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President—Sir ARTHUR MACNALTY, K.C.B., M.D., F.R.C.P.

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A Historical, Epidemiological and Ætiological Study of Measles (Morbilli; Rubeola)

By J. A. H. BRINCKER, M.B., D.P.H., F.I.C.

(*Principal Medical Officer, London County Council*)

DEFINITION

MEASLES is an acute specific contagious disease, probably caused by a virus, which invades the system via the respiratory tract. The period of incubation is from seven to fourteen days, and this is followed by a pre-eruptive period lasting about four days, during which time the patient has catarrhal symptoms, chilliness, sneezing, a cough, and running at the eyes and nose. During the pre-eruptive stage characteristic spots, known as Koplik spots, appear on the buccal mucous membrane.

The pre-eruptive period is followed by the characteristic blotchy deep mulberry red macular eruption which starts on the forehead and behind the ears and quickly spreads over the whole body. There is a rapid rise of temperature as the rash comes out, rapid respiration, bronchial catarrh, and congested mucous membranes.

In uncomplicated cases the temperature falls by lysis as the rash fades; slight branny desquamation of the skin occurs, and a faint mottled staining can usually be seen for some days after the temperature is normal.

The disease is not communicable in the incubation period but is highly infectious in the pre-eruptive stage, and the infection rapidly dwindles and is lost by the fourth or fifth day of the eruption.

HISTORICAL SURVEY

The disease cannot be recognized as such in any writings before Rhazes (d. tenth century). He gives an account of measles in his "Liber Continens" and states clearly that although there is a close affinity between smallpox and measles they are different diseases; smallpox being caused by "heat and putrefaction" in the fermented blood "acting in moisture" whilst measles is caused by a "vehement ebullition of the bile in the blood".

It is interesting to note that Rhazes, to support his views, says that he quotes from authorities who lived two hundred years before him. It may be inferred therefore that measles, as a separate disease, was also known to them. The views propounded by Galen (in his "Methods of Therapeutics", second century) as to the cause of disease and accepted as the theory of humoral pathology were the same as those subsequently enunciated by Rhazes to explain the cause of measles. A

contemporary of Rhazes—Isaac the Israelite—enunciated another and very curious hypothesis of its cause based on an older notion, namely, that measles was caused by the viciousness of the menstrual blood. According to this theory the noxious portion of the child's mother's blood was during pregnancy retained in the infant *in utero*; the mother therefore did not menstruate whilst carrying the baby. Sooner or later, however, the child had to get rid of this vice, and the process of its expulsion gave rise to the attack of measles. This hypothesis was apparently accepted by Thomas Willis (1660) who, in his treatise on medicine, couples smallpox and measles and refers to them as " mixed distempers ". The menstrual hypothesis was indeed an ingenious one, for it explained why every child suffered from measles and perhaps why many parents still think that every child must have measles.

Although the fact of infection generally was recognized for many centuries, measles was not accepted as an infectious disease until the sixteenth century when Jerome Frascator included it with other diseases like *variolae pestilentes febres* (enteric, influenza, and pneumonia), *febris quam lenticulas vel puncticulas aut peliculas vocant* (typhus) and *vere pestiferae febres* (plague) in his " De Morbis Contagiosis ".

In an English manuscript of 1325 the French " rugeroles " is translated by the word " maselas ", and in the " Book of Simples Englishes " by John Aderne, the French " rugoles " is translated by the word " maselys ". In a letter by Pace, Dean of St. Paul's, to Cardinal Wolsey (1518), the word " mezils " is used.

Even at this time there was still great confusion between smallpox and measles, for we find that Thomas Phare in his " Book of Children " (1553) writing of " small pockes and measils " says that " this disease . . . is of two kinds: varioli, ye measils; and morbilli, called of us ye small pocks ".

William Clowes, surgeon to St. Bartholomew's Hospital, in his " Proved Practice for all Young Chirurgeons " (1591) renders the word *variolae* by " measles "; and in (a schoolmaster) Levin's " Manipulus Vocabulorum " (1570) " Ye maysilles " is translated by *variole*. But by 1629 (at any rate in England) these two diseases are entered separately in the returns of deaths issued by the Parish Clerk, and in 1676 Sydenham in his writings clearly distinguishes between smallpox, measles, and scarlet fever.

The word " measles " apparently is of Teutonic origin—mas or maes, meaning a spot. There is another word " mesles " derived from the Latin diminutive *misellus*, a small miser, quoted in William Langland's " The Vision of Piers Plowman " (1362), and there it meant the leprous person. Later on the two words—" mesles ", the leprous, and " *maseles* " or " *measels* ", the disease we are now discussing, became confused, and finally were only used as the English equivalent of " morbilli ".

Up to the eighteenth century we find the words " morbilli ", " rubiolae ", " blacciae ", " lenticula ", " rossalia ", and " rossania " all mentioned in medical books, and there can hardly be any doubt that our disease measles was referred to by these words. The word " morbilli " originated from the Italian *morbillo*, so called to distinguish it from the more serious disease—the plague—which was known as " *il morbo* " (Hebra).

It might be inferred from this short historical summary that the early physicians were unable to distinguish between the various exanthemata which are now generally recognized. I cannot, however, bring myself to accept this conclusion, especially when I recollect that we still have to depend on the bacteriologist to distinguish for us between the various types of enteric fever, that the diagnoses of the food poisons have to be made by him, and that we are still in doubt whether scarlet fever embraces one or more specific entities.

May we not assume that the exanthemata, at any rate measles and smallpox, were so common in those times that they co-existed and often attacked the child at the same time? It must be remembered that, in pre-vaccination days, smallpox was largely a disease of children, and that measles or smallpox, and sometimes both

together, attacked the child population. Both were often so severe that they killed the sufferer in the prodromal stage of the disease. To-day in Bechuanaland, for instance, measles, which is still a very severe and indeed fatal illness in native races and communities, for long periods free from it, is said to accompany or follow smallpox, and the natives call it " the little smallpox ". There is also the Arabian teaching already referred to, in which *variola* was the *morbus* proper and *morbilli* was its diminutive.

That measles was distinguished from smallpox in the time of Queen Elizabeth follows from the following dictionary definition : " It is a disease with many reddish spottes or speckles in the face and bodie, much like freckles in colour " (Baret).

It must be remembered that the art of medicine in those days was under the sway of authoritative Arabian tradition, and that the practitioner was then taught to make the illness of his patient fit the formula laid down, just as to-day original research is sometimes hampered by the dead hand of authority. Remember the well-known saying of William James :—

> " There are three stages in the history of every medical discovery. When it is first announced people say it is not true. Then a little later when its truth has been borne in on them, so that it can be no longer denied, they say that it is not important. Then, after that, when its importance becomes sufficiently obvious they say anyhow it is not new."

The ingenious and authoritatively accepted hypothesis of " the menstrual vice " as the cause in one way or another of the exanthemata prevented the physicians of that day from recognizing them as infectious diseases. However, we are told that " certain cases of smallpox, in which the pustules were wholly or partially represented by, or changed into, broad spots level with the skin, red or livid in colour, and in which hæmorrhages occurred from the nose, lungs, bowels, or kidneys ", that is to say, cases of hæmorrhagic smallpox, were apt to be called by the name of " smallpox and measles mingled " (1670–1674). Sydenham's very clear description of the symptoms expressed in his account of the epidemics in London in 1670 and 1674 leaves no doubt whatever that he was describing cases of measles ; his description of their behaviour is as clear and minute in all essential points as they would appear in a modern textbook of infectious diseases (Obs. Med. Book IV, Chapter 3, 1765). It may be of interest to note that, in the first half of the year 1674, London was affected by a measles epidemic causing 795 deaths, and in the second half by one of smallpox, causing 2,507 deaths. But in his analysis of the cases, Sydenham points out that the measles epidemic caused excessive deaths attributable to pneumonia and diarrhœa amounting to a total average of 468 deaths per week for the first six months, whereas in the smallpox months these deaths were only 349 per week. In other words, he hints that many of the deaths in the first six months must have been indirectly due to measles although they were registered under such headings as " convulsions ", " teeth ", " diarrhœa ", and " consumption ".

