date, shown that this is the true explanation.¹

But it is particularly noteworthy that had it not been for the test of milk-infection afforded by the better class customers in this case, the ability of this milk-service to cause diphtheria would, in all probability, have escaped attention ; and it is more than probable that the clue to the true cause of diphtheria is often lost by reason of the limited amount of mischief induced by the consumption of an infective milk-service, where the milk is consumed in comparatively small quantities at somewhat distant intervals, and without any opportunity for increase in amount and in infectivity of the material cause of the disease such as is involved in storage.

The York Town and Camberley epidemic left as still unsolved the question as to the means by which the milk had acquired its infective property.

Mr. Power, however, discusses the question under a number of headings. He shows that no theory of infection of the milk directly by human agency, or of infection due to unwholesome conditions at the farm, afford any solution of the difficulty. He next refers to the cows themselves as agents in infection of their milk in one of two ways. The one regarded the cows as agents merely in transmitting *debris* of human diphtheria from water which they had consumed to the milk, the cows themselves suffering no illness or inconvenience in the process ; but this hypothesis had also to be set aside. According to the second hypothesis, says Mr. Power,

¹ See page 192.

“it would have been enough that one or other of the cows in milk in the early part of October, or a cow or cows newly coming into use for the dairy at that date, should have been attacked (say towards the end of September) by some infectious malady akin to diphtheria; that the material cause of such malady, becoming multiplied in the body of the cow, should have pervaded her system; and that at some stage of her malady (say in early October) this multiplied infective material should in due course have found its way into her milk, to be of necessity distributed to all the dairy’s customers.” Against this theory is the fact that seemingly not one of the cows at the farm had been ill at all. On the 13th of October a veterinary surgeon certified all the cows as in good health, and on the 21st of the month a second veterinary authority could not detect any disease among them; two only of the cows showing at that date the slightest signs of “chaps” on their teats. For the hypothesis, on the other hand, there is little to be said, unless it be allowed to regard the business of calving and cleansing as perhaps involving some unnoticed process morbid in its nature; and then one appearance of parallelism is indeed discernible, namely, that two cows, calving on the 17th and 23d of September respectively, began to supply milk for the dairy just about the time that the milk distributed from it commenced to infect people with diphtheria. As matter of fact, at the beginning of November one cow at the farm (not newly calved), which had suffered “chapped teats,” still had at the site of a “chap” a scab or crust not unlike those

which at a later stage of their malady had been observed to replace ulcers on the udders of certain Hendon cows.

In the meantime occurrences of diphtheria were multiplying, which could not be accounted for by infection from antecedent cases, or by any known defective sanitary circumstances; and the idea that this disease in the human subject was probably related to some disease in the lower animals was rapidly gaining ground. The subject had for a number of years received attention in the Medical Department of the Local Government Board, and by other observers in this and foreign countries; and Dr. Airy, in his summary report of 1880, referred to the endeavour which he had made "to ascertain if there had been any noticeable disease among cattle, horses, sheep, pigs, dogs, cats, poultry, or domestic vermin." His results were mainly negative, but he proceeds: "The only instance in which the circumstances were such as to raise suspicion of diphtheria being caught from lower animals was at Felstead, in Essex, where, just about the time when diphtheria broke out in the village, some sheep, suffering from throat disease of an unusual and fatal character, were herded close to the little school which was the scene of the outbreak. The almost simultaneous seizure of the two children first attacked appeared to point to one common source of infection, and there was no history of previous diphtheria with which both children could have come in contact. The evidence was not conclusive. In view, however, of recorded instances of the communication of diphtheria from man to the lower animals, such facts as this at

Felstead deserve to be noticed, as suggestive of the possibility of the reverse process of infection."

Adverting at that date to this phase in the natural history of diphtheria, Dr. Buchanan, F.R.S., wrote :¹ "On review of the whole circumstances observed by himself and recorded by others, Dr. Airy would require, for an understanding of the cause of diphtheria, a hypothesis of some specific living organism, having a life history of its own, not only in the diseased human body, but beyond the human body altogether. Of the presence of a micrococcus in the tissues of the body in cases of diphtheria, and of the production of a disease resembling diphtheria by the inoculation of healthy animals with diphtheritic material, we have already sufficient evidence ;² and some pathologists are disposed to affirm the absolute identity in nature of the disease in the animal with that in the human subject, and the necessary participation of the micrococcus in the transference of this disease from the one to the other.³ Now Dr. Airy notes, in the customary distributions of diphtheria according to place and time, certain specialities which, while they have concern for the practitioner, have a further and more important interest, as they may aid hereafter

¹ *Report of the Medical Officer of the Local Government Board for 1880*, pp. iv. and v. [C—3048], 1881.

² See, on this subject, Dr. Sanderson's paper in *Report of the Medical Officer of the Privy Council and Local Government Board* (New Series), vol. iii., where the *exclusive* ability of material derived from a case of diphtheria to produce diphtheria on inoculation into a healthy animal was represented as open to question.

³ See Oertel, Art. "Diphtheria," Ziemssen's *Cyclopaedia*, vol. i.

in the identification, in its external habitat, of the organism which seems to be thus intimately associated with the disease. Meanwhile, it is intended to make use of such opportunities as may arise for gathering further experience respecting this obscure disease." And, in pursuance of the line here indicated, a memorandum was prepared by Dr. Buchanan in 1884,¹ instructing the medical inspectors within his department, that in any local inquiries about diphtheria they would note, *inter alia*, any experience of apparent relation of the disease "to milk and to ailments, however trivial, in cows; the customs of the district as to animals bred, kept, and used as pets, especially noting any obscure diseases in lower animals related in any way to prevalent diphtheria in the human subject."

In 1886 a report on experiences of diphtheria, especially in its relation to lower animals,² was submitted to the Local Government Board by Dr. George Turner, medical officer of health for the East Herts combined sanitary districts. Dr. Turner's attention was directed to the subject in 1882, when, on dissecting the trachea of a pigeon in the expectation of finding strangles (*sclerostoma syngamus*), he saw the whole windpipe covered with a well-marked consistent membrane. The fauces of certain healthy pigeons were inoculated with this membrane, and a disease of a similar character resulted, showing "that the disease was communicable"; and it

¹ See Appendix No. I. p. 227.

² *Report of the Medical Officer of the Local Government Board for 1886* [C—5171], 1887.

was further noticed that in one case the affection spread through the nostrils up on to the eye of the pigeon. In 1883, when diphtheria was prevailing in the village of Braughin (Herts), it was ascertained, amongst other things, that the first cases were connected with a farm on which fowls were dying of a disease seemingly identical with that which had been recognised in pigeons. Much the same experience was obtained at Aldershot in 1886, and in other places turkeys and pheasants were also stated to have been similarly attacked. In one case diphtheria broke out in the home of a man who had bought a chicken at a low price because it was expected to die of "this diphtheria-like disease." And a further stage was reached, when it was found that the disease to which Dr. Turner gives the name of "fowl-diphtheria" could be produced as the result of inoculation with diphtheria membrane taken from a child's throat.

Other observers had recorded somewhat similar experiences. Thus, Dr. Robinson, medical officer of health for West Kent, described in 1888 a similar disease amongst fowls which followed on diphtheria in the human subject, and which was associated in the fowls with "membranous patches in the throat and windpipe." As to the method by which the disease was communicated, he writes to me: "It was during the boy's convalescence that the first fowl suffered. The boy himself described to me very clearly how he had leaned against the fence of the pen in which the fowls were kept, and expectorated therein."

As to turkeys, I would refer to a communication in the *Journal de Santé* of December 23d, 1888, where some account is given by Dr. Bild of the first occurrence of diphtheria which, after thirty years of practice, he had seen in the principal town of the Greek island Skiatos. It is stated that in June 1884 Dr. Paulinis was called to see several children who were simultaneously affected with diphtheria, and of whom 5 died. The epidemic invaded the whole town, and in five months 125 persons had been attacked and 36 had died. The cause of this sudden invasion being investigated, it was ascertained that in the locality where the prevalence commenced was a courtyard occupied by turkeys recently brought by boat from Salonica. These turkeys had exhibited false membranes in the roof of the palate, and all had died except one, and in this instance the bird is reported to have been still suffering from paralysis of its feet, which incapacitated it from walking.¹

Suspicion has also been raised as to the existence of some relation between diphtheria in man and in certain other of the lower animals, the evidence being especially abundant in the case of horses, sheep, and cats. But whilst a number of the experiments made on this subject lack the precision necessary to a scientific

¹ "Animals into which small doses [of a special chemical substance derived from pure cultures of the diphtheria bacillus] are injected are frequently attacked by diphtheritic paralysis."—*Bacteria and their Products*, by Dr. Sims Woodhead. London, Walter Scott. 1891.

investigation, there are others which are of a different character. Amongst the latter class of experiments are some recent ones relating to cats, and in this connection I would point out that cats have in the opinion of many observers for a long time held a somewhat prominent position in reference to this question of the relation of human diphtheria to the lower animals. Dr. Turner in 1883 summarised some of the information available, and he quotes a number of instances in which diphtheria in man has coincided, in point of time, with the occurrence amongst cats of a throat disease attended by such symptoms as "swelling of the neck, foul discharge from the nostrils, and running at the eyes." In most instances which have been recorded of this sort, the disease in the cat would appear to have been subsequent to human diphtheria; but this has by no means always been the case. Unfortunately, when the cat disease was secondary, *post-mortem* examination has rarely been resorted to in order to ascertain the precise nature of the ailment. At Petersfield, in Hants, Dr. Turner found "the evidence very clear" as to the communication of disease to the cat by certain children suffering from diphtheria; the cats in a row of houses in which the diphtheria had been prevalent were found "to be ailing, their throats were swollen, and there was discharge from the eyes and nose." He also records a case from Moulton, in Suffolk, in which similar disease in the cat is stated to have followed on the animal being fed on food which it shared with a child suffering from diphtheria. I would also refer to some experiments made

by Dr. Charles J. Renshaw.¹ Having seen that the stomach and bowels of a cat were duly emptied, Dr. Renshaw administered to the animal some diphtheria membrane taken from the throat of a living patient. The result was that the cat died on the seventh day, and *post-mortem* examination revealed "patches of diphtheritic membrane on the mouth, fauces, and lining of the bronchial tubes, also on parts of the bowels." A second cat was dealt with in the same way, and it died on the thirteenth day, when "the diphtherite" was found "lining the whole mucous tract, partly in patches, from the mouth to the anus."

Amongst instances in which the attack in the human subject is believed to have followed on disease in the cat, I would recall an incident referred to by Dr. Bruce Low in a report on an epidemic of diphtheria at Enfield, and it is the more interesting because the cat disease was in all probability first contracted from the human subject, then communicated from cat to cat, and then again from the cat to the human subject. Much of the diphtheria in Enfield was found to be associated with attendance at the elementary schools and with a particular milk-service; but as regards the incident referred to, both these sources of infection could be eliminated.

"The following," writes Dr. Low,² "is an illustration of the possible connection between diphtheria in children and in cats: A little boy was taken ill with what turned

¹ *British Medical Journal*, January 3d, 1885.

