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Special Report Series No. 10.

NATIONAL HEALTH INSURANCE.

MEDICAL RESEARCH COMMITTEE.

The Mortalities of Birth, Infancy and Childhood.

(Approved for publication by the Medical Research Committee, 3rd August, 1917.)

Medical Research Committee

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(B2406—r B1755) Wt. 24271—803. 750. 4/18. Sir J. C. & S. **Gp. 32.**

INTRODUCTION.

The studies in infant and child mortality which are here printed together were written at the request of the Medical Research Committee, but they were written primarily with a view to the planning of future lines for research rather than for publication as finished reports. At the present time, however, when rapidly growing interest in the subject of infant mortality is being shown by the public and by official bodies, and at a time when the state of war makes the possibilities of breaking new ground in research work highly uncertain, the Committee think that the publication of these essays may serve a useful object and should not be withheld.

To think of infant mortality as an entity or to attack it as a single problem appears to the Committee to be against the interests of efficiency, whether in administrative action or in the planning of new research work. It is only our relative ignorance of the causes of death in babies, infants and children that makes the common phrase " infant mortality " less obviously confusing or meaningless than a reference to " adult mortality " as a single object of executive action or scientific enquiry. The short essays published here, if they do nothing else, at least point clearly to the variety and complexity of the separate factors whose composite effects are summed up in the total annual death roll of babies and children. On the one hand we have to analyse and separate the physiological qualities, whether of the mother or the babe, and the separate physiological stages through which the growing infant passes in succession towards the full establishment of healthy childhood—and our knowledge even of this normal physiological progression is still highly imperfect. On the other hand we have to detect and classify the attacks made upon these stages of normal life by conditions of improper environment and by the infective parasites of disease. All these factors, if their combined results as shown in the annual revelations of the Registrar-General are to be overcome, must be studied separately, and success will probably come only by their being attacked and defeated in detail. The time has gone by when the multiplication of reports in repetition or amplification of the returns of the Registrar-General can serve any useful purpose except that of maintaining public interest.

Our knowledge of the separate factors which lead to illness or death at this or that stage of the physiological progress through which the infant rapidly passes in its normal development is still gravely incomplete. Into several of these factors the Committee at the beginning of their work had arranged co-ordinated schemes for research. But the claims made by the war upon the time of the scientific workers engaged has necessarily postponed all but a small part of these enquiries and they must be resumed as the first opportunities return. It may be mentioned here,

however, that encouraging progress has already been made in spite of the war in that part of these schemes relating to Rickets, both in London and in Glasgow, and at Glasgow the progress in our knowledge of Rickets and of Tetany in children is being accompanied by a wider inquiry into the relation of housing conditions to disease, of which the counterpart at other centres has been postponed by the war.

Enquiries into the causation of disease or death before or during birth, in infancy, and in childhood will fall into two main groups.

1. Analyses of the external conditions associated historically and topographically with different mortality rates.

2. Investigation of the particular physiological and pathological processes of the unborn babe, the infant and the child, conducted so as to show what external conditions at each stage are most likely to exercise unfavourable influence.

The present memoirs of Dr. Brend and Dr. Findlay come within the former group, that of Dr. Brownlee mainly within the latter, though it will be seen that the different lines of inquiry supplement each other.

For the better economy and concentration of administrative effort, it is plain that priority should be given to practical measures from which the greatest reduction of infant mortality is to be expected, rather than to those which, though likely to be beneficial, will only yield comparatively small results. A chief aim of research in this subject will therefore be to indicate the directions in which action can be taken with the greatest effect. As an example of a problem of which the solution will have an immediate practical bearing may be taken the question dealt with both by Dr. Brend and Dr. Brownlee, namely, at what age are adverse external conditions most likely to cause death? Supposing it were shown that the environment acting through the mother before birth had the greater influence, then the protection of the pregnant mother would be indicated as the most urgent measure for the reduction of infant mortality. But if, on the other hand, it were proved that the bulk of the deaths are due to causes acting directly upon the child after birth and that the varying conditions under which the mother has lived have comparatively little influence, then administrative action should have a different aim.

The evidence adduced by both authors tends to emphasise the relative importance of post-natal influences. If the greater weight ought to be attributed to pre-natal conditions, one would expect to find that where harmful conditions are present the excess mortality caused by them would decline progressively from birth onwards. The reverse, however, is known to be the case. Thus, diagram XI., p. 78, illustrating Dr. Brownlee's paper, expresses graphically the ratios of the death-rates at

various ages in Salford, London, Brighton, and the whole of England respectively, to those at corresponding ages given in the English "Healthy District Life Table" for the decade 1891-1900. The maximum differences are shown at the age of two years, at which age in Salford the mortality is four times as great as in the healthy districts. Dr. Brend's table, "Infant Mortality in Relation to Social Conditions," p. 13, records analogous facts, which are expressed again in Dr. Stevenson's statistics (quoted on p. 14), of "Infant Mortality in Relation to Father's Occupation."

If it be agreed, then, that it is the post-natal rather than the pre-natal environment which has the greatly predominating share in the causation of infant mortality (though here must not be lost sight of the warning given by Dr. Brownlee on p. 77), we have still to determine which of the factors in this environment are most adverse to healthy life and growth. Here the chief difficulties are found in the variety of the influences that may be involved, of which many may be contributory together and in close association.