Dr. Robert Watt (1808) in his " Relative Mortality of the Principal Diseases of Children ", made an analysis of the children under 10 years of age who died in Glasgow during thirty years. This analysis is one of the earliest and most memorable inquiries into vital statistics in this country. In his analysis Watt points out that, if child-life was first attacked by smallpox, a following epidemic of measles resulted in a lower fatality than if measles occurred first. He accounts for this by maintaining that, if a child recovered from smallpox, it was fortified against an attack of measles. And it would appear that he condemns vaccination as the direct cause of a higher mortality in measles. On these facts we should say that Watt's observations were correct but his conclusions wrong ; that whether attacked by smallpox or measles the child who was likely to succumb was the delicate or weakly individual—the rickety, the marasmic, the lymphatic, or pre-tuberculous child—and that the healthy child was the one who was more likely to survive. If therefore smallpox preceded measles it would kill

off the weakly and leave the strong. When measles followed, as the weakly had already succumbed from smallpox, the mortality from measles would naturally be lower.

This is true to-day, for, as will be pointed out, the fall in mortality of measles has undoubtedly been due to improvements in child hygiene and, consequently, the reduction of the number of children predisposed to the complications which are so fatal to child-life.

Geography

With the world-wide reduction of smallpox by the introduction of vaccination, measles has now become, with the exception of influenza, perhaps the most prevalent and widely distributed of all infectious diseases. It is met with in all countries and all climates, temperate, sub-tropical, and tropical. Measles may be rarer in some countries than in others, but this is due not to latitude but rather to the accident of their isolation, commercial or otherwise, from those densely populated communities in which the disease is endemic. On the whole it is more common in temperate climates, but that is due to the same cause, namely, that the densely populated and industrialized communities happen to live in temperate climates. When and where measles is accidentally imported into those isolated communities from which it has for some time been absent, it rages with great violence, attacking a large proportion of the population and producing a high death-rate, until it exhausts all susceptible material, and it may then disappear entirely from that community until it happens to be reintroduced. In this respect it follows the usual rules of epidemiology already known to and enunciated by Hippocrates.

As stated, measles is endemic in densely populated centres. In London, and in other cities, both in this country and on the Continent, it recurs in epidemic form at regular intervals which vary from two to seven years.

In less populous areas its general distribution varies, and epidemics occur at irregular periods. In closed communities, like preparatory and public schools, it may be absent for many years, but when it does break out it is usually associated with serious complications and incapacity.

Measles is essentially a disease of childhood. For instance, in London it is found that most children have been attacked before their 7th year, and therefore, so far as the elementary schools are concerned, it is a disease of infants' departments and is of no significance in senior departments.

In one of the first investigations carried out in London elementary schools, Dr. C. J. Thomas showed that measles did not become epidemic in a school or district until the susceptible elements reached 40%, that the epidemic raged until the susceptibles were reduced to a figure below 20%, and that the epidemic then died down. The 20% of children who were not attacked apparently developed a transient immunity, for they were found to be susceptible by the time the next epidemic occurred.

In London these epidemics recur regularly every two years, beginning in the late autumn, reaching their highest incidence in the winter or early spring—usually February or March—and exhausting themselves by May or June.

The 40% susceptible material in the community which is necessary to start an epidemic outbreak is made up of the susceptible children who have been admitted to school since the previous epidemic, together with that proportion of the 20% of susceptibles who escaped an attack during the previous epidemic and have again in the interval become susceptible to the disease.

This process of developing immunity in one epidemic, to lose it again before the onset of another, is now a well-recognized factor, and has been experimentally demonstrated in the field-work of many epidemiologists, notably by Professors Greenwood and Topley. It was known to the ancients and mentioned by Hippocrates in his writings on Epidemics (470 B.C.). The process is possibly one in which the person

receives repeated subliminal doses of the infection, incapable of producing the disease but enough to stimulate the organism to put up sufficient resistance to infection. When the immediate need for resistance disappears, the stimulus fades into the background and the person once again becomes susceptible.

The Registrar-General in his report for 1891 pointed out that :

> " When there has been a severe outbreak in any year in a given area, it will be found that the returns of the next year show a subsidence in the area itself, but an extension in the adjoining districts; another year, and these districts are also comparatively free, while a wider circle of surrounding districts has become infected."

In the same report attention is also drawn to the fact that high minimum rates of measles mortality are usually found in large populous areas, without breaks in the population, and that low minimum rates are apparently associated with populations broken up into detached groups " since the infection may, under such circumstances, fail to be conveyed from one group to another, in which case it may die out for a season ". This actually does occur in isolated regions such as the Hebrides, the Shetlands, &c.

The occurrence, on the other hand, of high maximum rates is due to bad sanitary conditions, or gross carelessness, or both. There is no doubt that the advances made in public health both as regards housing improvements, ante-natal and post-natal care of mothers, and greater attention to the feeding and care of children, have jointly contributed to the continuous fall in the death-rate of measles.

While, as already stated, measles is found in all latitudes, there is reason to believe that it is milder and more benign in temperate climates than elsewhere.

The season at which measles epidemics prevail varies greatly in different parts of the world. Severe epidemics have been reported as occurring at all seasons. In temperate countries they are more frequent in the colder than in the warmer months. Severe epidemics have, however, been reported in the middle of the summer in such countries as Spain and south Russia. Measles in London has become more or less stabilized. Usually, as already stated, the biennial epidemic begins at the end of October, but its effect, as regards both incidence and mortality, does not become appreciable until the middle or end of the following January. Both then increase rapidly, to reach their maximum in April, or early in May, and then there is a rapid fall until the epidemic exhausts itself by the end of June. From records published by Harman and Perkins this appears also to be true in the U.S.A., in Australia, and in South Africa, though in the two latter countries the months are reversed.

Neither the character of the soil, nor the degree of elevation above sea-level, nor the nearness to or distance from the sea appears to have the least influence upon the disease. In its relation to race, measles has no prejudices ; all races are susceptible to it and in all it is a disease essentially of childhood.

Measles is one of the most infectious of all the infectious diseases. It is spread by the movements of infected persons who, as already stated, are highly infectious long before the rash appears, and the disease is spread by " droplet infection ".

The intensity of different epidemics varies even in communities where the disease recurs at regular periods.

The severity and fatality of the cases depend on the prevalence, associated with the disease, of influenza, pneumonia, and streptococcal and other infections, just as in the past they depended on its association with smallpox. It will be noted that the mortality curve for measles follows closely that for bronchopneumonia.

Variability in the severity of outbreaks has been recorded in London and other English towns from time to time. In communities which have been long free from it, measles may become widespread, severe, associated with a variety of complications, and produce a very high mortality. This may be ascribed to many causes, some preventable and others possibly not. In the preventable group of causes are gross

ignorance as to how to limit the spread of the disease and to treat those suffering from it, exposure owing to lack of suitable housing and clothing, neglect of medical aid and nursing care, and gross insanitary conditions leading to secondary infection in persons whose resistance has been lowered by measles. We have come to appreciate how mass infection introduced into a susceptible community tends to raise the virulence of the infecting agent.

Amongst the apparently non-preventable causes, at any rate, in so far as any particular epidemic is concerned, is the condition of persons already weakened by previous neglect or disease. It is the tuberculous, the pre-tuberculous, the lymphatic, the bronchitic, the marasmic, and the badly-fed child that measles kills.

There have been numerous epidemics in which the mortality was for one cause or another excessively high, such for instance as the epidemics : (1) Introduced into the native population of the Amazon (1749). (2) In Estonia (1829). (3) Amongst Indians of Hudson Bay territory (1846). (4) Introduced by the white man into the Hottentot community of the Cape (1852). (5) In Tasmania (1854 and 1861). (6) In Mauritius (1874). (7) In the Fiji islands (1875) when between one fifth and one quarter (calculated at about 20,000 persons of all ages) of the population died from measles or its consequences. (8) Amongst the women and children in the Boer concentration camps in the South African war (1900–1901)—terribly fatal in its character. These women and children were brought together out of kindness, to prevent them from dying from starvation, but epidemic measles instead of hunger carried them off in their hundreds. This mortality was due entirely to lack of proper treatment, care and attention on the part of the mothers of the affected children and the women placed in charge of the camp.

Measles is a disorder in which the lightness or severity of the cases depends essentially upon the care and attention bestowed upon the individual patients. When, therefore, it breaks out in circumstances where proper care and attention are unobtainable or lacking, or where ignorance and neglect exist, it becomes a very alarming and deadly disease. Measles occurring during war-time becomes a serious disease. Examples of outbreaks at such times are on record and it has been shown that the causes of its deadliness under these conditions were the same, namely, improper care and attention, and that death was not due to the severity of the disease itself but to want of shelter, proper food, and medical and nursing attention which predisposed the patient to one or other of the fatal complications.