² *Report of the Medical Officer of the Local Government Board for 1888* [C—5813—I], 1889.

out ultimately to be fatal diphtheria. On the first day of his illness he was sick, and the cat, which was in the room at the time, licked the vomit on the floor. In a few days (the child meanwhile having died) the animal was noticed to be ill, and her sufferings being so severe and so similar to those of the dead boy, the owner destroyed her. During the early part of its illness this cat had been let out at nights in the back yard as usual. A few days later the cat of a neighbour who lived a few doors farther off was noticed to be ill. It had also been out in the back yards at night. This second animal (which, however, recovered) was the pet and playfellow of four little girls, who, grieved at the illness of their favourite, nursed it with great care. All four girls developed diphtheria, their mother being convinced that they got it from the cat—and indeed no other known source of contact with infection could be discovered. It is easy to imagine cats catching an infectious illness like diphtheria when we remember how often milk and other unused food from the sickroom is given to the cat, or by some people thrown out in the back yard for the benefit of the neighbours' cats, if they have none of their own. It is a frequent occurrence to see children carrying cats in their arms, and even kissing them. It is obvious that if the cat were ill with diphtheria the children under such circumstances would almost inevitably contract the disease."

Dr. Klein, writing in 1889, states "that cats are really subject to an infectious disease occurring in association with human diphtheria ; that in the naturally

acquired disease of the cat the affections of the lungs, liver, and kidney, in prolonged cases, are very marked ; and that the affection of the kidney is identical with that induced in cats alike by subcutaneous inoculation with diphtheritic membrane and with cultures of the diphtheria bacillus. In a word, this disease casually occurring in the cat is very similar to the malady artificially producible in that animal by inoculating it with human diphtheria material.¹ Hence arises a very strong sugges-

¹ Extract from Dr. Klein's paper in the *Report of the Medical Officer of the Local Government Board for 1889*, pp. 159, 160 : "From a culture on Agar directly derived from a human diphtheria membrane, the culture being nine days old, three cats were inoculated into the subcutaneous tissue of the groin, and on the following day three additional cats were inoculated with the same culture.

"All six showed, after twenty-four hours, swelling in the groin at the seat of inoculation, and were slightly off their feed. After three days the swelling in the groin was, in each case, considerable, the animals remaining quiet and off their feed. Two were found dead at the end of five days, two others after ten days, and the last two after eleven days. The *post-mortem* examinations showed—extensive hæmorrhage in the subcutaneous and muscular tissues, with oedema in the groin, abdomen, and thigh ; the tissue in many places discoloured, appearing as if split up by clefts into lamellæ, and almost gangrenous. The *lungs* and *spleen* were congested, the *liver* slightly congested. Both *kidneys* showed enlargement, and as well a remarkable change which consisted in almost the entire cortex being gray and fattily degenerated, the medulla appearing by contrast much congested. When examined with a lens the cortex appeared composed of numerous whitish streaks separated by the reddish Malpighian corpuscles ; near the capsule the whole tissue was uniformly white. This condition was noticed even in the two animals that died first, *i.e.* after five days, and it was more pronounced in the other four animals. Under the microscope it was seen that in all the uriniferous tubules—particularly the convoluted tubules—the epithelium was swollen and fattily degenerated, or broken down into

tion that the above infectious disease occurring naturally amongst cats may in its turn be a source of human diphtheria."

In an early part of these lectures I alluded to the almost prophetic foresight of Noah Webster, who in 1800 wrote on the epidemics of former centuries, and hinted at knowledge of which we are only now possessing ourselves. I should do his memory some injustice were I not once more to recall his words. As was his wont, he reminds his readers of the influence of "violent earthquakes" and "other singular phenomena" in Europe and America during 1797, and he then tells of catarrh in England, and of the bills of mortality in the northern states of America being that year "swelled very high" by such diseases as "anginas." And in the same connection he states that "in England a pestilence among cats swept away those animals by thousands; that

a granular *débris*. In figures 38, 40, and 41 [see original Report] the aspect of such a kidney is well shown.

"Now it especially deserves notice that this condition of the kidney is extremely characteristic of diphtheria disease in the cat. Not only does it occur uniformly and in a pronounced degree in cats subcutaneously inoculated with diphtheritic membrane, but, as I shall proceed later to show, this same peculiar condition of the kidney occurs also in cats naturally affected with a curious infectious disease, which would appear to stand in intimate relation to human diphtheria. In this connection I need hardly call the attention of the reader to a fact well known to pathologists, namely, that in the human subject also the cortex of the kidney in diphtheria which has lasted many days or some weeks shows similar whiteness due to fatty degeneration."

The throat, it should be added, does not in this cat malady show ulcerations and membranes.

the "cat distemper appeared in Philadelphia" in June, that it was very fatal in New York, and that "in the course of the summer and autumn it spread destruction among those animals over the northern states."

It was in 1874 that the first report was issued by the Health Department of the State in this country on the micro-pathology of diphtheria, the subject being dealt with by Dr. Burdon Sanderson, F.R.S., in a report to the Medical Officer of the Privy Council and Local Government Board, on the "Pathology of the Infective Processes."¹ That report, like many of the observations following upon it, whether made in this country, on the continent of Europe, or in the United States of America, tended to associate the occurrence of diphtheria with certain micrococci. Indeed, it was not until Klebs and Löffler, in 1883 and 1884, succeeded, the former in discovering, and the latter in isolating and cultivating, the organisms now known as the Klebs-Löffler bacilli, that a definite organism, invariably associated with diphtheria, was identified from amongst a number of microbes present in diphtheria membranes. Löffler in 1887 next announced that, in addition to the organism identified with his name and that of Klebs, there occurred in diphtheria membranes another organism resembling it in many essential respects, but differing from it pathogenically; and to this organism he gave the name of *pseudo-diphtheria-bacillus*. And, further, it was shown that the Klebs-Löffler bacillus, though present in most cases of

¹ *Report of the Medical Officer of the Privy Council and Local Government Board.* New Series, No. iii. [C—1068—], 1874.

diphtheria, was so only in the superficial layers of the membrane, and could also be found in the pharyngeal mucus of many healthy children.

Dr. Klein, dealing with this subject in 1888,¹ and having given the results of Löffler's experiments with the bacillus, writes: "Having regard to these facts, especially to the limitation of the Klebs-Löffler bacillus to the superficial parts of diphtheritic membranes, to its presence in the normal human fauces, and to the pathogenic action on animals of this bacillus not being essentially diphtheritic, it is no matter for surprise that the view that this bacillus is the cause of diphtheria has come to be discredited by many pathologists and bacteriologists."

Some point of obscurity was evidently involved in this Klebs-Löffler bacillus, and Dr. Klein proceeded to experiment with it by means both of inoculations and cultivations. The results obtained are summed up in a report submitted to the Medical Officer of the Local Government Board in 1889.² When rodents or birds were used for inoculative purposes, no definite results were obtained, but it was otherwise with cats. "A definite infectious disease," says Dr. Klein, "can be produced on the cornea and conjunctiva of cats, by inoculation into these tissues of particles of diphtheritic membrane derived from acute cases of human diphtheria."

¹ *Report of the Medical Officer of the Local Government Board for 1888* [C—5813—I], 1889.

² *Report of the Medical Officer of the Local Government Board for 1889* [C—6141—I], 1890.

And further, "the muco-purulent discharge from, as well as the opaque tissues bordering on, the [induced] ulcer of the cornea will, when transferred to the scraped cornea and conjunctiva of fresh cats, set up in them the same disease. Thus, proof has been furnished that the induced disease in the cat is of an infectious nature."

Dr. Klein had also, in the earlier of the two reports referred to, drawn attention to the numerous statements which had from time to time been made "as to the presence in diphtheria of various species of microbes, and as to the etiological relations of one and another of them to that disease;" but he regarded the discoveries by Klebs in 1883, and by Löffler in 1884, as being the first trustworthy starting point in the progress toward knowledge of a bacterial cause of this dire disease. He also announced that in connection with his experiments with the Klebs-Löffler bacillus, he had himself discovered other and more minute bacilli, which he believed to be morphologically related to diphtheria. On this point he wrote as follows in 1889:—

"I have shown that, from the opaque cornea of the cat infected directly with human diphtheritic membrane, I have isolated a minute bacillus, which, except in the matter of size, corresponds to bacilli to be observed in large numbers in the membrane of human diphtheria; bacilli which, in morphological and many cultural characters, can only with difficulty be distinguished from the Klebs-Löffler bacillus described by other observers as present in diphtheritic membranes. Also, I have referred to another species of bacillus as occurring in

diphtheritic membrane, which morphologically and as regards cultural characters I considered as identical with the Klebs-Löffler bacillus; noting further that with cultures of this species (the Klebs-Löffler bacillus) I was not able to produce any positive results in the cat, whereas inoculation of cats with cultures of the particular small bacillus isolated by me yielded positive and severe results, identical with those obtained by inoculation of the diphtheritic membrane itself. In addition, I have pointed out that whereas this smaller pathogenic bacillus grows well on gelatine at and even below 20° C., the other larger and non-pathogenic species isolated by me would not grow at this temperature; and I have intimated that while *not* considering this larger bacillus as different from the Klebs-Löffler bacillus, I was disposed to regard the other and smaller bacillus as a distinct species."

In his further investigations, Dr. Klein, having got rid of microbes adhering to or superficially embedded in human diphtheria membrane—organisms which he regards as accidentally attaching to the membrane—gives the following description of stained cover-glass specimens of diphtheria membrane that had been subjected to this cleansing:—

"Here were noticed first of all the cylindrical forms, shorter or longer, straight or slightly curved, and characterised by a minute knob-like enlargement at one or both ends. Then were noticed (very numerous represented and forming smaller or larger clumps) cylindrical forms in each of which was a distinct terminal

dot deeply stained. These forms which, when crowded together, look at first sight not unlike streptococci, are when carefully examined seen to possess a faintly blue-stained cylindrical portion, at each end of which is a deeply stained largish dot (some of them possess more than two such granules) of purple or pink colour, and show therefore a segregation of their protoplasm. The granules in question are either spherical or distinctly rod-shaped, and the terminal element is often cylindrical and possessed of a swelling. In addition were found numerous clumps of the cylindrical bacilli adhering to tissue cells or completely occupying their interior. Also there were conical forms occurring either singly or as dumb-bells joined at their bases; these forms were found scattered amongst the rest or amongst the clumps. All these microbes belong to two species—the one the true diphtheria bacillus, and the other the organism which in my previous report I identified with the Klebs-Löffler bacillus. But to which of these species a given sample belongs cannot always be determined by mere examination of cover-glass specimens, since the resemblance of the one to the other in the matter of size, shape, and general aspect is a very close resemblance.”

But in Agar tubes these organisms manifested themselves as colonies of two kinds of bacilli, which are described as being, “as regards character, shape, aspect, mode of rapidity of growth of the colonies, almost identical.” On making further subcultures on gelatine, the two sets of bacilli could, however, be differentiated. One kind, which was discovered in 12 only out of 22

diphtheria membranes examined, does not grow on gelatine at ordinary temperatures ; but the other bacillus, which was found in *every one* of the 22 samples of diphtheria membrane, grows well on gelatine at 18° - 20° C., and this latter organism Dr. Klein identifies as the true diphtheria bacillus.