Dr. Brend conducts his analysis of the hostile factors in the environment by eliminating such causes as operate both in localities in which there is a low infant mortality rate and in those in which it is high. Thus, for example, the sanitation and housing in rural districts may be, and often is, as bad as in urban districts with a far higher rate, and therefore he eliminates bad housing and sanitation as principal causes. He is finally reduced to the conclusion, stated on p. 18, that "the excess is due to some factor or factors in industrial towns, the centres of large cities, and mining areas, of which possibly the most important is a polluted state of the atmosphere."

If this conclusion be accepted, then the measures likely most speedily to reduce infant mortality must be "the clearing of slum areas, provision of open spaces, segregation of factories as at Letchworth, and prevention of atmospheric pollution," and these are measures urgently called for in the interests of all classes of the community.

Dr. Findlay's contribution is in general harmony with this. It is concerned, moreover, in large part with the results which may be expected, or have been claimed, from the establishment of ante-natal and pre-natal clinics, milk depots, and similar institutions. The evidence he brings forward, though it makes no pretensions to completeness, serves as a warning that the effects of such measures in the reduction of infant mortality should be carefully examined in estimating the amount of good to be expected from them. Should a high expectation be formed from *a priori* considerations, unchecked by critical examination of all available data, there is some danger that institutions of this kind, being comparatively easy to inaugurate, may come

to be regarded as substitutes for comprehensive schemes of town planning and housing reform.

While it may be agreed that the factors summed up in the phases "urbanisation" and "atmospheric pollution" are the most potent in causing the present high and preventable mortality among infants and children, these cannot be removed rapidly, and perhaps may never be completely removed. There will still remain a large field for administrative action of a palliative kind which, given an urban and harmful environment, must be directed to the removal of particular influences, whether of infectious disease or modes of living, coming into action as allies of the more persistent forces of urbanisation. Action of this kind can only properly be guided by closer investigation of the detailed pathology of infancy and childhood, like those indicated, for instance, in the suggestive memoir of Dr. Brownlee, supplemented by further bacteriological and bio-chemical analysis.

This is true for all disease and mortality in childhood, and it applies with special force to the mortality of young infants under one year of age, for this part of the death-rate does not appear to be at all closely related to external conditions of environment. A very large part of this mortality is due to premature births and to wasting diseases included under the names of "atrophy," "debility," and "marasmus." As to the nature of these diseases little definite knowledge exists, but Dr. Brownlee gives reasons for believing that infection plays a larger part than has hitherto been supposed. And here again administrative measures may have their future opportunity. His statistical analysis also provides evidence as to the nature of convulsions, which leads him to regard these rather as a manifestation of nervous instability than as a symptom common to a group of various diseases. Many other of the results of his statistical enquiries, given here in a preliminary form, point to the urgent need for systematic exploration of the rapidly changing physiology of the infant, and of the interaction with it of specific parasitic, chemical, and mechanical factors in the environment.

In the meantime it would be altogether erroneous to suppose that the plain need for further research and the present partial delay in its prosecution give any ground for postponing practical measures for diminishing the avoidable death-rate. Existing knowledge based upon research work is already almost a generation ahead of effective administrative action. We have no need for further enquiry to show that improvements in an admittedly imperfect midwifery service would certainly diminish blindness and death among babies, or that bad housing conditions are a causal condition of much disease in infants, or again that a purer milk supply in cities and districts where it is known to contain habitually the germs of tuberculosis would lessen or

abolish an important group of the diseases of children. The Committee have no direct responsibility for the advocacy of any administrative action, but they are concerned deeply to urge that the rapid removal of the known factors in the attack of improper environment upon young life would, quite apart from the urgent humanitarian claim for it, greatly aid the progress of further research into the effects of the less known factors which have still to be removed when their nature can be more fully revealed.

MEDICAL RESEARCH COMMITTEE,
15, BUCKINGHAM STREET,
STRAND, W.C. 2.

30th August, 1917.

QUOTATIONS FROM FARR.

"*There is, no doubt, great negligence on the part of the parents, great ignorance of the conditions on which health depends, and great privation among the masses of the poor, but there is no reason to suspect that any great number of the infants in these districts fall victims to deliberate crime; yet the children of the idolatrous tribe who passed them through the fire to Moloch scarcely incurred more danger than is incurred by the children born in several districts of our large cities.*

"*A strict investigation of all the circumstances of these children's lives might lead to important discoveries, and may suggest remedies for evils of which it is difficult to exaggerate the magnitude.*

"*The weaklier lives, it is said, are, under this state of things, cut off; but it may also be borne in mind that many of the strongest children are wounded and are left weakly for life.*

(Supplement to the XXVth Annual Report of the Registrar General, pp. xii. and xiii., 1864.)

* * *

"*The first thing to observe is that the fatality children encounter is primarily due to the changes in themselves. Thus* 1,000,000 *children just born are alive, but some of them have been born prematurely; they are feeble; they are unfinished; the molecules and fibres of brain, muscle, bone are loosely strung together; the heart and the blood, on which life depends, have undergone a complete revolution; the lungs are only just called into play. The baby is helpless; for his food and all his wants he depends on others. It is not surprising, then, that a certain number of infants should die; but in England the actual deaths in the first year of age are* 149,493, *including premature births, deaths by debility and atrophy; diseases of the nervous system,* 30,637; *and of the respiratory organs,* 21,995. *To convulsions, diarrhœa, pneumonia, bronchitis, their deaths are chiefly ascribed; little is positively known, and this implies little more than that the brain and spinal marrow, nerves, muscles, lungs, and bowels fail to execute their functions with the exact rhythm of life. The first two are said by pathologists to be often rather symptoms of diseases unknown than diseases in themselves. The total dying by miasmatic diseases is* 31,266; *but it is*

quite possible that several of the children dying of convulsions die in the early stages of some unrevealed zymotic disease, whose symptoms have not had time for development. Convulsion is a frequent precursor in children of measles, whooping cough, scarlet fever, fever; indeed, Dr. C. B. Radcliffe well remarks:—

> 'in the fevers of infancy and early childhood, especially in the exanthematous forms of these disorders, convulsion not unfrequently takes the place occupied by rigour in the fevers of youth and riper years.'