Such, for instance, were the outbreaks of measles : (1) In the National Army of Paraguay in the war with Brazil in 1865. (2) In the Confederate Army of America in 1866. (3) In the French Garde Mobile during the Siege of Paris in 1871. (4) During the last war, amongst recruits from the distant islands stationed at various training depots.

Ætiology

As already stated, measles ranks as one of the most highly infectious diseases, and in that respect must be placed in the same category with chicken-pox and smallpox.

The disease is characterized by signs and symptoms which cannot very well be misconstrued. Of the exanthemata, it is one of the most constant as regards its progress and development, from the instant when infection takes place through its periods of incubation, invasion, establishment, and cure. The attack is followed very rapidly by the development of a strong and lasting immunity, and by inference, the rapid elimination and disappearance of the infecting agent—the virus. This virus, as we know by experiment, is present in the blood of the sufferer during the period of invasion and perhaps up to the second day of the disappearance of the rash ; thereafter it is irrecoverable from the blood and rapidly disappears.

It is now known that an immunity due to the development of specific antigens rapidly takes place in the body tissues and is present in the blood of the patient soon

after the stage of convalescence, and that convalescent measles serum obtained from such a person may be used either to prevent an attack or to modify the disease in a person already infected with and incubating it. These antigens must therefore have a specific germicidal effect on the virus of measles and be responsible for the early loss of infectivity of the patient suffering from the disease.

Infants at the breast and up to 9 months old have a high resistance to infection, possibly due to antigens derived from the mother, a suggestion which would seem to be confirmed by the presence of this antigen in placental extract. Infants from 18 months to 2 years of age, on the other hand, are highly susceptible to measles and this susceptibility exists till about the 5th year, after which it diminishes.

As the ages 1 year to 5 years of a child's life are also those during which it is susceptible to those diseases which complicate measles, the mortality from measles is significant at those ages. The complications which are prone to attack the child are bronchopneumonia, ophthalmia, otitis media, diarrhœa. Measles, therefore, is a serious and dangerous disease for the pre-school child, and all preventive measures must aim at protecting the child at those ages. A child attacked should receive proper care and attention, and if these cannot be obtained in the home it is far better for the child to be admitted to a fever hospital where it can be treated as far as is possible under open-air conditions.

Bacteriology of Measles and Production of Experimental Measles

The cause of measles is as yet unknown ; but the results obtained in connexion with the production of experimental measles, whether in monkeys or in man, strengthens the view that the causal organism is a virus.

Inoculation of human beings with blood of patients ill with measles, even when very small quantities are used, will produce measles in the inoculated persons. This was first demonstrated by Francis Home, who, inspired by the successful results obtained by inoculation against smallpox, then newly introduced, took the blood of a patient in the eruptive stage of measles and applied it to the arm of a child in the same way as vaccination. The child developed an attack of measles in a mild form. This experiment is recorded by him in his " Medical Facts and Experiments " published in Edinburgh in 1759. Similar experiments have since been carried out by others with like results.

Herrman (1915) attempted to produce a form of active immunity in infants whilst still at the breast. As the child at the breast is assumed to be immune, he concluded that if, by inoculation with the virus, the child did develop the disease, it would be in a mild form. He therefore instilled into the nares daily doses of secretions which he took from measles patients. It was soon demonstrated that this experiment, though a forward step in the right direction, was unsafe.

More recently, investigators who have produced experimental measles in children have come to the conclusion that, in those in whom they succeeded in developing an attack, the symptoms produced by acquired measles were in no way different from or milder than those in cases developing the disease in the usual way. It may be assumed, therefore, that little or no progress can be made until the virus of measles has been isolated in pure culture and a vaccine prepared for active immunization.

In addition to the hæmolytic streptococci of many strains, invariably present, and the pneumococci which, as we now assume, are already present in a child exposed to measles and are responsible for the complication from which the child may subsequently suffer, Ruth Tunnicliff (1918) isolated and grew in pure culture a diplococcus (known as the " Tunnicliff diplococcus " or the " Greencoccus ") from the mucous membranes and blood of measles patients. As opsonins and other specific bodies were present in the blood of patients who had measles, Heklower concluded that this coccus had some significance in an attack of measles. But Park, Williams, and others

(1927) showed that the tests employed by Tunnicliff and Ferry and Fisher were of no value in establishing this coccus as the cause of measles.

Anderson and Goldberger (1911) carried out a series of experiments on monkeys to obtain, if possible, knowledge which might be of use in the prophylactic inoculation of humans against measles. They soon proved that monkeys, like men, are susceptible to the virus of measles ; that, when injected with blood from persons ill with measles, they developed an illness after from six to eight days which, as regards symptoms and reactions on the tissues, resembled human measles even to the extent of producing Koplik spots, leukopenia, and a subsequent desquamation. Again, they showed that the disease could readily be transmitted from monkey to monkey, by the usual methods of contact infection, by blood injections, and by transmitting the secretions of the mucous membranes ; and they proved conclusively that once they have suffered from an attack monkeys are immune against further attacks. Having established these facts they next attempted to produce a vaccine which could be used for prophylactic inoculation ; this they did by passage through monkeys, both in pure form direct from the sick animal and, also, by previously subjecting the virus to a variety of physical and chemical influences. They found that repeated transfers of blood from monkey to monkey resulted in an attenuation of the virus of measles to such an extent that it failed to induce the disease experimentally at the eighth transfer. Similarly, when passage of measles from monkey to monkey by contact was employed, the infection ultimately failed to infect.

The experimental work on monkeys by Anderson and Goldberger therefore led to no conclusions. It is still obscure why the measles virus lost its infectivity, and so it leaves the question of prophylactic vaccination against the disease still unsolved. But as success has already been obtained in such diseases as smallpox, distemper, and rabies, it is quite possible that this will before long be the case as regards measles.

Characteristics of Measles Epidemics in Europe and America

Measles is a disease which is well known and endemic in all European countries and on the Continent of North America. Its epidemiological aspects have been the subject of much study ; but this study has of necessity been incomplete as records of epidemics are very scanty. In England and Wales as a whole the disease was notifiable from 1915–1919. Notification by the medical practitioner was restricted to the first case in the home, the duty of notifying succeeding cases being placed on the parent.

Except in Denmark, and in New York, measles has not been notifiable long enough to afford sufficient information to permit of a comprehensive study of the disease in all its epidemiological aspects. A comparative study of its mortality has, however, been possible, and from this a fairly adequate knowledge of the behaviour of the disease has emerged.

In most temperate climates the disease is most prevalent in the winter and spring months, though summer epidemics have from time to time been recorded, as already stated, in the Iberian peninsula and certain other countries. In all these countries the disease is endemic and develops epidemic cycles, but each country seems not to affect the other as regards the spread of infection.

Taking the periods of maximum and minimum mortality as the best index of its prevalence it appears that the rate of spread under different conditions varies considerably, being more rapid in countries where the population is more or less evenly distributed and not collected in various centres.

The mortality curve has sharp fluctuations, the sharpness varying according to population distribution, but in every case a phase of high mortality is immediately succeeded by one of low mortality. This phenomenon tends to confirm the theory that immunization of the susceptible community is brought about on a large scale

by epidemics, and that the next epidemic will only occur when the susceptibles have increased to a sufficient number.

Season undoubtedly has a powerful influence on mortality. Except in the rare summer epidemics the most constant factor is the period of low mortality, which is September in most temperate countries, whilst the period of maximum mortality varies somewhat according to latitude. In this country it is in April, in the northern States of the U.S.A. it is in May, but in the southern States it is six weeks earlier.

Latitude also has an effect on the mortality of measles, but whether this is due to temperature, moisture, sunlight, or other unknown factor, has still to be demonstrated.

In this country severity of disease, or predisposition to complications, as shown by mortality, seems to go with latitude. As the table indicates, mortality is highest in the North and Midlands and lowest in the South. Whether this must be attributed to latitude or to density of population or industrial conditions remains still to be explored. But it must be remembered that measles, as such, does not kill the sufferer, deaths being invariably due to the complications following in the wake of the disease, the most important being bronchopneumonia.

Bronchopneumonia, apart from measles, has its maximum mortality in March and its minimum in August ; it is a disease very fatal in the young and is associated with the prevalence of the hæmolytic streptococcus and the pneumococcus, which, naturally, are more prevalent in industrial and urban areas with overcrowded and insanitary conditions. High mortality in measles may possibly occur in those persons who are harbouring these germs when they are invaded by the infection of measles, for the mortality of measles follows in the wake of, and does not coincide with, that of bronchopneumonia.

The parallelism of these mortality curves is very close if we compare the deaths for the ages 0–15 and even closer for the ages 1–4 years.