Another distinctive character of this bacillus deserves especial notice in connection with the experiences narrated as to milk-diphtheria. The Klebs-Löffler bacillus was at first supposed by Löffler not to thrive at temperatures below 22° C., and this habit of the bacillus was inconsistent with the provisional inference that certain features observed in prevalences of milk-diphtheria, and especially the marked incidence of the disease on persons who had consumed milk after its storage at the ordinary temperature of the atmosphere, were due to the development and multiplication of the organism during such process of storage. But the "true diphtheria bacillus," having been differentiated, was found by Dr. Klein to exist well and to thrive well at temperatures below 22° C.; indeed, milk inoculated with it and kept at an ordinary temperature, such as 18° - 20° C. (64.4° - 68° Fahr.), was found to be an excellent multiplying ground for the bacillus. "Such milk," says Dr. Klein, "as early as 2-3 days after inoculation shows numerous flakes of casein becoming gradually separated ; but at no time during experiment does the milk lose its fluid character. On examining a tube of such milk, after 3-5 days' incubation, by the culture test, *i.e.* by taking out a tiny droplet of this milk by the platinum hook and

rubbing it over the slanting surface of nutrient gelatine, there are noticed on this subculture medium, after several days at 19° - 20° C., innumerable colonies of the bacillus ; so that the multiplication of this bacillus must have been very considerable in the milk sample, though this had been kept only at 18° - 20° C."

And further, it is asserted that "when sterile milk is inoculated with the true diphtheria bacillus, and exposed to the higher temperature of 36° - 37° C. (96.8° - 98.6° Fahr.), the rate of multiplication of this organism is considerably less than in milk kept at 18° - 20° C."

Here then, doubtless, we have the explanation of those markedly different incidences of diphtheria, observed during the York Town and Camberley epidemic, upon persons using stored milk—as cream or skim-milk—on the one hand, and milk added to hot drinks—as tea, coffee, etc.—on the other hand.¹

On each occasion of milk-diphtheria to which I have referred there has been evidence, more or less precise, of some cow-ailment, so far trivial, it is true, as to be ignored by those versed in bovine diseases, but either affecting the physical properties of the milk, or being associated with some vesiculation, and later on with "chapping" and "scabbing" of the udder and the teats. From this aspect of the history of milk-diphtheria, I pass at once to certain further experiences obtained by Dr. Klein.

By further differentiation on the basis of the dissimila-

¹ See p. 174.

rity observed between the two organisms, hitherto included in the term Klebs-Löffler bacilli, Dr Klein has found that whilst the pseudo-diphtheria bacillus is incapable of producing in the cat any morbid condition resembling diphtheria, the organism to which he accords the name of *bacillus diphtheriæ* produces the diphtheria disease in that animal without fail. And in view of the evidence now before him, Dr. Klein found himself able to institute inquiry concerning the behaviour of milch-cows towards diphtheria. The results of this inquiry are told at length in the report of the Medical Officer of the Local Government Board for 1889, and they are summarised as follows by Dr. Buchanan :—

“Two milch-cows, in good health, inoculated subcutaneously at their shoulders with broth subcultures of diphtheria bacilli derived from a human subject, showed a swelling at the place of inoculation, beginning on the third day, increasing in size during the first week, and then becoming smaller. One of these cows, in the course of the second week, and the other in the course of the fourth week, became seriously ill, being until then in seemingly good health and yielding abundant milk; one died on the fifteenth day, the other was killed on the twenty-fifth day. Besides serious changes in the organs observed *post-mortem*, the tumours at each spot of inoculation were examined, and material was taken from them for microscopic and pathological study. The bacilli of diphtheria were found to have multiplied abundantly at the spot of inoculation, and these, transplanted into nutrient media, were able to form there

colonies of the same *bacillus diphtheriæ*, free from other forms of bacteria.

“It remains to tell the phenomena of the milk apparatus and of the milk in the two inoculated cows.

“On the fourth day in one cow, and about the same day in the other, while the cows were to an ordinary observer well and giving plenty of milk, small vesicles made their appearance on the cows’ udders, and these rapidly passed into pustules and crusted ulcers. Afterwards similar vesicles running the same course were found on one or more teats of each cow. Dr. Klein gives good reason, first, for believing that these sores were not the result of any accident, nor of the process of milking; and, secondly, for regarding the sores as really being local manifestations of a constitutional disease induced by the diphtheria inoculation. He then examines the lymph of the induced vesicles and pustules, and here ‘the *bacillus diphtheriæ* could be demonstrated unmistakably both in cover-glass specimens and by culture.’

“Next, with matters taken from the udder vesicles and pustules, on the day after the eruption had appeared on one of the inoculated cows, Dr. Klein proceeded to the inoculation of two calves. The calves showed at the spots of inoculation vesicles and pustules, similar to those of the cows themselves; the calves fell ill, were killed on the twenty-fifth day, and exhibited *post-mortem* appearances like those found in the cows.

“Now, as to the milk of the inoculated cows. On the fifth day, from a healthy teat, carefully guarded

against the introduction of accidental matter from the surface, milk was drawn into a sterilised beaker, and a drop (taken with all befitting precautions) was spread on the surface of nutrient gelatine. In three out of four tubes of this gelatine, bacterial colonies formed after the expected interval. There were eight colonies in all. All of these eight, Dr. Klein reports, were 'unmistakably colonies of the *bacillus diphtheriæ*.' There were no other organisms present.

"Finally, Dr. Klein records an outbreak of his cat-diphtheria, beginning with two cats that had been supplied with milk from one (or both) of the inoculated cows. This incident was not ordained beforehand, and was the consequence of violation of orders; it therefore lacks the precision wanted in an intentional experiment."

We thus learn that a cow-ailment exhibiting externally but little more than certain vesicles, pustules, and scabs, may be induced as the result of the inoculation of the milch-cow with the *bacillus diphtheriæ* from human diphtheria membrane; that this disease, once induced, is capable of being transmitted from cow to calf; and that from the milk of cows suffering from this ailment colonies of the *bacillus diphtheriæ* can be cultivated.

And, lastly, comes an accidental experiment, in which the drinking of such milk by cats was followed by cat-diphtheria, in which disease the same bacillus was again recognised.

Now we are better able to appreciate the import of those apparently trivial ailments in milch-cows, and to which so little importance has hitherto been attached by

veterinarians and dairymen, but which have so commonly been discovered in association with epidemics of milk-diphtheria.

In dealing with diphtheria in the cat, Dr. Klein explains that he has failed to obtain by culture the diphtheria bacillus from the diseased lung, liver, and kidney of the cats which he had infected by subcutaneous injection into them of the cultures of the diphtheria bacillus; and he accordingly arrived, with Löffler and others, at the opinion that the disease and death thus induced was due to a chemical poison produced locally at the seat of the inoculation.

There seem, indeed, the strongest grounds for concluding that the local action of the diphtheria bacillus and the constitutional effects of its chemical products are two very different phases of diphtheria. Discussing this point, Dr. Sims Woodhead expresses the belief that the poison manufactured by the bacilli is of so exceedingly diffusible a nature as to be readily carried to different parts of the body, where it gives rise, amongst other symptoms, to the various forms of paralysis and heart failure by its action on the nervous system. And, no doubt, Dr. Woodhead's contention is a right one. But further difficulty arises when it is seen that though diphtheria bacilli are not found in the human fauces after the acute stage of the disease has passed, there is no surety that some of the general symptoms, typical of diphtheria, will not supervene long after seeming convalescence has been established. It is this frequent delay in the display of such phenomena of the poison

that calls for further explanation. Is it to be regarded as due to a storing up at the site of the local disease, and on cessation of the pyrexial state, of matters which are later on suddenly set free for diffusion throughout the body? or may it be due to the cumulative action, in one or another part of the body, of a poison hitherto diffused throughout the tissues? Such questions must for the moment remain unanswered. Indeed, it is by no means clear what the poison consists in. There are, however, strong reasons for regarding it as an alkaloid derived from the tox-albumins.

Considerations such as these may tend in some measure to explain the variations in the intensity and character of diphtheria as it is commonly met with, and which go to indicate that in diphtheria we have to do with a poison lacking that stability which is so marked a feature of certain other of the specific fevers.

CHAPTER V

MEASURES for the prevention of a disease must, in order to be rational, be based on accurate knowledge as to the natural history of that disease. In the case of diphtheria our information as to the behaviour of the disease under varying circumstances is unfortunately far from complete, and our ability to speak with assurance as to the efficiency of means of prevention is correspondingly limited. But, as already indicated, there are certain points relating to the etiology of diphtheria, and especially as to the circumstances associated with its beginnings and its diffusion, concerning which we do now possess some very definite information, and in so far as this is the case, we ought to be able to speak with some confidence as to the needed measures of prevention. There are also other features of the disease which, though by no means free from obscurity, give us some indications of the directions in which other preventive action may, provisionally at least, be advocated. And lastly, the analogy of some of the other specific fevers enables us to suggest still further measures aimed at the prevention and control of diphtheria.

We have, in the case of diphtheria, a disease which is distinctly infectious, and which is especially communicable from person to person during the period of childhood and early adolescence. Hence it becomes of importance to adopt as a first means of prevention such measures as will ensure the isolation of the sick from the healthy.

The most effectual manner in which this can be secured is by the removal of the sick to hospital. And since the requisite isolation cannot, as a rule, be afforded in general hospitals, it is important to bear in mind that the statutory power conferred on sanitary authorities to provide isolation-hospitals for the inhabitants of their districts, is intended to enable them to undertake the isolation of diphtheria, as well as of the other infectious fevers. In the case of a sanitary authority, whose primary duty in this matter is concerned with protection against infection, such isolation should be so carried out as to reduce to the lowest attainable minimum the risk of the spread of infection to others. To this end, a ward in which diphtheria patients are placed, for isolation purposes, should never be in aerial communication with any other ward in which patients suffering from other diseases are placed. The means by which this result is commonly attained is by the provision of a separate pavilion for each infectious fever, or, where the population of a district is too small to warrant the maintenance of several different ward-pavilions, by such arrangement of ward rooms that each apartment, whilst remaining aurally dis-

tinct, shall open separately into the outer air.¹ In 1882 I submitted to the Local Government Board a report on The Use and Influence of Hospitals for Infectious Diseases,² and I then reported that out of a total of about 1510 provincial sanitary authorities which in 1879 existed in England and Wales, 296 possessed some means for the isolation of infectious diseases other than that belonging to the poor law authorities. Many of the buildings in question were of a very imperfect character, and at that date the removal of diphtheria patients to isolation-hospitals was the reverse of general. Since the date on which the above estimate was based, loans have been granted to over a hundred sanitary authorities in connection with the provision of new isolation-hospitals, and although some of these loans have had to do with the replacement of former hospitals or the extension of existing ones, yet, on the other hand, hospitals have been erected otherwise than by means of loans sanctioned under the Public Health Act 1875, and hence the number of these loans may be taken as a fair indication of the progress made in this matter.