Many of the cases of pneumonia may also in like manner be whooping coughs and other latent zymotic diseases. In the second year of life pneumonia, bronchitis, and convulsions are still the prevalent and most fatal diseases; many also die then of measles, whooping cough, scarlatina, and diarrhœa. Scarlet fever asserts its supremacy in the second, third, fourth and fifth years of age. Whooping cough is at its maximum in the first year, measles in the second, scarlatina in the third and fourth years. Thus these diseases take up their attacks on life in succession and follow it onwards."

(Supplement to the XXXVth Annual Report of the Registrar General, p. xxviii., 1875.)

HISTORICAL NOTE.

By A. K. Chalmers, M.D., D.P.H.

The interest in the causes of death in infancy and early childhood which has arisen during recent years is in a sense the belated harvest of a seed-time which began before the period of registration. Several factors would seem to have contributed to the production of this delay. When Bills of Mortality or Registers of Interment in particular burial grounds afforded the only record of fatal disease, the information recorded seems to have varied with the locality and the interest of the keeper of the register. It was not always complete or adaptable to the purpose of detailed statistic.

In the earliest we have seen (1699), the recorder's attention was directed more to civil conditions than disease. Age, save in the case of still births, can only be inferred from the position of the deceased in the family as child, son, daughter, wife, servant, etc.; sex is always stated, occupation frequently, but disease never. Apart therefore from supplying a figure which may represent the total number of deaths occurring annually, those registers throw little light on the contemporary mortality of infants; even when age was added to the records the term "infantile mortality" was loosely applied to ages under 10, and included still births.

As the eighteenth century advanced provision was made for recording ages, and a separate column was introduced for disease. But so little importance would seem to have been attached to the causes of death that when Watt undertook his inquiry into the relative mortality of the principal diseases of children* in the years between 1783 and 1812 he found entries relating to disease "the only thing on which we cannot always rely with implicit confidence."

Another factor became operative about this time, which was sufficiently speculative in character to absorb much of the attention given to the subject. Medical thought, in the absence of precise data on which to base inquiry, would appear to have been dominated to a large extent by the decline in the major epidemics and the doctrine of substitution in disease.

The speculation was an attractive one. It definitely affected Watt's writings, and later found sympathetic support in Farr's statement that "the zymotic diseases replace each other; when one is rooted out, it is apt to be replaced by others which ravage the human race indifferently wherever the conditions of healthy life are wanting." (R.G.'s Report, 1872, p. 224.)

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* *Treatise on the History, Nature and Treatment of Chincough*, by Robert Watt, M.D., 1813.

To Watt, however, the question was more than simple substitution of one disease by another. The substituting disease became the dominant one, not only because that which it replaced had ceased to be prevalent, but mainly because the patient thereby lost an opportunity of acquiring the protection against other diseases which attack conferred.

This early anticipation of the modern theory of immunity was reached in an interesting way.

Watt's inquiry covered a period of thirty years, including the close of the eighteenth and beginning of the nineteenth centuries. In the earlier years he found that "the deaths by smallpox were chiefly in infancy, hence the deaths under two or three years of age bore a very great proportion to the whole deaths. . . . More than half of the human species died before they were ten years of age, and of this half more than a third died of smallpox." By 1808 the deaths from smallpox had been considerably reduced, but the anticipated saving of child life did not occur, and he put the question, "How are we to account for the same, or nearly the same, number of deaths under ten years of age?" The answer would appear to have surprised Watt himself. "In smallpox we have the deaths reduced to nearly a fifth of what they were twenty-five years ago; in the same period the deaths by measles have increased by more than eleven times." Measles had replaced smallpox as a cause of death among children, and with some regret Watt proceeds: "However novel and strange this opinion may appear, it must be admitted that while the smallpox was in full force they had the power of modifying and rendering measles mild, and now that they are in a great measure expelled the measles are gradually coming to occupy the same ground which they formerly occupied."

So far the evidence for substitution was conclusive, but Watt carried the inference further, and advanced the doctrine of immunity. Incidentally, he is refuting the suggestion that the comparatively recent introduction of infant vaccination, "by infusing some peccant or vicious humour into the constitution," had done positive harm. To him the malignity of measles had another explanation. He saw no ground for accepting the hypothesis of a "peccant humour," and adds, "but that smallpox do good to those who survive the disease by rendering the system insusceptible of other infections, or by rendering those diseases, when they do take place, more mild, must, I think, be admitted."*

Apart from the speculative aspect of the question other evidence was accumulating which was turned to a useful purpose by Edmonds in 1835.† In a paper to *The Lancet* he introduces the

* For the results of a recent enquiry into the effects of Vaccinia on the well being of children, see paper by J. Parlane Kinloch, M.D., in *The Lancet*, June 30th, 1917.

† "On the Mortality of Infants in England," by J. R. Edmonds, B.A., Trinity College, Cambridge; *The Lancet*, Vol. I., 1835-6, pp. 690-4.

subject by observing that "the very great diminution of the mortality of infants in England is one of the most remarkable phenomena of modern times," and in support constructs a Table from the London Bills of Mortality for the 100 years ending 1829, as supplying one of the best proofs. His figures are sufficiently striking and suggest the query whether the causes of the reduction of infant mortality since the earlier years of the eighteenth century have received quite the attention they deserve. Discarding the numbers which he gives his rates may be arranged thus :—

DYING UNDER 5 YEARS PER 100 BORN IN SEVERAL PERIODS.