Incidence and Mortality

The following summary is taken from Creighton's book : During a full half century of registration (1801–1851) in all England and Wales the incidence of measles has fluctuated somewhat from year to year, but the disease has always remained one of the notable causes of deaths amongst infants.

In the decennial period 1871–1880, the annual average death-rate of measles was 377 per million living. In the next decade 1881–1890 it rose to 441. Most deaths during these periods were recorded from May to July, owing to the greater number of attacks in summer and not to the excessive fatality of the disease at that season.

From 1845–1874, it appears that the deaths touched a higher point in mid-winter (November–January) than in the summer, a fact which may be readily accounted for by the injurious effects of the town air in winter upon a disease which is largely one of the respiratory organs.

Most of the deaths from measles fall at present upon the ages from 6 months to 3 years, just as they did when the deaths were comparatively few from 1768–1774.

Deaths of adults, which were not altogether rare in the first great epidemic of modern times in 1808, are seldom heard of at present, for the same reason that adult deaths used to be uncommon in smallpox, namely, that the disease is contracted by almost everyone in infancy or childhood. Although the deaths from measles sometimes reach large totals, yet it is the common experience of practitioners that a strong or healthy child rarely dies of measles, and that the fatalities occur amongst the infants of weakly constitution and especially in the numerous families of the working classes in the most populous centres of mining, manufactures, and shipping.

These facts, taken from Creighton, give us an account of the incidence and death-rate of measles in England and Wales during the last century. It will be seen that

measles was then, as it is now, a serious disease, providing a high mortality, affecting chiefly the younger members of the community—but not invariably so, for on occasions there were indications that mortality occurred even amongst adults.

As far as London is concerned, there has been a definite reduction, since the ten-years' period 1891–1900, in the death-rate of measles, and this is more pronounced in character since the ten years' period 1911-1920, as the following figures will show :—

Death-rate per million of population—London.

		Males	Females
1851-1860	...	578	493
1861-1870	...	625	526
1871-1880	...	558	463
1881-1890	...	693	582
1891-1900	...	631	539
1901-1910	...	486	398
1911-1920	...	417	308
1921-1930	...	192	146
1931-1932	...	128	88
1933-1934	..	130	96
1935-1936	...	85	61

It will be noted that the mortality is invariably lower in girls than in boys.

Again it will be observed that the big decline in mortality began in 1920 and has continued ever since. This drop in mortality is sometimes ascribed to the falling birth-rate. This cannot be the case, for the number of measles cases reported from the schools during every biennial epidemic remains the same ; that is to say, the incidence of the disease amongst children remains the same, but the actual number of deaths each year must be ascribed to the general improvement in child health which has come about by legislation and education. We no longer see, in the same numbers, children who are tuberculous, rickety, debilitated, or marasmic, or who suffer from those deficiencies which lead to complications which are the causes of mortality in those attacked by measles.

This material improvement in the health of children must be attributed to the better attention and care given to mothers and children as a result of various enactments. These enactments have enabled local authorities to provide means for improving the health and vigour of children and to appoint officers, such as health visitors, maternity and child welfare doctors, and school doctors, to enforce them, and generally, by education, parents and teachers have learned that measles is a dangerous and destructive disease in the young, more especially in those who have previously been injured by disease or neglect.

The introduction of a system of school medical inspection by the London County Council in 1900 was undoubtedly responsible for drawing attention to the many defects which existed in children attending school, and at the same time made it possible to control the spread of infection in school. In fact, soon after the inception of school inspection, an investigation as to the behaviour of measles in schools was carried out by Dr. Thomas (to whom I have already referred) and Dr. Davies, the Medical Officer of Health of Woolwich, in which exclusion of susceptible children from infants' schools was tried with the view of controlling the mass spreading of the disease. This experimental exclusion of contacts, varied in degree from time to time, has been carried out and carefully controlled during every epidemic in London since 1900. The steps taken to control measles epidemics in London have been attended with success, for they have undoubtedly been responsible, if not for preventing epidemics, at any rate for slowing their progress through London. One of the causes of the lowering of the death-rate from measles is that both parents and teachers have come to recognize the disease as a serious one. The findings, in the several reports on

the epidemics, played an important part in securing the enactment of the Maternity and Child Welfare Act 1918—whereby local authorities were empowered to appoint health visitors, and to provide district nurses—and drew attention to the need of admitting selected cases of measles to fever hospitals. This control of measles in schools has been brought to a high standard of efficiency, for during each biennial epidemic there is now a complete co-ordination of forces between, on the one hand, the London County Council as the school authority through its teachers, school doctors and school nurses and attendance officers, and, on the other hand, the Metropolitan Sanitary Authorities through their Medical Officers of Health, health visitors, and district nurses. These co-ordinated agencies now deal with children in school, at home, at play, whether as sufferers, as contacts, or as those who should be protected against infection. Children suffering from measles who cannot be satisfactorily treated at home, whether owing to overcrowding, insanitary arrangements, or to want of medical and nursing attention, are now admitted at as early a stage as possible to one of the fever hospitals, where they are nursed back to health under open-air conditions. Their removal to hospitals from overcrowded homes also prevents the disease from attacking the younger members of the family who are not as yet attending school.

Legal Enactments

The following Acts, all placed on the Statute Book since 1900, viz. :—

Midwives Acts, 1902, 1918,
Medical Inspection (Examination and Provision of Meals) Act, 1907,
Education Act, 1921 (which repealed the last-named Act, the provisions of which it re-enacted),
Notification of Births Act, 1907,
Notification of Births (extension) Act, 1915,
Maternity and Child Welfare Act, 1918,

have, in one way or another, directly or indirectly, played a part in the reduction of the mortality from measles in the child community in so far as they have resulted in the lessening of nutritional diseases.

Gradually, the more common factors contributing to death from measles are disappearing. On the other hand there are indications of an increase in a previously unknown complication of measles, viz. post-measles encephalitis. The ætiology of this disease is still unknown, but it is a very fatal complication.

As a result of school medical inspection and attendance at child welfare centres, teachers and parents have learned, as already stressed, that measles is a disease particularly dangerous to children of pre-school age ; that needless exposure to infection, especially of the young child, should be avoided ; that patients, for their own sake and to prevent risk to others, require isolation and to be kept in a well-ventilated room ; that the best treatment to prevent complications is the open-air method, and that consequently a child is better in hospital than at home ; that the causes of death are the complications following on measles and not the disease itself. The danger lies in the presence and spread of the hæmolytic streptococcus, the pneumococcus, and the diphtheria bacillus. This fact is now so well established that in the infectious hospitals of the London County Council it has become a routine method of treatment to give each child with measles a prophylactic dose of diphtheria and scarlet fever antitoxin on admission.

Periodicity of Measles Epidemics

This subject was brought very prominently before this Society in 1918, by the late Dr. Brownlee. In his contribution, which must have entailed a great amount of

calculation and time, Brownlee demonstrated, by means of statistical analysis and periodigrams, that, in London, measles had come to behave in a static way, and had a recurrent periodicity which could be accurately represented mathematically.

His periodigrams clearly indicated to him that there were two types of measles existing in London, one north of the Thames with a recurrent periodicity of ninety-seven weeks, and the other south of the Thames with a recurrent periodicity of eighty-seven weeks. This theory of periodicity was based on evidence, previously obtained and presented to the Royal Society in a paper on the behaviour of tuberculosis. The existence of one kind of age-distribution of mortality from phthisis in Cornwall and of two other kinds in Ireland and in London led Brownlee to believe that there were three strains of tubercle bacilli producing three types of phthisis, viz. the " young ", the " middle-age ", and the " old-age " phthisis in these places. Similarly, his study of measles led him to believe in the theory of the continuous variation of the germ of measles, governed by physico-chemical laws. He was of the opinion that these changes could, as it were, be studied *in vitro* and therefore apart from environment.

Dr. Brownlee said : " Of periodicities in infectious diseases two explanations are possible . . . these two explanations have very different bases. In the one the infecting organism is the main factor. In the second, the conditions of the people." He went on to say : " Of course, these theories are not mutually exclusive ; the point to be determined is their relative importance. My opinion is strongly in favour of the first hypothesis."