Speaking generally of the infectious fevers which are received into isolation-hospitals, it has been held that, given adequate means of ventilation and warming, some

¹ Diagrams showing how this result may be obtained in town and village hospitals, are appended to the official *Memorandum on the Provision of Isolation-Hospital Accommodation*, issued by the Medical Officer of the Local Government Board. Eyre & Spottiswoode. 1888.

² *Supplement to the Tenth Annual Report of the Local Government Board, 1882* [C—3290], re-issued in 1884.

2000 cubic feet of air per patient may be regarded as a satisfactory minimum, provided it is so contrived that each bed shall stand in its own allotted floor space of some 156 square feet, and, above all, have not less than 12 feet of wall space. But these allowances of air space have been laid down on the assumption that there will be the due mingling of mild with severe attacks, and of convalescing with acute cases. Where this no longer holds good, it becomes obvious that a different minimum standard is called for.

The experience which is available as to the isolation of diphtheria in hospitals is mainly derived from the metropolis, and it affords indication that the conditions obtaining are hardly comparable with those relating to the other specific fevers. This is especially so in respect of the rate of fatality. At the London Fever Hospital, where 96 diphtheria patients were isolated in the five years, 1886-1890, the mean annual rate of fatality was 18.1 per cent of admissions; the variations lying between 4.5 per cent on 21 cases in 1890 and 33.3 per cent on 8 cases in 1888.

At St. George's Hospital, where 52 cases were admitted in each of the two years, 1888 and 1889, the mean annual mortality was 38.4 per cent. From statistics supplied to me by Dr. H. S. Hawkins of St. Thomas's Hospital, I find that on 113 cases admitted in 1888 the mortality was at the rate of 46.9 per cent, on 180 admissions in 1889 it was 49.4 per cent, and on 103 admissions in 1890 it was 42.7 per cent. And lastly, 821 diphtheria patients were admitted into the

hospitals of the Metropolitan Asylums Board during 1888-1889, and of these 321 died, giving a fatality rate of 42·5 per cent.

We have thus evidence of a very high fatality rate amongst such diphtheria patients as have been isolated in certain London hospitals, and it is evident that it is very largely due to the fact that severe attacks form a large proportion of those sent to hospital.¹ Under these circumstances it becomes necessary to suggest that more than ordinary methods are requisite to prevent the possibility of harm from the aggregation together in one ward or building of a number of selected severe cases of diphtheria ; and, pending the results of an inquiry which has for some time past been in progress, I would propose that some 3000 cubic feet be allotted to patients in diphtheria wards, and that the excess beyond the ordinarily allotted 2000 cubic feet should be largely utilised in providing for each bed such ample wall-space that one patient will run but little risk of inhaling the exhalations from his immediate neighbour's air-passages. The inquiry to which I refer is that announced by the Statistical Committee of the Metropolitan Asylums Board in their report for the year 1888, in which it is stated that "the effect of aggregating a number of diphtheria cases on one site is engaging the attention of the several medical superintendents."

Of the isolation of diphtheria in hospital in rural

¹ In the case of the general hospitals, admission is often sought for the purposes of tracheotomy, as a last resource, rather than for reasons of isolation.

areas but little is known. It has rarely been carried out systematically ; but in certain districts, as, for example, within the Gloucestershire combined sanitary area under Dr. Francis Bond's supervision, the result is highly spoken of in so far as preventing the spread of the disease is concerned.

In cases where isolation of diphtheria in hospital is, for one or other reason, impracticable, the nearest procurable approach to the advantages afforded by isolation-hospitals should be aimed at. This will, as a rule, involve an upper storey of a dwelling-house being devoted to the sick and any immediate attendants, together with an intelligent application to the special circumstances of the principles laid down in the "General Memorandum on the Proceedings which are advisable in Places attacked or threatened by Epidemic Disease," issued by the Medical Officer of the Local Government Board, and especially of those points which are embodied in paragraphs 8 to 12 and 18. This memorandum will be found in Appendix No. III.

But in view of the danger attaching to uncontrolled cases of mild diphtheria, its allied "sore-throat," "croup," etc., which have been referred to, and this especially in connection with so-called "school influence," there is another form of isolation which is of the utmost importance. I refer to the restrictions that should be imposed upon school attendances.

In the Code of Regulations issued by the Lords of the Committee of Council on Education, 1889, it is laid down in Article 88 that "the managers must at once

comply with any notice of the sanitary authority of the district in which the school is situated, requiring them, for a specified time, with a view to preventing the spread of disease, either to close the school or to exclude any scholars from attendance ; but after complying they may appeal to the Department if they consider the notice to be unreasonable."

In exercising this power, sanitary authorities are naturally guided by the advice of their medical officers of health ; and I would here draw attention to a memorandum issued by the Medical Department of the Local Government Board, in which the considerations are laid down by which sanitary authorities should be guided in deciding whether it is desirable to close a school or merely to exclude scholars from infected houses and localities. The memorandum will be found *in extenso* in Appendix No. II. The power of restricting or otherwise controlling school attendances referred to in it relates solely to schools receiving a Government grant through the Education Department, but the principles embodied in it apply equally to other elementary schools, to Sunday schools, and to institutions where children and young people are gathered together.

In many occurrences of diphtheria more good may often be expected from a system of exclusion of special scholars than from actual school closure. One of the most prominent dangers connected with the diffusion of this disease lies largely in the presence within schoolrooms of comparatively trivial and even unrecognised attacks, which, under conditions of school aggregation, tend more

than under any other known circumstances to maintain the disease and to form connecting links between one and another outbreak of well-marked diphtheria. But the system of exclusion, supplemented by careful inquiry by schoolmasters and schoolmistresses as to the existence amongst the scholars themselves, or amongst others in their houses, of any cases of "sore-throat,"¹ or of "colds" of a suspicious type, with a view to the immediate elimination of such scholars and investigation by the local health officer, has often succeeded in preventing further mischief. In cases where first efforts in this direction have failed, or where the disease is at the outset widely diffused amongst the scholars, absolute closure of the school seems indicated.²

¹ The experience recorded as to sore-throat of a suspicious type in infants should be borne in mind in this connection. See p. 41.

² In considering these alternative methods the following remarks by Dr. Wilfred W. E. Fletcher, from the annual report for 1890 on the Ormskirk rural sanitary district, deserve attention:—

"It has often been observed by those who object to the closing of schools for infectious illness that such a proceeding is wholly unnecessary, some, indeed, going so far as to say that it is really useless because the children play together in the streets and lanes, and, in fact, mix as freely with one another as they do when at school. The latter part of this statement I do not deny, for, doubtless, the children do freely mix; but I have on a previous occasion tried to point out the great difference existing in the two conditions. In the one, the children are shut up in a room, generally too hot, and seldom sufficiently ventilated; while in the other, they are in the open air. In the first case everything is in favour of spread, in the second the danger of spread is, though not completely removed, at any rate very greatly reduced; and the more experience I gain the more do I feel persuaded that the early closing of schools (I am speaking of schools in the country) is the very safest and best course to follow, both in

And it should be remembered that if success in controlling the beginnings of diphtheria is to be attained, the cordial co-operation of school officers and sanitary officials must be secured. Otherwise the more severe measure of school closure, with its greater interference with the work of education, will often become necessary. Adoption of the system of compulsory notification of infectious diseases has also proved of much use to the same end.

And where a school—whether public or private—has been broken up on account of diphtheria, re-assembly of scholars should only be contemplated provided it is supplemented by careful inquiry and examination concerning any recurrence of sore-throat. Again and again, when advice as to a daily examination of the fauces of every scholar in private schools has been disregarded, has the re-assembly of the pupils been followed by recurrence of diphtheria, and this, at times, in an aggravated form.

Inquiry is at times made as to the length of time during which such daily examination of throats should be maintained. The answer to this question involves several considerations, notably the question of the interests of the children's health and of the school itself. Almost invariably I have found fresh cases of sickness diminish in frequency after the school infected has been closed, and on only one occasion have I found it necessary to advise a second closure for the same epidemic, and this because the school had been reopened without previously being disinfected, the result naturally being a fresh outbreak. I need hardly say that I gave advice to disinfect the school during the time it was first closed, and thought my advice had been followed."

crudescence of infectiveness, which has already been referred to in some detail, and also the length of the period of incubation in diphtheria.

On the latter point there is a great lack of precise information. There are cases in which the infection has seemed to operate almost immediately on exposure to it, and there are others in which the result has appeared to be delayed for a period of two weeks or even more. The circumstances cited by Dr. Bruce Low in connection with the outbreak at East Haddon¹ may perhaps be looked upon as affording evidence of extreme brevity of incubation period; and the following story with which he has supplied me, and which has to do with the same outbreak, may be looked upon as suggesting a much more prolonged period:

E. H., æt. 29, housemaid at the hall, assisted to wait upon the children in the crowded tent on the wet afternoon of August 21st, the day of the school treat. She partook of none of the food provided. She admits she was at times in close proximity to some of the invalids ("diphtheritic") who had been brought from their beds to join in the treat.

She left the village [East Haddon], early next day, August 22d, for her annual holiday, which she spent with her relations in a locality in the neighbourhood of Hull, and where, so far as could be learnt, no cases of diphtheria had occurred for some time. She saw no sick persons during her visit, nor did she hear of the

¹ See pp. 123-125.

existence of any cases of throat ailment of any kind at that time in the locality.

She returned to her situation on the evening of September 5th [fifteen days after the gathering in the tent], and felt chilly as she was driven in a closed conveyance from the station to the village. The same night she had some uneasiness in the throat. She states that up to that time she had felt perfectly well. Two days after, viz. September 7th, the diphtheria membrane was seen on her throat by the medical man in attendance.

But it is not possible to say that either of these cases is free from ambiguity. In the first case there was, as already explained, possibility of the operation of milk infection; and before accepting the latter case as affording proof of an incubation period of fifteen days, it would be necessary to eliminate the possibility of one of those mild "sore-throat" attacks from which adults at times suffer during diphtheria epidemics, and this without known inconvenience, followed by recrudescence in aggravated form of the throat-mischief as the result of some exposure involving the chill referred to. Examination of a number of instances in which a definite period has been assigned as the incubation period of diphtheria has led me to the conclusion that a large proportion of them are not free from sources of error; and under these circumstances I hesitate to speak dogmatically upon the subject. I have also a strong belief that the contagium of diphtheria is in marked contrast with certain other contagia, such as

small-pox, in respect of its stability, and that the variations in its quality may have to do with variations in the incubation period. The condition of the surface on which the poison is received has also, I expect, a very material influence on the length of time which elapses between exposure to infection and the symptoms of diphtheria in the individual. When the specific poison reaches an inflamed or otherwise unhealthy or abraded surface of the tonsils, such as may result from catarrhal sore-throat, scarlatina, measles, exposure to filth emanations of various sorts, etc., then I see no reason why the processes involved in diphtheria may not begin to take effect immediately; whereas, on the other hand, it is probable that even unhealthy fauces may, whether the surface be abraded or not, resist any such action for a more or less prolonged period by reason of some such condition as the existence of a surface coating of mucous exhibiting one or other chemical reaction. In fact, we know that in artificial culture of pathogenic microbes, certain of them, while thriving perfectly well on diverse nutritive media, grow and multiply much more rapidly on some than on others. And it has been pointed out by Dr. Sims Woodhead and others that "the diphtheritic poison is always most active when alkaline," its toxic power being very considerably diminished by acidity of the medium in which it is produced.