Period.	*Rate.*
1730–1749	74·5
1750–1769	63·0
1770–1789	51·5
1790–1809	41·3
1810–1829	31·8

The decrease here shewn is prolonged and continuous, and to obtain comparable figures we may bridge the gap of the century which followed by taking the last available years from the Registrar-General's Reports for 1911–15. In London, the total births for these years were 545,922, and the deaths under 5 years 91,844, so that we have a rate of 16·8, as compared with 31·8 in the early years of last century, and 74·5 in the corresponding years of the eighteenth century.

Leaving aside the fluctuation in individual years, which may be followed in detail in the R.G.'s Reports since 1838, it is thus possible to bring into some sort of focus the movement in child mortality over a period of close upon two centuries, during which the rate has fallen by approximately 77 per cent. The period covers practically all the industrial development of modern times, the concentration of populations in towns and their growth, to an almost unmanageable size. Yet, despite these influences commonly regarded as adverse, and without anything which can be described as intentional effort, the movement in child mortality has been quite definitely towards its reduction. It is easy to suggest questions, but often more difficult to answer them. Yet the movement here suggests that there may be differences in the viability of children, determined not only by differences in the sanitary surroundings of their birth, but by the character of the stock from which they spring, and especially whether it has established a tolerance of the conditions under which it lives. In tuberculosis we have something akin to this ; the children of a rural stock migrating to towns being more susceptible to fatal attack of the disease than those of parents already inured to the conditions of town life. The child mortality of a modern industrial town would in this sense be loaded by a factor which is not operative in the mass, at least among children born to an older

population whose chances of surviving childhood would in consequence be improved. Leaving this consideration aside, it may be well to quote Edmonds' rearrangement of his figures to shew that in the period 1730–79 the mortality rate under 5 years was 66·2 per cent., and in 1780-1829 only 37·7 ; while almost 100 years later—1911–15—it had fallen to 16·8.

About this time ante-natal mortality also began to receive some attention. From an early period it would appear to have been the custom to record the burial of still born children, and to include them among the deaths in childhood, and there is an interesting reference by Farr to an early inquiry into the frequency of ante-natal deaths recorded by Granville in the Westminster General Dispensary Report for 1818. The proportions are interesting. Of 400 pregnant women observed by Granville, 128 had miscarried one or more times during the preceding ten years, so that collectively during these years they had given birth to 556 live children, and had 305 miscarriages, 185 of which were under three months, 65 from three to six months, and 55 from six to nine months.

The Period of Registration. So far it had been possible to deal with individual causes of death in relation to total deaths only, but the increasing accuracy and character of the information regarding age distribution, yielded by the Census Enumerations from 1841 onwards, together with the introduction of civil registration of births and deaths, rapidly placed the question of age distribution in a different focus, of which those familiar with Farr's work need not be reminded. The increase in the infant death-rate of 1875 led to a detailed scrutiny of the principal causes, and the results are stated in terms almost identical with those of the more recent movement—improper or insufficient food, bad management, bad sanitary surroundings, opiates, maternal neglect, early marriage, employment, and debility of mothers. Day nurseries, even the contrast of a low rate with a high proportion of maternal employment, are all considered.

It may be worth a moment's consideration to ask whether the failure on the part of Public Health Authorities to take action for improving the conditions of child life arose from lack of appreciation of the importance of Farr's inquiry. At this date, however, the decline in the general death-rate had scarcely become established, and time was required to shew that the infant death-rate would fail to be affected by the efforts which were beginning to be made for the reduction of the general death-rate.

Indeed, deliberative effort to conserve infant life can be said only to have begun with the recognition of the contrast which the movement in the death-rate of infants presents when compared with that of the general death rate. Broadly speaking, the latter fell continuously and considerably during the fourth quarter of last century, while fluctuations in the infant mortality rate

remained fairly constant, and without any very marked indication of a corresponding decrease.

The steady decline in the birth rate tended to emphasise the comparatively stationary character of the infant mortality rate, while similarity in the conditions associated with a high infant death rate and physical inefficiency among the survivors in after life received increasing attention from the several commissions of inquiry which followed the period marked by the South African War.*

In France the question was already receiving attention, and many of the earlier efforts to combat the infant death rate in this country were frankly founded on the experience of the Gouttes de Lait (Consultations des Nourrissons) which had been established in many towns in France.

According to the theory on which these were provided, the principal cause of excessive infant mortality was misfeeding or failure of breast feeding, and the remedy lay in the supply of a colourable imitation of maternal milk made sterile by heat.

Incidentally, the health of the nursing mother became of importance, and in the case of working mothers found expression in an extension of the interval between confinement and return to work, and in many places in the provision of meals free or at moderate cost, and sometimes in association with works-crêches.

Inquiry into the causes of death among infants, moreover, brought certain other features into prominence. It had been observed that infant deaths were unequally distributed throughout the several months of the first year. Deaths occurring under one month were seen to form about one-third of all the deaths occurring during the first year of life, while of the deaths occurring in the first month fully one-half occurred during the first week. Again, these last when they came to be examined were found to belong for the most part to a category quite different from that of the majority of the diseases proving fatal in the later months. Largely they were recognised to be due to developmental defects, to immaturity in some form. Logically, they should probably be grouped with deaths which take place *in utero*. They might be described as miscarriages occurring *after* birth. In any case they served to open out the field of inquiry to include the ante-natal period, and supplied the argument which placed the health of the prospective mother within the purview of the Notification of Births (Extension) Act.