The late Sir William Hamer, in a very able paper, went over the whole ground of Brownlee's hypothesis. With data prepared for him by Mr. B. E. Spear (of the Statistical Section of the Public Health Department, London County Council), he showed that Brownlee's conclusions did not hold, and that such periodicity of measles as exists could very readily be explained from the point of view of environment. Hamer pointed out that prior to 1870, the peak periods of measles mortality actually occurred in mid-summer, and that since that time the periods between predominant " peaks " in successive years had decreased generally from approximately one hundred and eight weeks in the forties to a minimum of about eighty-eight weeks late in the eighties, and thereafter had remained, roughly speaking, about one hundred and four weeks in recent years ; in fact, that the periodicity of measles was not static as Brownlee asserted. Hamer further stated that there was abundant proof that variations in periodicity were directly associated with alterations in environmental conditions. Of these, decreased aggregation of susceptibles and activity as regards the putting into operation of those preventive measures already referred to, had been chiefly responsible in affecting the behaviour of measles during the last fifty years.

Firstly, as regards the number of susceptibles, the birth-rate reached a maximum in the late eighties and has been steadily declining until the last year or two. Secondly, as to preventive measures, these were first seriously undertaken some twenty years ago and an appreciation of the importance of these measures by teachers, parents, and local education authorities has grown steadily since that time. Thirdly, the carrying out of measures dealing generally with the health of both mother and child has almost eliminated such conditions as marasmus, malnutrition, rickets, &c. Fourthly, these measures tend to a greater appreciation of an open-air life and the avoiding of all unnecessary exposure of the younger children to infection.

The operation of all these factors combined serves to explain the behaviour of measles in London ; firstly, in the shortening of intervals between successive epidemics in the late eighties, with a gradual tendency to the lengthening of the interval subsequent to that ; secondly, in bringing about, through the preventive measures developed in the early years of this century, the curtailment of each individual measles epidemic, with a consequent increase in the accumulation of susceptible persons

which resulted in the unusually explosive epidemics of 1911 and 1920. The regular series of biennial explosions of measles in London can be explained by the fact that the metropolis, by reason of its parts being so closely linked together by its various means of communication, now acts as one large magazine of susceptible, and so of explosive, material. When, therefore, measles is introduced into this magazine it leads to one short explosion which burns up the susceptible material as if by one large sheet of flame which, epidemiologically, is not instantaneous, but from start to finish takes about six months to complete.

Hippocrates (470 B.C.) in his "Treatise on Air, Water and Places" remarks on the constitutional tendencies of various populations in Europe and Asia, which when once formed, were perpetuated by heredity. Hippocrates had a wide conception of the facts of disease and prepared the way for the scientific study of life. He drew attention to the intermittency of epidemics and so may be called the father of the periodicity of infectious disease. His theories were, centuries later, confirmed by writers such as Sydenham and Graunt (National and Political Observations upon the Bills of Mortality, London, 1662) and in more recent times they have been proved experimentally by Professors Greenwood and Topley (1923, 1925).

In their more recent work ("Experimental Epidemiology", 1936) Greenwood and Topley summarize the knowledge gained by the various methods of epidemiology employed (descriptive, statistical, bacteriological, and immunological) and conclude that, after all, questions in epidemiology can only be answered by finding out what really happens in an infected herd, and not by deducing what might happen from our knowledge of what occurs in individual hosts. They state :—

"Our observations, and the interpretations that we have placed upon them, are in general accord with the view expressed by Hamer (1919) that the periodicity of such an epidemic disease as measles is probably due to periodic changes in the constitution of the population exposed to risk, leading, after each epidemic wave, to a gradual re-accumulation of susceptibles. These natural epidemic waves are not the minor fluctuations of our mortality curves, they correspond rather with the widely spaced waves observed with very slow rates of immigration, or with the effect produced by adding susceptibles to the population surviving from an epidemic prevalence. In the natural world, the re-accumulation of susceptibles is by births rather than by immigration; but there are specialized herds, such as schools in general and boarding schools in particular, in which the immigration of non-immunes term by term is probably a decisive factor in determining the course of events. . . . This ever-varying state of the immunological constitution of the herd is the main factor determining the intervals at which the epidemic waves of such an endemic epidemic disease as measles will occur."

As regards the mechanism by which this immunological constitution is determined they say :—

"We regard sub-lethal or latent infection as the essential factor involved in the immunization of any human herd."

Stocks, in his paper (1928), says that at the end of an epidemic of measles quite a number of children are immune, without suffering from the disease, but that a large proportion of these lose their immunity again in a year or two and so are added to the number of susceptibles amongst whom the disease may spread in the next epidemic.

In spite of the fact that measles in this country is an endemic disease, there are quite a number of isolated communities where it is non-existent, and when it is accidentally introduced it behaves like a new disease and attacks the susceptibles in that closed community until they are exhausted, and then it disappears. At the other extreme is an urban community, like London, where the disease is endemic and where the conditions of spread have become such that the disease recurs almost

like clockwork every two years ; one can almost predict the very week in November when the disease becomes epidemic and begins to spread from district to district and school to school.

Between these two extremes one meets with a variety of herds, some in which the disease recurs in epidemic form at irregular periods varying between two and seven years.

Amongst the former are certain fairly isolated rural communities and also our public and preparatory schools, where the scholars live a more or less sheltered and carefully guarded life. The members of these different herds are all of the British

TABLE I.—COUNTY OF LONDON: MEASLES DEATHS AND DEATH-RATES PER 100,000 LIVING

Males

Period	All ages	0 –	1 –	2 –	3 –	4 –	0–5	5 –	10 –	15 –	20 +
1851-60											
Deaths	6,976	1,212	2,595	1,461	798	427	6,493	412	38	8	25
Rate	57·8	317·0	806·0	453·5	256·8	142·6	396·7	30·5	3·2	0·7	0·4
1861-70											
Deaths	8,852	1,715	3,451	1,890	906	436	8,398	398	24	7	25
Rate	62·5	376·0	894·4	492·9	242·2	121·0	428·6	24·7	1·7	0·5	0·3
1871-80											
Deaths	9,265	2,080	3,685	1,661	839	461	8,726	468	29	9	33
Rate	55·8	396·8	806·0	367·8	191·4	108·0	379·7	24·6	1·7	0·6	0·4
1881-90											
Deaths	13,119	2,756	5,074	2,389	1,306	774	12,299	757	34	6	23
Rate	69·3	501·9	1,033·7	478·9	271·7	164·6	494·0	34·9	1·8	0·3	0·2
1891-1900											
Deaths	13,085	2,939	5,404	2,197	1,239	696	12,475	558	20	7	25
Rate	63·1	536·3	1,106·5	437·0	253·8	146·1	498·3	24·8	1·0	0·3	3·2
1901-10											
Deaths	10,368	2,391	4,471	1,670	897	513	9,942	394	15	5	12
Rate	48·6	457·0	951·2	344·3	189·1	110·5	411·4	18·0	0·7	0·2	0·1
1911-20											
Deaths	8·074	1,758	3,418	1,349	684	409	7,618	427	12	5	12
Rate	41·7	386·2	798·0	318·4	164·6	97·5	355·6	20·1	0·6	0·3	0·1
1921-30											
Deaths	4,025	940	1,809	610	281	168	3,808	200	8	4	5
Rate	19·2	247·4	476·1	164·9	80·3	49·4	209·2	10·9	0·4	0·2	0·0
1931-32											
Deaths	525	106	251	83	22	24	486	33	3	1	2
Rate	12·8	169·6	412·7	141·4	37·6	40·7	162·3	10·0	0·9	0·3	0·1
1933-34											
Deaths	517	80	244	78	48	25	475	36	3	—	[illegible]
Rate	13·0	136·2	418·1	137·5	85·1	44·5	165·8	11·2	1·0	—	0·1
1935-36											
Deaths	331	77	134	49	27	24	311	18	—	—	[illegible]
Rate	8·5	133·3	240·2	94·3	51·2	44·8	114·4	6·0		—	0·1

race, born and bred in the same country and at the same time. The germ of measles which attacks them is the same, bred at the same time and under the same climate. The difference between the herds is one of housing, nutrition, segregation, and the mobility of the individuals composing them.

These environmental factors, together with those just referred to, namely, the character and size of the susceptible herd as opposed to the character and size of the immunes, that is, whether immunity is permanent or transient, must govern the periodicity of the epidemic outbreak.

In New York the periodicity curve of measles appears at the present time to be

undergoing a state of evolution similar to that experienced by London in the period 1912–1918. Instead of an epidemic year being regularly followed by one of non-epidemicity, we observe here a phenomenon of " break step ". That is, we observe two successive years of epidemicity followed by one of non-epidemicity, and these are followed by the usual rule of an epidemic year being followed by a non-epidemic one, and then the curve repeats itself by a succession of two epidemic years followed by one of non-epidemicity. What is responsible for this " break-step " phenomenon as well as the persistent lower mortality of measles in New York when compared with that in London can as yet not be explained.