But, making allowance for the obscurity attaching to the natural history of diphtheria in this respect, I may express the belief that the most common period of incubation in diphtheria is from two to three days; that

less frequently the period is diminished to twenty-four hours or extended to four days; and that the limit between an almost immediate operation of the infection and a delay of six or seven days, practically covers the period of incubation period for preventive purposes.

Oertel says¹:—"The time which elapses between the moment when the diphtheritic contagion comes in contact with the body, and that when the development of the poison becomes both subjectively and objectively appreciable is variously stated; it depends, in the first place, on the quality and quantity of the infecting material itself, and secondly on the power of resistance, as well as in the structure and texture of the tissues, which permit the penetration and absorption of the diphtheritic matter with varying facility." He also refers to two cases in which the infection was the result of kissing, and in which he felt himself able to fix the time of the outbreak of the disease at two days after infection; and he adds that, "we may . . . state positively that the latent course of diphtheria occupies from two to five days."

In cases in which milk has served as the vehicle of the infection, and in which conditions, such as storage of the supply, have favoured the multiplication of the bacilli and subsequent formation of chemical poison, as also the direct reception of the poison into the stomach, there seems reason for believing that the period of incubation is generally a brief one. The history of milk-

¹ Article on "Diphtheria" in Ziemssen's *Cyclopædia of the Practice of Medicine*, vol. i. London: Sampson Low & Co.

epidemics points to such shortening, whatever the cause may be.

Reverting, in this connection, to the question of the precautions to be taken in the reassembly of schools, and making allowance both for instances in which observers have suggested twelve and even fourteen days as a probable period of incubation, and also for the possibility of some unobserved trivial attack of nasal or other obscure form of diphtheria within that interval, I have not, in any case, felt able to advise the discontinuance of skilled examination of throats, etc., for a less period than one fortnight after the date when such examination became necessary, either on account of the discovery of a case of the disease or of the reassembly of a school or other similar institution which had been temporarily closed on account of diphtheria.

It has long been matter of observation that the infection of diphtheria remains at times attached both to premises and to articles, such as clothing and the like ; and though it is by no means certain that recurrences of diphtheria on the same premises or within the same households always, or even most commonly, find their explanation in a retained infection, yet experience has shown the need for following up methods for separating the sick from the healthy, such as have been adverted to, by measures of disinfection and of cleansing.

Of true disinfection, that is to say of processes that ensure the destruction of infection, our knowledge is at present very limited ; and of trustworthy aerial disinfection we know still less. But experience has pointed to

the value of subjecting rooms, whether in dwelling-houses or school premises, etc., to the influence of such a disinfectant as sulphurous acid and to subsequent processes of cleansing such as are indicated in the General Memorandum printed in Appendix No. III. § 18, (*d*) and (*e*); and these measures should never be neglected.

For articles of clothing and of bedding, which admit of being subjected to boiling for a few minutes, no more effectual process for the destruction of infection exists; and as regards other articles of this class which cannot well be boiled, except at the risk of damage, and which it is inexpedient to destroy by fire, no process is more efficient than their treatment in a high-pressure steam apparatus such as is now provided by many sanitary authorities for the use of and for the protection of the inhabitants of their districts.¹

Such further measures of disinfection as are called for in the case of diphtheria relate mainly to the management of the sick-room, where it is important that all discharges from the throat and nares should be at once received into vessels charged with a solution of perchloride of mercury (see Appendix No. III. §§ 10 and 18), or on to rags, etc., which can be at once destroyed by burning.

The considerations raised in connection with milk-epidemics of diphtheria point to another important measure of prevention. Again and again has a marked

¹ Further details on this subject will be found in the *Report of the Medical Officer of the Local Government Board for 1884* [C—4516], 1885.

incidence of the disease been observed on consumers of certain milk-supplies ; whilst, on the other hand, it has been equally obvious that other persons who have regularly partaken of the same supplies, but who have only consumed the milk after it had been boiled or otherwise cooked, have experienced immunity from attack. Indeed, there is now abundant evidence to show that it is essentially in its raw and uncooked form that milk has so often served as a vehicle and multiplying ground for the infection of diphtheria. Dr. Klein, as the outcome of his study into the degree of temperature that is fatal to the diphtheria bacillus, finds, as a uniform result of many experiments, that exposure to 60° C. (140° Fahr.) for five minutes suffices to destroy its vitality.¹ The boiling-point of milk is 214° – 218° Fahr.; and we have thus in the boiling process a definite safeguard against infection conveyed to us by milk-services.

It is indeed difficult to understand why the English public adhere so tenaciously to the use of milk in an uncooked form. It is notoriously one of the most favourable vehicles for the communication of a number of the most fatal infections to which man is subject, and the process of boiling is not known to impair its value as an article of diet.²

¹ *Report of the Medical Officer of the Local Government Board for 1889* [C—6141—I.], 1890.

² Since this was written, Prof. Leeds and Dr. E. P. Davis (*Amer. Jl. Med. Sc.*, June 1891) have reported otherwise. But, according to the Supplement to the *Brit. Med. Jour.*, July 4th, 1891, "Professor Leeds believes that milk may be rendered 'practically sterile' by heating to 68° C. (155° F.) for six minutes without suffering any important diminution in its digestibility." Beyond that temperature digestion did not seem so easy.

Some, it is true, object to the taste which boiled milk acquires ; but even this can be almost entirely obviated if a reasonable time be allowed to elapse between the process of boiling and the consumption of the milk ; as, for example, by boiling the morning's supply directly it is delivered and storing it till afternoon, and by reserving the afternoon's supply till next morning after subjecting it to the same process. The boiling of the milk immediately on its arrival goes also to arrest the multiplication of bacilli and the manufacture of chemical products which subsequent boiling might not render inert.¹

But in milk-epidemics of diphtheria the comparative immunity from attack of those who have only drunk milk in tea or coffee has also been remarked. To some extent this may be due to the small amount of milk which is thus consumed. But the immunity has doubtless another explanation ; and Dr. Klein's further observations are extremely interesting in this connection. Whilst the diphtheria bacillus was found to grow on Agar or in broth more rapidly at 36-37° C. (96·8-98·6 Fahr.) than at 19-20° C. (66·2-68·0° Fahr.), it exhibits precisely opposite results when milk is resorted to as the cultivating medium, hardly any multiplication taking place at the higher temperature, even after a lapse of four days. Thus we find as the result of experiments made in the bacteriological laboratory both confirmation and explanation of some of the most interesting observations made in current etiological research.

¹ On this point see also Appendix No. III. § 6.

The relation of human diphtheria to disease in the lower animals suggests, amongst other things, the need for increased study of the ailments to which milch cows are subjected, with a view to the adoption of intelligent measures of precaution, and also the desirability of avoiding risk of infection from animals, and especially from cats and other domestic pets, suffering from ailments such as those which have so often occurred in connection with diphtheria in children and in other persons.

Such other measures for the prevention of diphtheria as may usefully be referred to involve essentially general considerations affecting wholesomeness of residence and surroundings. Whatever the relation between faulty sanitary circumstances and diphtheria with its allied "sore-throat" may be, it is certain that any occurrence of that disease should always be utilised for the discovery and remedy of any conditions tending to cause injury to health, and that every effort should be made to secure for dwelling-houses dryness of site, freedom from injurious influences likely to result from oscillations of sub-soil water, cleanliness of soil, freedom from effluvia such as are concerned with faulty sewers, drains, or with noxious animal and vegetable refuse, together with free movement of air and ample sunlight.

With regard to the latter points I would observe that there are grounds for connecting the prevalence of different forms of sore-throat and the tendency to recurrence of diphtheria in certain localities and premises with the absence of due air-movement and insolation,

and for regarding the dampness and tendency to fungoid growths which have so often been associated with maintained diphtheria as but manifestations of a condition that favours the development and multiplication of the diphtheria bacillus.

MM. Roux and Yersin, while studying the etiology of diphtheria in the Pasteur Institute, have found that the pathogenicity of the bacillus of this disease is rapidly modified by sunlight and contact with air; whereas, if the air be excluded, the diminution in toxicity brought about by light is comparatively slight.¹ Herein may lie the explanation of some of those persistent prevalences of diphtheria and undefined throat-mischief amongst persons inhabiting damp, shaded localities, so situated in valleys or amid foliage as to prevent the due exposure of dwellings and of soil to the combined action of sustained sunlight and movement of air. Under any circumstances, we may well find in the results of these experiments a further suggestion for preventive measures in so far as the influence of residence is concerned.

The following Conclusions as to the natural history and prevention of diphtheria may be provisionally arrived at.

¹ Much the same conclusion has been arrived at as to the destruction of the tubercle bacillus on exposure to combined sun and air. As to Koch's views on this subject see a paper by the author on "The Dwelling-House in Relation to Tubercular Consumption" in *St. Bartholomew's Hospital Reports*, vol. xxvi. 1890.

CONCLUSIONS

1. That a disease which, judged by the descriptions given of it by different authors, is not to be distinguished from diphtheria as met with in the present day, was known before the Christian era, and prevailed in this country at intervals between the 14th and 18th centuries.

2. That during the past twenty years there has been a progressive increase in the rate of mortality from diphtheria in England and Wales.

3. That whilst the diphtheria mortality remains as heretofore greater in sparsely peopled than in densely inhabited districts, a specially marked increase of its incidence is in progress in the group of large cities and towns. The disease is becoming, in fact, more and more one affecting urban populations.

4. That, the steady increase in the diphtheria mortality has coincided, in point of time, with steady improvement in regard of such sanitary circumstances as water-supply, sewerage, and drainage.

5. That, alike in the country generally, and in the group of large towns, synchronously with the steady increase in the rate of mortality from diphtheria, the death

rates from all causes, from the group of "zymotic diseases" (including diphtheria), and from enteric fever, have undergone continuous and marked diminution.

6. That the broad geological features of a district have not, as such, any observed influence on the development and diffusion of diphtheria.

7. That dampness of site, an aspect involving exposure to cold wet winds, and a surface soil favourable to the retention of wetness and of organic refuse, tend apparently to the fostering and the fatality of diphtheria.

8. That season has a marked influence on the manifestation, and, above all, on the mortality, from diphtheria. Epidemic prevalences of the disease commonly commence in September, reach their highest point during October and November, and then subside slowly during the following months of December and January—the smallest amount of mortality being witnessed in the months May to July.

9. That there is some excess of diphtheria mortality in females as compared with males, and that it is probably due, at all periods of life, to greater opportunity of exposure of females to infection.