Certain analogies from experiments on pregnant animals suggest that the maternal tissues exercise a selective influence against the offspring when the food supply is inadequate for both. It became therefore an easy inference to assume that if the effect of environment in this literal and limited sense was so readily

* The first detailed statement of Infant Mortality in the R.G. Reports appears in 1905.

demonstrable, other conditions of environment prejudicial to the health of the adult could not fail to reduce the resistance of the child. It is at this point that opposing views as to the different values to be attached to nature and nurture enter into most violent conflict, and incidentally this conflict has given rise to an effort to find a true death-rate of infancy in the causes which prove fatal before post-natal influences have had time to operate. It would seem to be erroneous, however, to adopt a view which regards the child's tissues as wholly passive. We know, although at present we cannot explain the fact, that the death-rate of male infants invariably exceeds even in apparently similar circumstances that of females, but the contrast indicates a diversity in cell-resistance which there is no reason to think is confined to sex differences.

If the differences in child mortality could be ascribed to the same causes which have produced differences in the adult death rate, the reduction which has taken place at adult ages should have been reflected in the curve of the infant rate during the past forty years. This we know has not been the case, and the question whether, and to what extent, the maternal tissues are prejudicially affected by urbanisation, and to what extent these react on the vitality of the infant, presents a wide field of inquiry which has scarcely yet been entered.

Certain contrasts in the movement of the rate for separate quarters of the first year have been observed. There has been a fall in the rate during the six-to-twelve months' period, and to a lesser extent in the three-to-six months' period. In the later months of the first year certain infectious diseases, diarrhœa, and some forms of lung disease prevail and may cause very considerable fluctuation in the total rate of individual years.

On the other hand, the apparently refractory character of the rate during the first three months of life may be due in part to a more strict compliance with the requirement to register as a living birth every child who breathes for however limited a period—a view which strengthens the plea for the registration of still births.

Much of the difficulty attending a consideration of the causes of death during this period, and particularly during the first weeks of life, is simply the result of defective knowledge of the conditions which underlie the production of premature birth and congenital defects on the one hand, and atrophy and debility on the other. The obscurity indeed is reflected in the causes of death as certified, for it would appear that the rate from prematurity may sometimes increase, while that from atrophy decreases, although the combined rate may remain practically stationary.*

* See Trans. XVIIth International Congress of Medicine, London, 1913. Sect. Obstetrics and Gynæcology "Infant Mortality in First Four Week of Life."

The difficulty in defining the ultimate line of cleavage between ante-natal and true post-natal causes of death in early infancy is but one of many questions that may be answered by direct appeal to clinical and laboratory observation. Meanwhile, the very serious loss of life during infancy, and the conviction that much of it is preventable, has appealed to the philanthropic instinct of the nation, and in 1906 the first of a series of National Conferences on Infant Mortality was held in London, and did much to stimulate public interest therein.

Since then legislative sanction has been granted to local authorities to undertake wide schemes for the welfare of infancy and childhood. It is certain that these will receive the most careful consideration before adoption, but it may be well to anticipate the possibility of disappointment if they come to be regarded as in any sense substitutionary for fundamental reform in many of the conditions of home life.

The Relative Importance of Pre-Natal and Post-Natal Conditions as Causes of Infant Mortality.

By William A. Brend, M.D. (State Medicine), B.Sc.

(*Received 9th November*, 1916.)

CONTENTS.

Part I.

INFANT MORTALITY IN RELATION TO ENVIRONMENTAL CAUSE.

Part II.

INFANT MORTALITY IN RELATION TO PATHOLOGICAL CAUSE.

Part III.

THE DECLINE OF INFANT MORTALITY, AND MORTALITY IN EARLY CHILDHOOD.

THE RELATIVE IMPORTANCE OF PRE-NATAL AND POST-NATAL CONDITIONS AS CAUSES OF INFANT MORTALITY.

PART I.

INFANT MORTALITY IN RELATION TO ENVIRONMENTAL CAUSE.

1.—The Extent and Distribution of Infant Mortality.

Under the best circumstances a certain loss of infant life during the first year is unavoidable, but there is no exact means of determining this "natural" death-rate, as it may be termed, since we cannot study mankind under purely natural conditions. We can, however, determine the lowest death-rates which occur in communities of some size, and thus obtain a measure of the excess of infant mortality in less favourably situated communities. The following were the lowest rates of infant mortality in different parts of the British Isles in 1914 :—

Lowest Rates of Infant Mortality, 1914.

Area.	Population.	Deaths under 1 year, per 1,000 births.
England :—		
Berkshire ... Rural Districts	138,635	54
Oxfordshire ,, ,,	101,197	55
Wiltshire ... ,, ,,	162,987	57
Buckinghamshire ,, ,,	142,538	58
Herefordshire ,, ,,	74,116	58
Cambridgeshire ,, ,,	73,188	59
Somersetshire ,, ,,	232,604	61
Devonshire ... ,, ,,	227,775	62
Dorsetshire ... ,, ,,	105,663	62
Suffolk, West ,, ,,	72,957	63
Sussex, East ,, ,,	128,705	64
Westmoreland ,, ,,	36,570	66
Essex ... ,, ,,	265,461	67
Northamptonshire ,, ,,	118,609	67
Surrey ... ,, ,,	230,156	67
Scotland :—		
Sutherlandshire	18,829	46
Argyllshire	64,354	50
Ross and Cromarty	72,726	54
Kirkcudbright	36,226	69
Shetland	26,503	69
Ireland :—		
Roscommon	93,956	38
Cavan	91,173	40
Leitrim	63,582	42
Donegal	168,537	48
Longford	43,820	58
Sligo	79,045	58
Galway	182,224	60
Mayo	192,177	60

This table shows that large numbers of people in widely separated parts of the country, and subjected to very different

climatic conditions, are living in an environment which does not give rise to an infant mortality rate of from more than from 40 to 60 per 1,000 births, and it could have been much extended by including smaller districts. It is certain that even these figures could be lowered, and it will be seen later that probably any rate over 30 should be regarded as preventable, but provisionally 50 deaths under one year per 1,000 births may be taken as the standard by which excess of infant mortality can be measured.