IN TEN-YEAR PERIODS (1851-1930), AND FOR THE YEARS 1931-1932, 1933-1934, AND 1935-1936

Females

All ages	0 –	1 –	2 –	3 –	4 –	0–5	5 –	10 –	15 –	20 +	Period
											1851-60
6,790	1,022	2,440	1,559	793	434	6,248	454	34	14	40	Deaths
49·3–	267·3	754·7	477·0	254·7	145·2–	380·4	33·2	2·8	1·1	0·5	Rate
											1861-70
8,486	1,456	3,249	1,850	945	488	7,988	397	41	15	45	Deaths
52·6	320·2	843·6	476·6	251·5	135·1	406·5	24·2	2·8	1·0	0·5	Rate
											1871-80
8,682	1,735	3,364	1,638	909	430	8,076	518	32	12	44	Deaths
46·3	332·3	736·4	360·9	206·1	100·8–	351·1	26·7	1·9	0·7	0·4	Rate
											1881-90
12,330	2,251	4,684	2,365	1,340	746	11,386	841	37	13	53	Deaths
58·2	406·9–	948·3	473·1	274·8	159·0	454·8	38·2	1·9	0·6	0·4	Rate
											1891-1900
12,484	2,490	5,066	2,190	1,276	699	11,721	682	25	8	48	Deaths
53·9	451·3	1,032·5	435·4	256·7	146·8	465·3	30·0	1·2	0·4	0·3	Rate
											1901-10
9,532	1,970	4,006	1,725	823	511	9,035	437	15	3	42	Deaths
39·8	381·1	856·0	358·3	171·8–	110·5	375·3	19·8	0·7	0·1	0·3	Rate
											1911-20
7,399	1,389	3,074	1,325	675	374	6,837	491	19	15	37	Deaths
30·8	310·6	724·1	315·7	163·9	90·0	322·7	23·1	0·9	0·7	0·2	Rate
											1921-30
3,548	694	1,599	610	274	144	3,321	194	8	3	22	Deaths
14·6	187·6	432·2	169·4	78·3	42·4	185·5	10·7	0·4	0·1	0·1	Rate
											1931-32
412	75	179	69	39	22	384	23	3	—	2	Deaths
8·8	122·2	301·2	119·9	67·8	37·3	130·2	7·1	0·9	—	0·1	Rate
											1933-34
439	84	178	67	36	31	396	38	—	—	5	Deaths
9·6	146·0	314·6	120·5	64·8	55·4	140·8	12·1	—	—	0·2	Rate
											1935-36
272	59	119	39	12	16	245	21	1	2	3	Deaths
6·1	104·9	224·3	77·4	23·3	30·3	92·8	7·2	0·3	0·5	0·1	Rate

The tables and charts are appended to illustrate various points which I have dealt with in this paper.

Table I provides a complete statistical analysis of the deaths and death-rates of measles for both sexes and for the different age-periods since 1851. It will be noted that : (1) Measles is more fatal amongst males at all times and at all ages. (2) There has been a steady decline in the measles death-rates and that this has been particularly evident since 1921. (3) In London measles is most fatal at the age-periods 1 and 2—more correctly 9 months to 2½ years. After 2½ years it becomes less serious and is of no importance after the 5th year of life.

Table II sets out the death-rates for measles, irrespective of sex, for the decennial periods 1861–1930.

TABLE II.—MEASLES.

Death-rates per 100,000 living at each age-period.

Period	All ages	0 –	1 –	2 –	3 –	4 –	5 –	10 –	15 –	20 +
1861-70	57·2	348	869	485	247	128	24	2	1	0
1871-80	50·8	365	771	364	199	104	26	2	1	0
1881-90	63·4	454	991	476	273	162	37	2	1	0
1891-1900	58·3	494	1,069	436	255	146	27	1	0	0
1901-10	43·9	419	904	351	180	111	19	1	0	0
1911-20	34·3	341	752	299	156	93	22	1	0	0
1921-30	16·7	218	454	167	79	46	11	0	0	0

Table III shows the total deaths and death-rate of measles for the calendar years 1910–1937 in London and in New York.

TABLE III.—MEASLES 1910-1937.

	Comparative figures for London		Comparative figures for New York	
Year	Deaths (calendar year)	Death-rate (per 1,000)	Deaths (calendar year)	Death-rate (per 1,000)
1910	1,986	0·44	785	0·16
1911	2,577	0·57	659	0·14
1912	1,828	0·40	671	0·14
1913	1,547	0·34	628	0·12
1914	1,376	0·31	560	0·11
1915	2,286	0·51	630	0·12
1916	822	0·19	490	0·09
1917	2,019	0·50	560	0·10
1918	1,649	0·42	790	0·14
1919	353	0·08	218	0·04
1920	1,016	0·22	736	0·13
1921	244	0·05	165	0·03
1922	1,563	0·34	977	0·17
1923	386	0·08	245	0·04
1924	1,330	0·29	506	0·09
1925	345	0·07	130	0·02
1926	933	0·20	706	0·12
1927	181	0·04	37	0·01
1928	1,318	0·30	346	0·06
1929	206	0·05	29	0·00
1930	1,027	0·23	154	0·02
1931	115	0·03	134	0·02
1932	822	0·19	58	0·01
1933	101	0·02	213	0·03
1934	855	0·20	25	0·00
1935	19	0·00	105	0·01
1936	584	0·14	81	0·01
1937	25 (52 weeks)	0·01	25	0·00

It will be noted that throughout these years both the total deaths and the death-rates are lower in New York than they are in London.

It may be asked, why is there this difference ? It is not due to season, for measles in both cities occurs at the same time of year. It is not due to such a fatal complication as bronchopneumonia being excluded from the measles deaths, for if we examine the bronchopneumonia deaths in London and New York we find the number in London three to four times as great as in New York (*see* Table IV). It should also be remembered that pneumonia is a more serious and fatal disease in New York than in London. A possible cause of the better positioning of measles in New York may be found in the fact that the New Yorker, however poor, has a better appreciation of the value of preventive measures than the Londoner. For instance, the teeth of a New York child are better cared for than those of the London child. The New Yorker has a better appreciation of the value of diet. Preventive measures may possibly be found to be the cause.

TABLE IV.—LONDON.

Deaths from measles and pneumonia.

Age-period	Measles deaths 1923	1924	1925	1926	1927	Total	Bronchopneumonia deaths 1923	1924	1925	1926	1927	Total	Pneumonia (all forms) 1923-1927
0-1	88	287	72	227	46	720	705	1,028	875	742	737	4,087	4,713
Births	..	...	...	...	...	411,298	...	...	...	...	...	411,298	
D.R. per 100,000 births	...	...	...	...	...	175·1	...	...	...	...	...	993·7	1,145·9
1-5	286	969	249	659	124	2,287	468	948	608	597	613	3,234	4,008
Population	...	...	...	...	...	246,197	...	...	...	...	...	246,197	
D.R. per 100,000 living	...	...	..	...	...	185·8	...	...	...	...	...	262·7	325·6
5-10	11	56	22	40	8	137	34	34	47	29	53	197	368
Population	...	...	...	...	...	342,843	...	...	...	...	...	342,843	
D.R. per 100,000 living	...	...	...	...	...	8·0	...	...	...	...	...	11·5	21·5
10-15	—	7	—	—	—	7	8	9	13	7	12	49	157
Population	...	...	...	...	...	337,753	...	...	...	...	...	337,753	
D.R. per 100,000 living	...	...	...	...	...	0·4	...	...	...	...	...	2·9	9·3
15+	1	18	2	7	3	31	1,002	1,107	1,236	1,157	1,160	5,662	
D.R. per 100,000 living	...	...	...	...	...	0·2	...	...	...	...	...	28·7	

NEW YORK CITY.

	Measles	Pneumonia (all forms)
0-1		
D.R. per 100,000 births	66·7	1,373·9
1-5		
D.R. per 100,000 living	45·7	249·8
5-10		
D.R. per 100,000 living	3·7	28·7
10-15		
D.R. per 100,000 living		17·8
10+		
D.R. per 100,000 living	0·1	

TABLE V.—EFFECT OF LATITUDE ON MEASLES MORTALITY 1922-1930.