10. That age has an important influence on the incidence of diphtheria; the greatest number of cases, actually and relatively, both fatal and non-fatal, occurring at the ages 3 years to 12 years.

11. That prevalences of recognised diphtheria are commonly associated in their beginnings, during their continuance, and after their apparent cessation, with a large amount of ill-defined throat-illness, and that fatal

attacks of diphtheria in many localities get registered as croup, laryngitis, etc.

12. That there is reason to believe that attacks of so-called "sore-throat" exhibit under certain favouring conditions a "progressive development of the property of infectiveness," culminating in a definite specific type which is indistinguishable from true diphtheria.

13. That diphtheria in the human subject commonly begins as a local disease manifesting itself at the point to which the contagion has been conveyed aurally or otherwise, and that a morbid condition of the tonsils, such as sore-throat, whether due to faulty sanitary circumstances, or dependent on such diseases as scarlatina, measles, etc., operates, in the presence of diphtheria, strongly as a predisposing cause to attack by that disease.

14. That apart from age susceptibility, "school influence" so-called tends to foster, diffuse, and enhance the potency of diphtheria, and this, in part at least, by the aggregation of children suffering from that "sore-throat" which commonly is prevalent antecedent to, and concurrently with, definite diphtheria.

15. That there is abundant evidence to show that diphtheria has often been conveyed through the medium of milk, and on several occasions strong presumption has arisen that infectivity of the milk has been due to some condition affecting the cow herself.

16. That the intimate cause of diphtheria is a micro-organism, the *bacillus diphtheriæ*, cultivations of which, derived from human diphtheria membrane, when inoculated into the cow, produce a communicable disease,

which is associated with certain definite symptoms, and with the secretion of milk charged with the same specific bacilli.

17. That a specific communicable disease can be produced in cats as the result of similar inoculations, and that, on one occasion at least, the consumption by cats of the milk of cows suffering from the disease referred to has led to the production of "cat-diphtheria."

18. That, with a view to the prevention of diphtheria, the following points should receive attention:—(a) the separation of the sick from the healthy, including the control of school attendances; (b) the application to infected places and things of measures of disinfection and cleansing; (c) the use of such milk only as has been boiled or otherwise cooked; (d) the avoidance of infection from domestic animals; (e) such choice of residence as will secure dryness and general wholesomeness of site and surroundings, together with ample exposure to sunlight and free movement of air.

APPENDIX No. I

Issued by the Medical Officer of the Privy Council in 1859.

HEADS FOR LOCAL INQUIRY IN DISTRICTS WHERE DIPHTHERIA HAS BEEN EPIDEMIC

1. *As regards the General Features of the District.*

(a) What is the character of the district as to level, exposure, soil, drainage, and (if rural) cultivation, or (if urban) density of building?

(b) What is the source, and what the general character of the water supply of the district?

(c) Is the district liable to ague, to autumnal fever or diarrhœa, to bronchocele, or to any other endemic disease?

2. *As regards the Duration, Extent, and Novelty of the Epidemic in the District.*

(a) When was the first, and when the last case of diphtheria in the district?

(b) What was the number of attacks of diphtheria, what the number of deaths occasioned by it, and what the number of houses among which the attacks were distributed?

§ Append any lists which individual practitioners will furnish, according to the accompanying form, of the cases which they respectively have attended.

(c) Is there any local recollection of diphtheria having prevailed before in the district or neighbourhood? If so, when? and to what extent?

3. *As regards contemporaneous or recent Diseases in the District.*

(a) Did other varieties of sore-throat (*i.e.* varieties not attended by the formation of false membrane) prevail in the district at about the same time as diphtheria? If so, did they precede, or accompany, or follow its prevalence? And did they in any cases prove fatal, or present unusual features?

(b) Did scarlatina prevail in the district at about the same time as diphtheria? If so, did it precede, accompany, or follow? And did it present unusual features?

(c) Did erysipelas or puerperal fever?

(d) Did common continued fever?

(e) Did any other disease, either of the human subject or of the lower animals, prevail in the district to an unusual extent, or with unusual features, either during, or shortly before, or shortly after, the prevalence of diphtheria?

4. *As regards Local and Personal Conditions predisposing to Diphtheria.*

(a) In what number, and with what severity, did cases occur in dry and airy parts of the district, as compared with low-lying, damp, and confined parts?

(b) In what number, and with what severity, did cases occur in thoroughly well-constructed and well-kept houses or rooms as compared with houses or rooms in which the atmosphere was offensive from defects of drainage, or from over-crowding and non-ventilation, or from other kinds of uncleanness?

(c) Had the houses in which diphtheria was prevalent been previously much subject to any [and, if any, what?] other kinds of disease?

(d) In what number, and with what severity, did cases occur among persons enjoying affluent or comfortable circumstances of life as compared with persons suffering privation?

(e) What has been observed as to the influence of age, occupation, habit of body, and personal antecedents, in increasing or diminishing the liability to contract diphtheria, or to suffer any of its symptoms in a severe form?

Was any difference in this respect observed between persons who had, and persons who had not, previously had scarlatina?

5. *As regards the Communicability of Diphtheria.*

(a) Did it often happen [and if so, give instances] that cases of diphtheria occurred singly in households where there were children in free communication with the patient?

(b) Did it often happen [and if so, give instances] that all or nearly all the inmates, or all or nearly all the children, of considerable households were eventually attacked with diphtheria, in houses where one case had arisen? or that they were attacked with any other kind of sore-throat?

(c) Where two or more cases occurred in succession in one house, what commonly was the interval between them?

(d) To what extent is it the case (either as regards the district generally, or as regards particular houses and establishments in the district) that the persons first attacked with diphtheria had previously been in communication with houses wherein that disease was prevailing? or with houses in which some other kind of sore-throat was prevailing? or with houses in which scarlatina was prevail-

ing? or with houses in which erysipelas, or any other kind of febrile or inflammatory disease, was prevailing?

If in any case diphtheria seems to have resulted from such communication, what was the nature of the communication? And what time elapsed after the communication before the new case of diphtheria commenced?

Did it ever appear that diphtheria was propagated by accidental inoculation or contact with the morbid secretion of the throat?

If, among persons equally communicating with the sick, some were attacked with diphtheria while others remained free from it, to what was this difference attributed?

6. *As regards the Symptoms of Diphtheria.*

Did diphtheria, as observed in the district, differ in any [and, if any, what?] important respect from the account given of it generally in the following paragraphs, viz.—

(a) That the essential local sign of the disease, seen on inspecting the throat of a patient in the early stages of diphtheria, is the presence of a fibrinous exudation, more or less firmly coagulated upon the inflamed surface of the fauces, tonsils, and pharynx, where, blended with the epithelium of the part, widening as the inflammation extends, and becoming thicker by successive additions to its deep surface, it appears as a continuous raised layer of white or whitish membrane (*diphthera*) and tends after some days to be thrown off, like a slough, in a partially decomposed state?

(b) That the diphtheritic inflammation is never primarily attended by any ulceration or sloughing of the mucous membrane, though in some cases these processes occur at later stages of the disease; but that always at first there lies beneath the false membrane a merely excoriated surface,

on which, while in this state, there may coagulate, before healthy epithelium is restored, successive new layers of fibrinous matter, more or less mixed with the corpuscular products of inflammation?

(*c*) That the diphtheritic inflammation, besides generally extending to the mucous membrane of the nose (where also, though rarely, it may begin, and where in either case its presence may occasion epistaxis), sometimes descends along the mucous membrane of the air-passages, superadding, in such cases, the ordinary symptoms and dangers of croup to those of the original affection?

(*d*) That usually the lymphatic glands below the jaw, and sometimes the cellular membrane of the neck, are more or less irritated and swollen during the inflammation of the throat?

(*e*) That the disease is not, except sometimes at its beginning, attended by febrile excitement, but is commonly, throughout its course, marked by signs (often by alarming signs) of depression?

(*f*) That more or less irritation of the kidneys is of very frequent, if not universal, occurrence at some period or the other of the disease, involving, while it lasts, an albuminous state of the urine, and the presence in it of microscopical casts of the urinary tubules?

(*g*) That the disease may be complicated with other internal inflammations, especially with pneumonia, and that intestinal hæmorrhage may occur during its course?

(*h*) That patients often remain in a state of anæmia and weakness, even of dangerous weakness, long after the throat affection has ceased, and that some of them, during this condition, suffer functional nervous disorder, such as impairment of vision, partial loss of sensation, or paralytic or convulsive affection of voluntary muscles?

§ Append any notes which individual practitioners will furnish, of carefully observed cases of diphtheria, wherein either its less frequent symptoms or complications have occurred, or its common symptoms have been minutely investigated, *e.g.*,

Of cases, if any, where cutaneous eruption has appeared, the exact character of which should be specified, as also the period of the disease during which it was visible, and the issue of the cases in which it was observed ;

Of cases, if any, in which the skin has desquamated ;

Of cases in which the throat affection has been accompanied or followed by serious inflammation of internal organs, or by any kind of hæmorrhage ;

Of cases, if any, in which dropsy has ensued ;

Of cases in which peculiar nervous sequelæ have been well marked ;

Of cases, if any, in which a blistered or otherwise excoriated surface of the patient's skin, or the mucous membrane of the pudenda, has taken on anything like diphtheritic inflammation ;

Of cases in which the urine has been specially examined day by day during the disease ;

Of cases in which the temperature of the body has been noted ;

Also of any carefully made *post-mortem* examination, especially such as may illustrate the internal complications of the disease ;

Also of any precise observations which may show the value of particular symptoms as guides to favourable or unfavourable prognosis.

7. *As regards the Treatment of Diphtheria.*

(a) Has any treatment been found more effectual than

the use of ordinary escharotics (*e.g.*, nitrate of silver or hydrochloric acid) to arrest the formation of false membrane in the throat? If any cases were treated without escharotic or stimulant applications, what was the result?

(*b*) Has any treatment been found more effectual than the use of alcoholic stimulants to counteract the depression which belongs to severe cases of the disease?

(*c*) If tracheotomy has in any case been performed for the relief of laryngeal obstruction arising in the disease, what has been the number and what the result of such cases? Has any treatment been, under the circumstances, more successful than tracheotomy?

(*d*) What treatment has been adopted, and what result has ensued, in cases of internal inflammation complicating the disease?

(*e*) Has any treatment been found more effectual than the use of ordinary tonics to remove the sequelæ of the disease, especially those that affect the nervous system?

(*f*) What knowledge has been obtained as to the fact of any particular drug exerting a specific influence against the disease?

PRIVY COUNCIL OFFICE,
LONDON, S.W., 1859.

In 1885 certain Additional Instructions as to points to be observed in "Diphtheria Inquiries" were issued to the Inspectors of the Medical Department of the Local Government Board by the Medical Officer, Dr. George Buchanan, F.R.S. They related essentially to the following matters:

(*a*) The question of an infective organism of the nature of a local miasm, and capable of becoming air-borne.

(*b*) The relation of diphtheria to the keeping of animals,

and especially of animals domesticated in and about dwellings.