2.—The Avoidable Loss of Infant Life in the United Kingdom.

We are now in a position to estimate the annual loss of life in the United Kingdom, which appears to be due to preventable causes. The total number of births registered in 1914 was 1,101,836, and the number of deaths under one year of age was 114,591, giving an infant death-rate of 104 per 1,000 births. If this rate had been 50 per 1,000 the number of deaths would have been 55,092. Thus, nearly 60,000 lives were lost owing presumably to unnatural influences.

3.—Infant Mortality in Town and Country.

Infant mortality is highest in industrial towns and mining districts. The following table shows the highest urban rates, and the rates in some of the leading cities :—

Highest Rates of Infant Mortality, 1914.

Town or District.	Population.	Deaths under 1 year, per 1,000 births.
Ashton-under-Lyne	45,494	184
Burnley	109,131	158
Barnsley	53,008	153
Gateshead	118,684	151
Middlesborough	124,635	151
Stoke-on-Trent	239,515	145
Nottingham	264,970	145
Dublin (Registration Area)... ...	434,678	145
Belfast	386,947	143
Preston	118,118	143
Swansea	119,720	142
Liverpool	763,926	140
St. Helens	99,601	139
Wigan	90,842	139
Oldham	150,055	138
Dudley	51,668	137
Newcastle	271,523	137
South Shields	110,604	137
Sunderland	152,436	136
Dundee	176,584	135
Glasgow	1,053,926	133
Paisley	86,593	133
Sheffield	472,299	132
Manchester	731,830	129
Leeds	457,507	124
Birmingham	860,591	122
Bradford	290,642	122
Birkenhead	135,789	122

In London the infant mortality rate in 1914 was only 104, but the general rate is reduced by the low rates in the ring of outlying districts. In the central parts the rates range from 120 to 140 per 1,000 births.

The difference between urban and rural death-rates is one of the most constant and striking features in the distribution of infant mortality. We may note the effect of urbanisation on a large scale in the following table given by the Registrar-General for Ireland, showing the rates in "Civic Unions," which are districts containing towns with a population of 10,000 or upwards, and the rest of Ireland :—

Infant Mortality in Ireland, 1914.

Area.	Population (1911).	Deaths under 1 year, per 1,000 births.
Total "Civic" Unions	1,629,634	120·7
Rest of Ireland	2,753,974	63·9
All Ireland	4,383,608	87·3

The influence of rural conditions in keeping the death-rate low is also seen on a large scale in countries where a considerable proportion of the population is engaged in agriculture or stock-raising. For instance, the infant mortality rate for the latest year available was 51 in New Zealand, 65 in Norway, 71 in Australia, 71 in Sweden, and 78* in France.

An analysis of the rates in France in 1912 is given in the following table :—

Area.	Population.	Deaths under 1 year, per 1,000 births.
Towns of 5,000 inhabitants and above	15,228,000	111·4
Rest of France	24,422,000	57·8
All France	39,650,000	78·0

The statistics for England and Wales as a whole do not show such striking differences as those presented by Ireland and France, the rates for 1914 having been 121 in the aggregate of

* This figure is not strictly comparable with British rates, since in France deaths occurring before registration, *i.e.*, before the third day, are regarded as still-births.

county boroughs, 99 in other urban districts, and 85 in rural districts ; but this is due partly to the fact that the distinction between " urban " and " rural " for registration and for statistical purposes does not always conform to the differences in the meanings of these words as commonly understood. In the tables previously given for France and Ireland the lines of division were based upon population, but in England and Wales the Registrar-General, when classifying deaths according to municipal boroughs, urban districts, and rural districts, is unable to proceed on this basis, since the distinction between these areas is often a matter of history or of convenience, and may have little relation to the population and real character of the district. In consequence we find included in the urban class a large number of " urban districts," with populations ranging from 5,000 to 1,000 or even less, which are little more than rural villages ; and on the other hand we find included in " rural districts " large villages which have gradually grown up and perhaps coalesced with adjacent villages until they really form a town of some size, though for registration purposes each still forms a rural district. This development has been particularly marked in the northern counties of England, where great mining areas, such as those of Chester-le-Street in Durham, with a population of 67,667, and an infant mortality rate of 140, and Easington in the same county, with a population of 64,935, and an infant mortality rate of 159, contain large densely crowded villages with very little of a really rural character about them.*

The best comparison between really rural and exclusively urban conditions is furnished by the aggregate of rural districts of the southern counties of England, and the county boroughs of the northern counties which are the great centres of industrialism. The infant mortality rates in these two groups of areas are as follows :—

County Boroughs of the North	130
Rural Districts of the South	66

4.—The Causes of Infant Mortality.