Mortality per 100,000 *Living at Ages* 0·5 *in England and Wales.*

	1922	1923	1924	1925	1926	1927	1928	1929	1930	Average
NORTH.										
County Boroughs ...	264	209	205	241	132	232	130	229	160	200
Other Urban Districts	153	188	120	184	72	153	60	104	103	126
Rural Districts ...	87	156	34	153	36	113	47	104	59	88
All Areas	203	195	154	210	99	190	96	172	128	161
MIDLANDS.										
County Boroughs ...	162	157	106	198	78	111	106	143	105	130
Other Urban Districts	70	113	81	84	71	32	101	30	100	76
Rural Districts ...	28	63	29	44	38	26	38	28	37	37
All Areas	90	115	76	112	64	57	86	68	86	84
SOUTH.										
London	375	89	285	77	219	44	346	56	287	198
County Boroughs ...	92	101	45	64	58	96	142	17	186	89
Other Urban Districts	56	54	66	35	76	12	81	27	67	53
Rural Districts ...	23	26	31	20	29	21	56	15	34	28
All Areas	198	71	157	55	130	39	201	36	170	117
WALES.										
County Boroughs ...	70	240	71	260	31	128	64	292	112	141
Other Urban Districts	59	259	24	259	40	87	109	93	74	112
Rural Districts ...	36	82	21	69	38	62	55	24	38	47
All Areas	54	204	33	205	38	88	83	115	71	99
ENGLAND AND WALES.										
London	375	89	285	77	219	44	346	56	287	198
County Boroughs ...	206	184	152	211	103	175	121	183	143	164
Other Urban Districts	94	145	85	129	68	75	85	60	92	93
Rural Districts ...	42	78	30	66	35	50	46	43	42	48
All Areas	154	138	120	138	91	101	119	99	121	120

1922-1930.

	North	Midlands	South	Wales	England and Wales
London	—	—	198	—	198
County Boroughs ...	200	130	89	141	164
Other Urban Districts ...	126	76	53	112	93
Rural Districts	88	37	28	47	48
All Areas	161	84	117	99	120

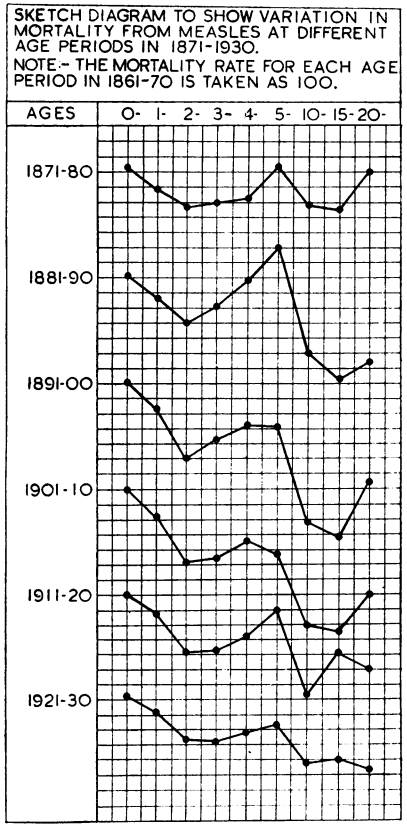

CHART I.—Measles mortality curve for the different ages (0-20 years) in London from 1871 to 1930 in ten-year periods.

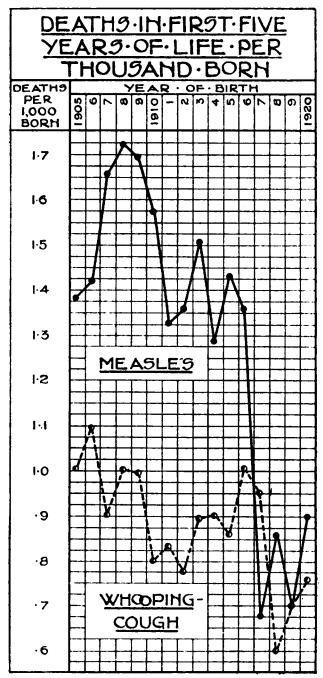

CHART II.—Measles mortality curve in the first five years of life per 1,000 born.

It will be noted that there has been a material improvement in the measles mortality of babies born since the year 1916.

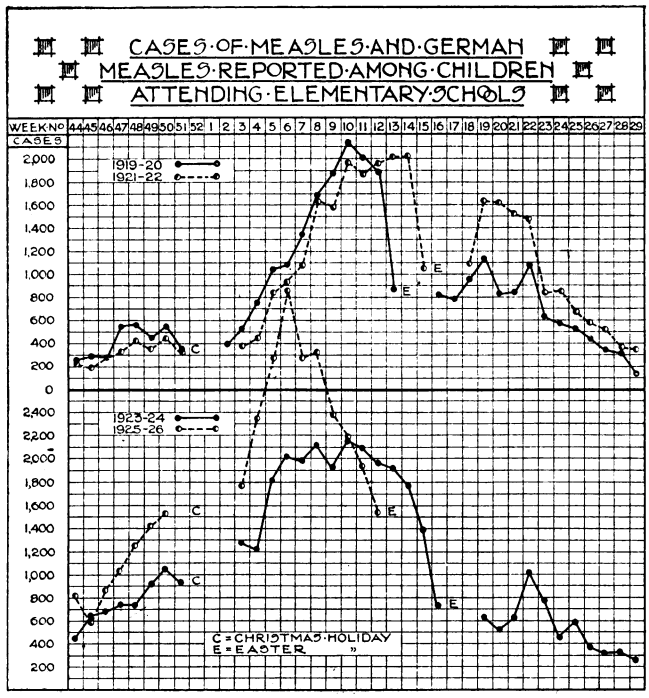

CHART III.—Measles cases reported from elementary schools in London during an epidemic period.

It will be noted that the increased prevalence of measles begins to show itself about the first week in November. The Christmas holiday usually causes a slacking-off, and it is not until three or four weeks after the schools reopen that the cases substantially increase. Thereafter the number of cases increases rapidly to a maximum which is reached in March or April. Then there is a rapid drop and the epidemic exhausts itself by the end of May.

Mortality of measles is closely associated with incidence, the greatest fatality occurring a week or two after the greatest incidence. When a school is attacked it is usually found that the epidemic exhausts itself in that school in about four weeks.

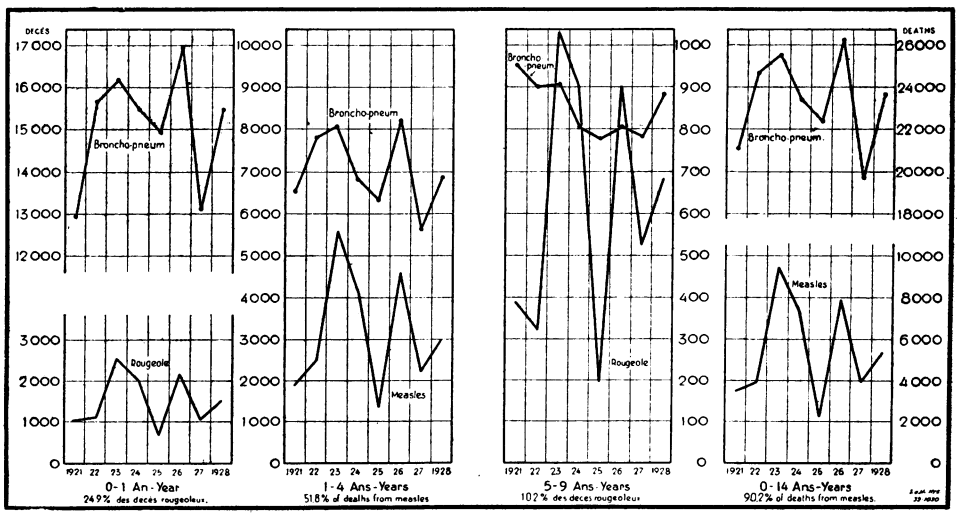

CHART IV.—Co-variation between mortality from measles and from bronchopneumonia from 0-14 years, from 1921-1928 in the United States of America. (Absolute figures for deaths.)

It will be seen that the mortality of measles follows that of pneumonia and does not anticipate it. Bronchopneumonia following on an attack of measles is therefore one of the telling factors in the mortality of measles.