(c) The association with diphtheria of such ailments as are locally termed "croup," "mumps," "colds," and minor "sore-throat."

(d) The bearing of school attendances on diphtheria prevalences.

(e) The extension of diphtheria otherwise than by personal communication.

(f) The question as to the progressive development of infectiveness in throat disease and diphtheria.

(g) The occurrence of ailments, however trivial, in milch cows, whether after calving, during "drying-off," on change of diet, or otherwise ; and the relation of any such ailments in cows to diphtheria amongst consumers of their milk.

APPENDIX No. II

Memorandum, prepared in the Medical Department, on the circumstances under which the Closing of Public Elementary Schools or the Exclusion therefrom of particular Children may be required in order to prevent the spread of disease.

1. It is attempted in these notes to bring together the information in the possession of the Local Government Board, derived from the reports of the Board's own medical inspectors and of local medical officers of health, respecting school-closure and exclusion from school as precautions against infection. It is sought to indicate the best means

of preventing the spread of disease by school-children among their fellows, while avoiding any unnecessary interruption of the work of education.

2. In the Code of Regulations approved by the Lords of the Committee of Council on Education, the following Article (Art. 88) prescribes as one of the general conditions required to be fulfilled by a public elementary school in order to obtain an annual Parliamentary grant, that—

“The managers must at once comply with any notice of the sanitary authority of the district in which the school is situated, requiring them for a specified time, with a view to preventing the spread of disease, either to close the school or to exclude any scholars from attendance, but after complying they may appeal to the Department, if they consider the notice to be unreasonable.”

3. The diseases for the prevention of which school-closure, or the exclusion of particular children, will be required, are principally those which spread by infection directly from person to person, such as scarlet-fever, measles, diphtheria, whooping-cough, small-pox, and rōtheln, the order in which the several diseases are here given being about that of the relative frequency with which their occurrence gives rise to these questions at schools. More rarely, the same questions arise in connection with enteric fever and diarrhœal diseases, which spread not so much by direct infection from person to person, as indirectly through the agency of local conditions, such as infected school privies.

4. It will be seen that Article 88 quoted above confers upon sanitary authorities an alternative power with respect to public elementary schools.

(a) To cause particular scholars to be for a specified time excluded from attendance ; or

(b) To require the school to be closed for a specified time.

5. *A. First, as to exclusion from school of particular scholars.*—Here it will be convenient to consider the circumstances under which the requirements of the public health will be satisfied by the less severe measure of the exclusion from school of particular children.

(a) It may be laid down as a universal principle that all children suffering from any dangerous infectious disorder (*i.e.* of a nature dangerous to some of the persons attacked by it, however mild in other cases) should be excluded from school until there is reason to believe that they have ceased to be in an infectious condition (*see* section 126 of the Public Health Act 1875).

(b) Furthermore, as it is rarely possible to provide effectual separation of the sick from the healthy within the homes of children of the class attending public elementary schools, it must commonly be necessary that all children of an infected household should be excluded from school; first, because otherwise such children might attend school while suffering from the disease in a latent form, or at an unrecognised stage; and secondly, because it is known that infection may attach itself to, and be conveyed by, the clothes of a person living in an infected atmosphere, even though the person himself remain unaffected. The same considerations will sometimes make it desirable to prohibit the attendance at school of all children from a particular street or hamlet.

In the case of infectious diseases involving little or no danger to life, such as mumps or skin diseases, school interests may be more particularly considered. In such case, however, the rule of prohibiting the attendance of every child while in an infectious state

will commonly prove to be the right one ; for if disease should spread to other scholars owing to the continuance of an infected child at the school, there will be greater ultimate loss of attendance, with corresponding loss of credit, to the school.

6. *B. Secondly, as to the closing of schools.*—This, by more seriously interfering with the educational work of a district, is a much more grave step for a sanitary authority to take than to direct the exclusion of particular scholars. It is a measure that seldom ought to be enforced, except in presence of an actual epidemic, nor even then as a matter of routine, nor unless there be a clear prospect of preventing the propagation of disease, such as could not be looked for from less comprehensive action.

The mere fact that in an epidemic many of the sufferers are school-children does not necessarily show that the disease was caught at school ; but the school may with probability be regarded as spreading infection, if, in a large majority of households attacked, the first case be a child attending school ; and with still greater probability, if a number of children living at a distance from one another, and with no circumstances in common, except that they attend the same school, should be simultaneously attacked, and if it can be ascertained that a child or teacher in an infectious state has actually been attending the school.

7. The medical officer of health, on becoming aware of the presence of dangerous infectious disease in his district, should, under articles 2 (7) and 18 (6) of the Board's General Orders prescribing the duties of medical officers of health, send immediate notice to the teacher of the school or schools which the children of infected households may

be attending, requesting that such children may be excluded from school for such time as he (the medical officer of health) may specify as being necessary. Ready compliance with such request may often render formal action under Article 88 of the Education Code unnecessary.

The attention of school-attendance officers and of schoolmasters should also be drawn to the following considerations. Frequently they themselves will obtain the earliest information of the occurrence of infectious disease among scholars, and it is most desirable that such officer or master should without delay communicate the facts to the medical officer of health. Absence of any child from school on the plea that it is suffering under one of the before-mentioned diseases, and absence of several children of one family from school at the same time, no matter what name be given to the complaint that keeps them at home, should be reported to the health officer. In practice it has been found that this notification of absentees has materially aided the local health officer in taking measures for the suppression of infectious disease, to the advantage alike of the district and of the school. Furthermore, schoolmasters may properly be asked to take note, especially when an epidemic threatens or is present, of symptoms occurring in any of their scholars that may indicate the commencement of disease, febrile in nature. Besides heat of skin, such symptoms are shivering, headache, and languor, especially if commencing suddenly, vomiting, rashes on the skin, and sore-throat. When scarlet-fever or diphtheria is about, every trace of sore-throat should be looked upon as suspicious.

In any case where such symptoms are observed, the safest course will be to exclude the child from school until assurance can be had that it may attend school without harm to itself or danger to other scholars.

8. As regards duration of exclusion from school of particular children, the time to be specified will vary in different diseases and different cases, and in this matter the sanitary authority will doubtless be guided by the advice of their medical officer of health, who may properly be entrusted with some general duty of acting for the authority in this subject matter.

Medical officers of health, having to specify a time during which any scholars are to be excluded from attendance at any school, should have regard as far as practicable to the circumstances of the particular scholars suffering from infectious disease or living in infected households. Not only the nature of the infection and the length of illness, but the environments of the individual as affecting the retention of infection will deserve consideration. The period of exclusion, for example, will need to be different according to the conditions of a patient's lodgment, according to the sufficiency of the separation that can be effected between a patient and excluded scholars, and according to the opportunities of effectual disinfection that can be afforded to the household. Thus a hard and fast rule, such as has been laid down in some districts where scarlatina has been present, that no child shall go to school from an infected house for three months after the disease has begun in that house, is not to be commended. It is indeed possible that under the circumstances of a particular household, a child

convalescent from scarlatina, or living in the same house with convalescents, should not in the interests of other children be permitted to return to school until after so long a period as this ; but the same ought not to be assumed of all households in the district that may be invaded by scarlatina. The better plan would be for the sanitary authority to secure, during a shorter period, the exclusion of individual sick persons and their housemates from school ; and when that period is about to expire to cause fresh inquiry to be made as to the expediency of further exclusion, and, if found requisite in particular cases, to cause fresh notice to be given to the school managers.

9. In deciding whether an outbreak of infectious disease among children of school age may be best combated by closing the school, or whether it will suffice to exclude the children of infected households, the two most important points to be considered are :—

The completeness and promptness of the information received by the officers of the sanitary authority respecting the occurrence of infectious cases.

The opportunities which exist for intercourse between the children of different households elsewhere than at school.

10. The more prompt and full the knowledge of cases of infectious disease that the sanitary authority are able to obtain, the better will be the prospect of checking such disease by keeping away from school the children of infected households, and the less will be the necessity for closing schools. If the cases be few in number, and their origin known, the exclusion from school of the children of infected households will probably suffice, but this measure

will fail where there are many undiscovered or unrecognised cases, or where the known centres of infection are peculiarly numerous.

Commonly, the failure of carefully considered measures of exclusion to stay the spread of an epidemic which shows a special incidence upon school children, may be regarded as pointing to the continued attendance at school of children with the prevalent disease in a mild or unrecognised form, and a strong case will appear for the closing of schools.

If by reason of the absence or exclusion of a large number of children, the attendance at a school be greatly reduced, it may be found better to close it altogether. This is especially apt to occur in the case of epidemics of measles, a disease which is very infectious in the early stages, before the characteristic rash has appeared, and while the symptoms resemble those of a common cold.

11. The second material consideration, in deciding as to the desirability of closing schools during the prevalence of infectious disease, is the amount of opportunity for intercommunication between the members of different households elsewhere than at school. In sparsely populated rural districts, where the children of different households, or of separate hamlets, rarely meet except at, or on their way to, the village school, the closing of the school is likely to be effectual in checking the spread of disease. It is less likely to be useful in a town or compact village (particularly where houses are sublet and yards are in common), where the children of different households, when not at school, spend their time in playing together, and often run in and out of each other's houses. In some such places the closing of schools has even appeared to do harm rather than good.

In rural districts, where epidemic diseases are less fre-

quently prevalent, school closing may be required as an exceptional measure to meet an exceptional state of things. As regards more populous places, it must not be forgotten that if schools were to be closed whenever an infectious disease was prevalent, there are many places where schools would hardly ever be open.

It will sometimes be necessary to close a school for a day or two to allow of the rectification of sanitary defects of a nature to extend disease, or in order that the school may be disinfected or purified. It has happened that infectious sickness in the master's family has forbidden the attendance of scholars. These more temporary and occasional closures of schools are contemplated in the Education Code, and are to be regarded as having a real importance of their own.

12. In places where there are several public elementary schools, if an outbreak of infectious disease be confined to the scholars of one particular school it may be sufficient to close that school only. But where different schools have all appeared to aid in the spread of disease (though perhaps to an unequal extent) the sanitary authority may consider it advisable that all should be closed, lest children in an infectious state who previously attended the schools that are closed should be sent to others that might remain open.

It must be remembered that sanitary authorities have no power in respect of Sunday schools, or other private schools, except in so far as these may contravene sec. 91 (5), sec. 126, or other provision of the Public Health Act 1875; but it will often be expedient to invite the co-operation of managers of such schools in efforts for securing the public

health. Experience shows that they are usually ready to defer to the representations of the authority responsible for the public health of the district.

13. Reports to sanitary authorities, advising the closure of a school or schools in any district, are to be treated as "special" reports within the meaning of the General Orders of the Local Government Board of March 1880, and copies of them should accordingly be sent to the Board. These reports should state the grounds upon which the medical officer of health advocates the closure of the school or schools in preference to the exclusion of particular scholars.

14. All notices of the sanitary authority for the closing of public elementary schools should be addressed in writing to the managers, and should state the grounds on which the closing is deemed necessary.