Infant mortality, then, is essentially a result of urbanisation, the difference between the death-rates in urban and rural environments being even more marked than in death-rates from tuberculosis. This of course has long been recognised, but little attempt has been made to determine the special urban factor

* Dr. Fletcher, reporting on the so-called Rural District of Chester-le-Street, has at once drawn a good picture of the conditions and paid a tribute to the miners' wives. He says : " As a class, however, and bearing in mind their inferior house accommodation and depressing surroundings of pit-mounds and black, coal-dusty paths, roads and open spaces about their houses, and the general absence of gardens, the miners and their wives deserve credit for their indoor cleanliness and tidiness, a condition the maintenance of which involves much labour in dry and windy weather, when everything becomes smothered in coal-dust."

or factors which are primarily responsible. The reports of Dr. Newsholme, which have now become classic, have shown that a number of influences must be considered, such as defective sanitation, poverty, overcrowding, bad housing, disease or insufficient nutrition of the mother, industrial employment of the mother, absence of breast feeding, and maternal ignorance. No doubt each of these factors operates to some extent, and the view might be taken that each is rather worse in an urban than in a rural area, the aggregate difference accounting for the excessive mortality in the urban areas. On the other hand many of these conditions are common to both urban and rural environments, and by a process of exclusion it may be possible to define more closely the special influence or influences in industrial surroundings which are mainly responsible. The difference in the relative importance given to different factors may be illustrated by quoting the views of two eminent authorities. Dr. Newsholme, while he attaches weight to many other causes, says : " Infant mortality is the most sensitive index we possess of social welfare and of sanitary administration, especially under urban conditions."* Sir George Newman, on the other hand, says : " It is now a well-established truism to say that the most injurious influences affecting the physical condition of young children arise from the habits, customs, and practices of the people themselves, rather than from external surroundings or conditions. The environment of the infant is its mother. Its health and physical fitness are dependent primarily upon her health, her capacity in domesticity, and her knowledge of infant care and management."† And again : " *The principal operating influence is the ignorance of the mother, and the remedy is the education of the mother.*"‡

As regards many of the factors held to be prejudicial to infant life it will not be seriously contended that they are less active in rural than in urban areas. Poverty is often looked upon as one of the greatest causes of infant deaths. Yet *per se* it does not appear to be so. The wages paid in agricultural districts are notoriously the lowest paid in the community, yet the infant mortality rate in rural Wiltshire averages only about 60, while in Kensington the average is over 100. The earnings of the Connaught peasant or the Highland crofter do not approach those of the miners of Durham or Glamorganshire, yet the loss of infant life among them is only one-third of that in mining areas. The influence of poverty is felt most directly in *housing* and *food supply*, yet it is impossible to say that in these respects rural districts are better off than towns. It is well known that housing in many rural districts is deplorable. A cottage may look picturesque, but its thatched roof and creepers

* " Infant and Child Mortality." Supplement to Thirty-ninth Annual Report of the Local Government Board.

† Annual Report for 1914.

‡ Annual Report for 1913. Italics in original.

may hide defective walls and floors, unsound drainage, low ceilings, and ill-ventilated rooms, fully as bad as those in the worst quarters of cities. Sir John Gorst says : " I have seen magnificent children, living in hovels condemned as unfit for human habitation in the West of Ireland, models of health and vigour."* The rooms may be overcrowded and there may be no adequate conveniences for cooking or maintaining cleanliness. As regards food supply, there is no reason to suppose that the agricultural worker is better off in this respect than the town dweller. It is well known that the poor in rural districts are often insufficiently fed, and meat for the family may be an exceptional luxury.

To compare in detail urban and rural *sanitary services* for the supply of water, removal of refuse, excreta, etc., demands too much space for this paper, but it seems probable that, on the whole, towns are better off in these respects than country districts. In most cities the water supply has now attained a high degree of excellence. There is little reason to doubt that in some northern towns the insanitary ash-pit system still contributes to infant mortality from epidemic diarrhœa, but in the better class metropolitan boroughs and in many residential towns the drainage system and arrangements for removal of refuse are highly efficient, yet the infant mortality rates in these districts may range from 80 to 100 or more. On the other hand the sanitary conditions in many rural districts are often primitive ; and we may point again to the West of Ireland where many villages are still very insanitary and the habits of the people sometimes most unhygienic, yet where are found the lowest rates of infant mortality in the British Isles.

Industrial employment of women might at first sight be thought an important urban factor, but here also special investigations have failed to establish a close and constant connection between women's labour and high infant mortality. In Wigan, for example, where only 12 per cent. of the total married women and widows were engaged in non-domestic work, the infant mortality rate was 180 in 1913, whereas in the textile town of Rochdale, with a percentage of 28 so employed, the rate was only 106. Dr. Newsholme says :

> " The most that can be inferred from the figures is that the industrial employment of married and widowed women cannot be regarded as, in itself, the chief cause of excessive infant mortality. Thus Glamorgan and Northumberland (31 each), Durham (26), and Monmouth (38) have the lowest proportion of industrially employed married and widowed women of all the thirty counties under consideration. They have also the highest infant mortality. Lancashire (85), Staffordshire (65), and the West Riding of York (57) have high proportions of occupied wives and widows, with a high

* *The Children of the Nation*, 1906.

infant death-rate ; Gloucester (75), Berks (70), Oxford (68) and Hereford (67) have high proportions of occupied wives and widows, with a low infant mortality."*

Dr. Greenwood, formerly Medical Officer of Health for Blackburn, found very little difference in the infant mortality rates among mothers industrially employed and those not so occupied, and he says :—

> " As a result of this investigation I came to the conclusion that no case has been made out for the further restrictive legislation in the prohibition of employment of women in the cotton mills in Blackburn."†

Dr. Jessie Duncan in Birmingham found that there was scarcely any difference in the weights of children whose mothers were industrially employed and those whose mothers were not. We may see that hard work is not necessarily incompatible with low infant mortality, for women often undertake heavy labour about farms, and even toil in the fields in many parts of France and the remoter districts of Scotland and Ireland. The unprecedented demand for female labour during the war does not seem so far to have caused any rise in the infant mortality rate.