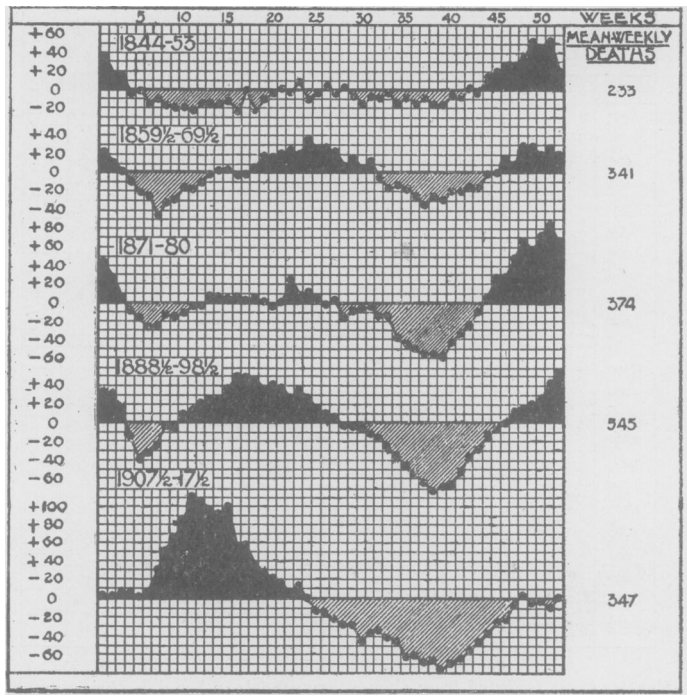

CHART V.—Measles : mean weekly deaths in ten-year periods. Illustrating Sir W. Hamer's criticism of Brownlee's contention (*see* p. 44).

To make the argument clearer, the chart is calculated on a mean mortality for ten-year periods. Note that in the decennial period 1859–1869 the maximum measles mortality was in mid-summer. In subsequent decennial periods the maximum has gradually shifted until in the decennium 1907–1917 the maximum mortality was in the spring, and this has remained so ever since.

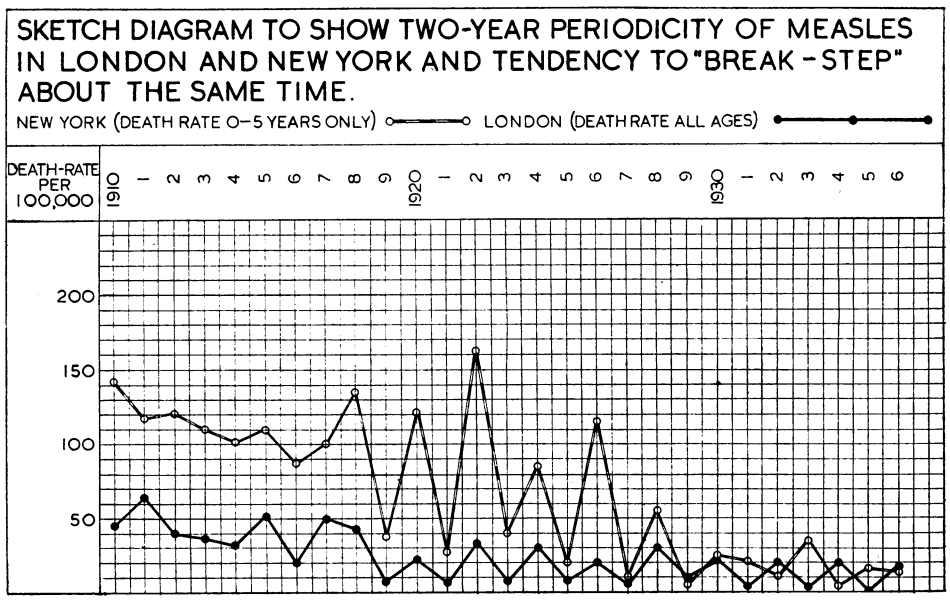

CHART VI.

Note the " break-step " phenomenon which has occurred in New York recently. This break-step phenomenon, the cause of which is as yet undetermined, also occurred in London in 1907–1908.

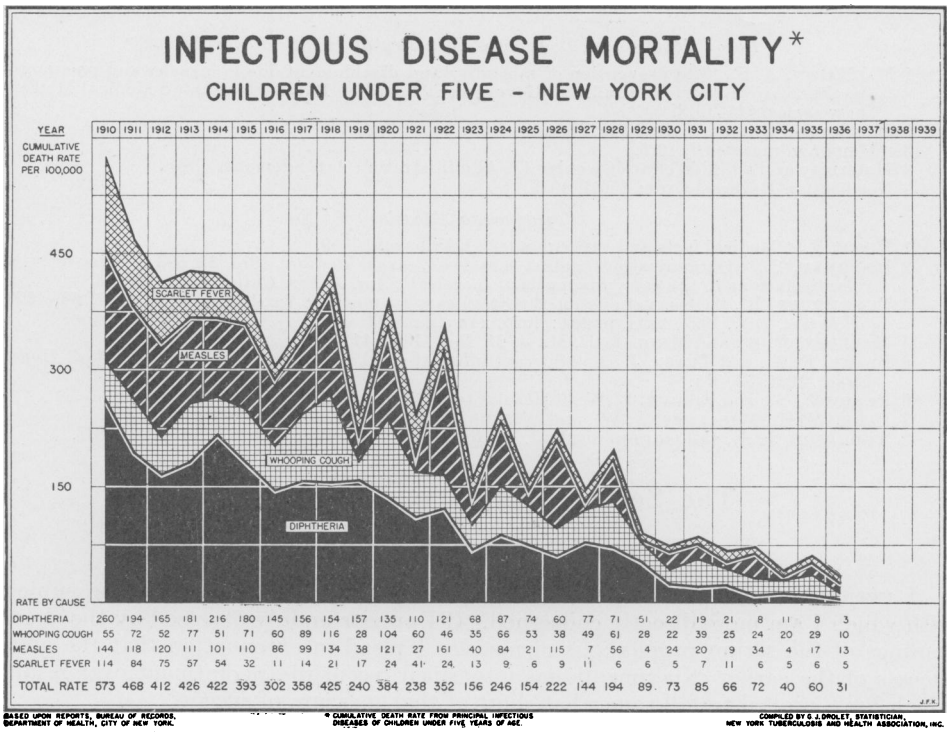

CHART VII.—Showing the incidence of the more common infectious diseases in New York.

It will be noted that measles is the outstanding feature that regulates the curve. The " break-step " phenomenon is also to be observed here.

[I am deeply indebted to Mr. W. L. Parry of the Public Health Department, and to Mr. B. E. Spear of the Statistical Section of the Public Health Department, London County Council, both for the material contained in these tables and charts and for advice given during the writing of this paper.]

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The Serum Prophylaxis of Measles

By WILLIAM GUNN, M.R.C.P., D.P.H.

I INTEND in this paper to restrict myself to the clinical aspects of the subject with which I am more directly concerned. If I appear unduly obsessed by the shortcomings of the serum prophylaxis of measles I plead in extenuation that the great success of the earlier experiments has intensified recent disappointment over results which have proved to fall somewhat short of that measure of success.

The use of immune serum in measles prophylaxis was first suggested by the laboratory researches of Anderson and Goldberger. These workers in 1911 inoculated monkeys with material derived from acute cases of measles, and obtained febrile reactions, with or without rashes, in about one half the inoculated animals; they found successful reinfection to be impossible, presumably on account of the presence of antibodies in their blood following the primary inoculation. The credit for the first employment of immune serum in measles prophylaxis is usually attributed to Nicolle and Conseil who applied the method in 1916 in Tunis but did not publish their results until 1918. Zingher, in collaboration with Park, carried out preliminary experiments in the same year (1916), but details of their inoculations were withheld until 1924 (Zingher). In their hands the measure gave highly satisfactory results and was thereafter widely practised with a high degree of success in America and on the Continent, particularly by Degkwitz in Munich and Debré in Paris. We in this country were slow to take notice of the new method.

In 1925 Dr. W. S. C. Copeman made us familiar with the technique of measles control by means of serum, and two years later Miller and Smith gave an account of 10 cases which they had treated in private practice at Harrogate. Five of the 10 inoculated were apparently protected, and the remaining five had clearly modified attacks. Later in the same year, Benson and Lawrie described an account of a ward outbreak of measles successfully controlled by serum in the Edinburgh City Fever Hospital, and Kingsbury (1927) described an extensive experience of the method among natives on Malayan rubber estates. McClean in 1928, in a brief note on the use of immune serum in three cases, expressed disappointment with his results; his failures were probably due to the fact that the serum he used was not pooled from several donors. Towards the end of 1927 the method was first applied in one of the fever hospitals under the control of the late Metropolitan Asylums Board, and the results were published at the end of 1928. In the preliminary experiments convalescent serum was compared side by side with Tunnicliff's measles antitoxin (horse), Ferry and Fisher's measles antitoxin (horse), and Degkwitz's immune serum (sheep). It was found possible to arrive at a decisive verdict on the merits of these reagents;