All such notices should specify a definite time during which the school is to remain closed; this should be as short a period as can be regarded as sufficing on sanitary grounds; a second notice may be given before the expiration of the first, if it should be found necessary to postpone the reopening of a school. The managers of schools, after complying with the requirements of the sanitary authority, have the right of appeal to the Education Department if they consider any notice to be unreasonable.

GEORGE BUCHANAN.

December 1890.

APPENDIX No. III

General Memorandum on the Proceedings which are advisable in Places attacked or threatened by Epidemic Disease.

1. Wherever there is prevalence or threatening of cholera, diphtheria, fever, or any other epidemic disease, it is of more than common importance that the statutory powers conferred upon sanitary authorities for the protection of the public health should be well exercised by those authorities, acting with the advice of their medical officers of health.

2. Proper precautions are equally requisite for all classes of society. But it is chiefly with regard to the poorer population, therefore chiefly in the courts and alleys of towns, and at the labourers' cottages of country districts, that local authorities are called upon to exercise vigilance, and to proffer information and advice. Common lodging-houses, and houses which are sublet in several small holdings, always require special attention.

3. Wherever there is accumulation, stink, or soakage of house refuse, or of other decaying animal or vegetable matter, the nuisance should as promptly as possible be abated, and precaution should be taken not to let it recur. Especially examination should be made as to the efficient working of sewers and drains, and any defect therein and any nuisance therefrom, or from any foul ditches or ponds, should be got rid of without delay. The ventilation of sewers, the ventilation and trapping of house drains, and the disconnection of cistern overflows and sink pipes from

drains should be carefully seen to. The scavenging of the district, and the state of receptacles for excrement and of dust-bins, will require close attention. In slaughter-houses, and wherever animals are kept, strict cleanliness should be enforced.

4. In the removal of filth during periods of epidemic disease, it is commonly necessary to employ chemical agents for reducing or removing the offence, and harm which may be involved in the disturbance of the filth. In the removal of privy contents these agents are more particularly wanted if the disease in question be cholera or enteric fever. The chemical agent should be used liberally over all exposed surfaces from which filth has been removed. Unpaved earth close to dwellings, if it be sodden with slops or filth, ought to be treated in the same way.

5. Sources of water-supply should be well examined. Water from sources which can be in any way tainted by animal or vegetable refuse, especially those into which there may be any leakage or filtration from sewers, drains, cesspools, or foul ditches, ought no longer to be drunk. Above all, where the disease is cholera, diarrhœa, or enteric fever, it is essential that no impure water be drunk.

The liability of leaky water-pipes to act as land drains, and to receive foul matters as well as land drainage through their leaks, is not to be overlooked. And such leaky pipes, running full of water with considerable velocity, are liable to receive, by lateral insuction at their points of leakage, external matters that may be dangerous. This latter fact is not recognised so generally as it should be; and ignorance of it has probably baffled many inquiries in cases where water services have in truth been the means of spreading disease.

If, unfortunately, the only water which for a time can be got should be open to suspicion of dangerous organic impurity, it ought at least to be boiled before it is used for drinking, but then not to be drunk later than twenty-four hours after it has been boiled. Filtering of the ordinary kind cannot by itself be trusted to purify water. It cannot be too distinctly understood that dangerous qualities of water are not obviated by the addition of wine or spirits.

6. When there appears any probable relation between the distribution of disease and of milk supplies, the cleanliness of dairies, the purity of the water used in them, the health of the persons employed about them, and the health of the cows that furnish milk, should always be carefully investigated. Even apart from any apprehension of milk being concerned in a particular outbreak of disease, it is desirable that English people should adopt the custom, which is always followed in some continental countries, of boiling all milk at once upon its reception into a house.

7. The washing and lime-whiting of uncleanly premises, especially of such as are densely occupied, should be pressed with all practicable despatch.

8. Overcrowding should be prevented. Especially where disease has begun the sick-room should, as far as possible, be free from persons who are not of use to the patient.

Ample ventilation should be enforced. It should be seen that windows are made to open, and that they are sufficiently opened. Especially where any kind of infective fever has begun, it is essential, both for patients and for persons who are about them, that the sick-room and the sick-house be constantly traversed by streams of fresh air.

9. The cleanliest domestic habits should be enjoined. Refuse matters should be speedily removed or destroyed ;

and things which have to be disinfected or cleansed should always be disinfected or cleansed without delay.

10. Special precautions of cleanliness and disinfection are necessary with regard to infective matters discharged from the bodies of the sick. Among discharges which it is proper to treat as infective are those which come in cases of small-pox and scarlatina from the affected skin ; in cases of cholera and enteric fever from the intestinal canal ; in cases of diphtheria and scarlatina from the nose and throat ; likewise, in cases of any eruptive or other epidemic fever, the general exhalations of the sick. The caution which is necessary with regard to such matters must, of course, extend to whatever is imbued with them ; so that bedding, clothing, towels, handkerchiefs, and other articles which have been in use by the sick may not become sources of mischief, either in the house to which they belong or in houses to which they are conveyed. So far as articles of this class can be replaced by rags or things of small value, it is best to use such things and burn them when they are soiled. Otherwise clothing and infected articles should be subjected to the disinfectant of the sick-room, or be removed for disinfection by heat.

In enteric fever and cholera the evacuations should be regarded as capable of communicating an infectious quality to any nightsoil with which they are mingled in privies, drains, or cesspools ; and after such disinfection of them as is practicable, they should be disposed of without delay and under the safest conditions that local circumstances permit. They should not be thrown into any fixed privy receptacle, and above all, they must never be cast where they can run or soak into sources of drinking water.

11. All reasonable care should be taken not to allow infective disease to spread by the unnecessary associa-

tion of sick with healthy persons. This care is requisite, not only with regard to the sick house, but likewise with regard to schools and other establishments wherein members of many different households are accustomed to meet.

12. If disease begins in houses where the sick person cannot be properly accommodated and tended, medical advice should be taken as to the propriety of removing him to an infirmary or hospital. Every sanitary authority should have in readiness a hospital for the reception of such cases.

Where dangerous conditions of residence cannot be promptly remedied, it will be best that the inmates, while unattacked by disease, remove to some safer lodging.

13. Privation, as predisposing to disease, may require special measures of relief.

14. In certain cases special medical arrangements are necessary. For instance, as cases of cholera in this country often begin somewhat gradually in the comparatively tractable form of what is called "premonitory diarrhœa," it is essential that, where cholera has appeared, arrangements should be made for affording medical relief without delay to persons attacked, even slightly, with looseness of bowels. So, again, where small-pox is the prevailing disease, it is essential that all unvaccinated persons (unless they previously have had small-pox) should very promptly be vaccinated; and that re-vaccination should be performed in cases properly requiring it.

15. It is always to be desired that the people should, as far as possible, know what real precautions they can take against the disease which threatens them, what vigilance is needful with regard to its early symptoms, and what (if any)

special arrangements have been made for giving medical assistance within the district. For the purpose of such information, printed handbills or placards may usefully be employed, and in cases where danger is great, house-to-house visitation by discreet and competent persons may be of the utmost service, both in quieting unreasonable alarm and in leading or assisting the less educated and the destitute parts of the population to do what is needful for safety.

16. The present memorandum relates to occasions of emergency. Therefore the measures suggested in it are essentially of an extemporaneous kind; and permanent provisions for securing the public health have, in express terms, been but little insisted on. It is to be remembered, however, that in proportion as a district is habitually well cared for by its sanitary authority, the more formidable emergencies of epidemic disease are not likely to arise in it.

17. Provision by the public authority for disinfection by heat of bulky articles, and of those which cannot without injury be exposed to chemical agencies, ought always to be in readiness. Without such provision no complete disinfection can be effected. Partial and nominal disinfection, besides being wasteful, may be mischievous, as giving rise to a false security.

18. The following system of domestic disinfection may be commended to sanitary authorities who have already provided adequate public means for the disinfection and for the disposal of infected matters and things:—

- (a) For the purposes of the sick-room, such as the reception of soiled handkerchiefs, sheets, and the like, as well as for the swabbing of floors, a

valuable disinfecting solution may be made with perchloride of mercury. It is well to have this solution slightly acid, coloured also in such a way that it shall not readily be confused with drinks or medicines ; and proper caution should be given to avoid accidents in its use. Sanitary authorities will find it advantageous to have such a solution¹ prepared under the direct instructions of the medical officer of health, and supplied of a uniform strength at the infected house upon the order of that officer.

(*b*) In places provided with proper systems of excrement disposal, excrements of cholera and enteric fever, after being treated in detail with the same disinfecting solution in ample quantity, may be safely put into the ordinary closet ; but special care as to the flushing of drains and sewers, and special frequency in the removal and exchange of excrement receptacles, will commonly be wanted. Where the only closet is one that communicates with a cesspool or privy pit, the best arrangement for the disposal of infected stools that, under these improper local circumstances, may be found practicable will have to be adopted.

(*c*) A substance generally available in the removal of filth from privies and ashpits, and for application

¹ A solution fitted for the desired purposes may be made with $\frac{1}{2}$ oz. corrosive sublimate, 1 fluid oz. hydrochloric acid, and five grains of commercial aniline blue, in three gallons (a bucketful) of common water. It ought not to cost more than 3d. the bucketful, and should not be further diluted. The use of non-metallic vessels (wooden or earthenware house tubs or buckets) should be enjoined on those who receive it, and articles that have been soaked in it should be set to soak in common water for some hours before they go to the wash.

to foul earth and the like,¹ is sulphate of iron (green copperas), either in a strong solution made by stirring crystals of the salt with five or ten times their bulk of hot water, or in the form of powder, to which form the crystals may be readily brought after desiccation. This agent should be used in quantity sufficient to destroy all odour, and in the removal of filth accumulations it should be well mixed with successive layers of the matter to be removed. The dry form of application is to be preferred where masses of wet or semi-solid filth have to be dealt with.

- (d) For disinfection of the air of rooms, after the room has been prepared by the removal of persons and of such articles as are best disinfected by heat, and by the closure of windows and crevices, sulphurous acid gas in ample quantity may be evolved, the doors being kept closed for six hours or more. The amount of sulphurous acid required for the disinfection of a moderate sized room can be obtained by burning $1\frac{1}{2}$ lbs. of sulphur (roll brimstone) in a pipkin over a small fire placed in the middle of a room, with an old tray or the like to protect the flooring. These processes should be effected by skilled persons acting under the directions of the medical officer of health.

- (e) After measures of disinfecting a room have been taken, all wall paper should be stripped from the

¹ The removal of dangerous filth is here the object to be attained. It cannot confidently be stated that either the iron salt or any available substance will effect a true disinfection of such masses of filth as are here in question.

walls and be burned, and the room ought to have its ceilings and walls thoroughly washed or lime whited.

19. For detailed information on disinfection by heat, on hospital accommodation, on scarlatina, and on small-pox, and on questions of school administration during the prevalence of infectious disease, see the Office Memoranda and Reports on these subjects.

GEORGE BUCHANAN,
Medical Officer.

LOCAL GOVERNMENT BOARD,
MEDICAL DEPARTMENT,
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