Breast feeding is undoubtedly an important factor in maintaining health in infants, but there is no reason to suppose that it is not as widely adopted in towns as in the country. Dr. Newsholme has estimated that over 80 per cent. of wage-earning mothers suckle their children. Dr. Manby, of the Local Government Board, who specially investigated this question in Widnes where infant mortality is very high, found that breast feeding among the working classes was " almost universal." It may be noted that the poorer the home the more likely is the infant to be breast fed since it is the most economical course, and also to some extent because of the wide-spread belief among the uneducated that so long as a mother suckles her child she will not again become pregnant. It is certain that the proportion of mothers of the wealthier classes who suckle their infants does not reach 80 per cent.

Skilled attendance in child-bed by doctor or midwife is probably more fully provided in urban than in rural districts. In St. Helens, Cardiff, Bootle, Walsall and Stoke-on-Trent from 80 to 100 per cent. of all births are attended by midwives, yet infant mortality in these towns is very high. On the other hand there is no Midwives Act in Ireland, yet infant mortality in that country is very low. Ancillary services, such as infant clinics and consultation centres, are also few and far between in rural districts.

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* Op. cit. The figures in brackets indicate the number of married and widowed women engaged in occupations per 1,000 females aged ten years and upwards.

† *Jour. Roy. San. Inst.*, Vol. XXXII, 1911.

Maternal ignorance is now regarded as one of the greatest causes of infant deaths, but again it is difficult to explain the distribution of infant mortality on this view. We cannot assume that the Connaught peasantry—many of whom can neither read nor write—are so much better instructed in the care of infants that in spite of poverty and hard conditions infant mortality among them is one-half that among the mothers of Kensington, and one-third that of Bradford, where so much has been done to instruct mothers by means of health visitors and schools for mothers. It will be shown later that infant mortality in the peripheral districts of London and other large cities is much lower than in the central areas, yet it is difficult to believe that mothers living in peripheral districts such as Wandsworth, Stoke Newington, East Ham and Ilford are appreciably better instructed in the care of infants than those in central areas such as Bermondsey, Finsbury and Shoreditch. If instead of areas social classes be examined, it will be found that the wives of woodmen and foresters must be credited with as great a knowledge of the conditions governing infant welfare as that possessed by the professional groups, and it must be believed that the wives of agricultural labourers and shepherds excel in this respect all other classes of manual workers.

That there is a certain amount of ignorance among the poor as to how to rear infants is undoubted, but it is possible that those who emphasise ignorance as the great cause of infant mortality do not fully appreciate the difficulties against which the poor in both town and country have continually to struggle. In consequence they are apt to attribute to ignorance conditions which are the outcome of the environment. Here is a picture of rural conditions furnished by Mrs. Bruce Glaisher :—

> I have myself lived among such women for over twelve years—for six of them in a 5*s.* a week cottage in Derbyshire—and know by first-hand experience, as well as by intimate friendship, what the work of such a home involves.
>
> There are no " modern appliances " ; no hot water at the sink ; too often hardly a decent oven, or a boiler for washing clothes ; lighting is by candle or paraffin lamps ; and mud will be mud—inches deep—and be brought into the house at all hours of the day in wet weather as the children run to and fro. On a small wage, in an overcrowded kitchen, to bake the bread and wash the clothes, to prepare meals thriftily, to keep the children clean and mended and warmly provided for, and not to let that home degenerate into an unkempt hovel or herself and her children sink into a condition of grubby animalism, is to be a skilled and heroic toiler ; sixteen hours a day for seven days a week.—*Daily News*, February 21st, 1916.

Dr. Wanklyn, of the London County Council, has vigorously described the difficulties against which the poor have to contend, and the following is an account he gives of a London tenement which is typical of many such habitations* :—

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* " Working-class Home Conditions in London." Trans. Roy. Soc. of Med., 1913.

> The tenement comprises the two top rooms of a small house, without any offices, conveniences, or adjuncts of any kind except a wall cupboard. The front room measures 14 ft. by 11 ft. by 6ft. 6 ins., and the back room 9 ft. by 7 ft. by 6 ft. 6 ins. They are in fair repair, but some woodwork running round the room is said to be infected with bugs. . . . There is no place for storing food, or crockery or knives and forks, and the rest, except one wall cupboard in the front room. There is no scullery, no sink, or even water for washing up ; no draining board or any place on which to handle clean things ; no water-closet nearer than at the foot of thirty-six stairs ; the w.c. is in the back yard, and is used in common by thirteen people in the house—no one person is responsible for its cleanliness. There is no slop sink or a sink of any kind nearer than the w.c. There is a wash-house ; it is in the basement below the level of the back yard ; it is used on separate days by the various inmates of the house. The yard may serve as a drying ground, but it is a long way off from the attic. There is no coal or wood store except the wall cupboard in the front room. There is no cold water tap nearer than in the back yard or the basement. It was stated that as soon as the tenement was occupied water was to be laid on to a tap placed half-way between the first and second floors, with a small sink placed underneath it. There is a small cooking range, but no hot water supply. Shortly afterwards there came to live in this tenement a man and wife and four children, the six persons permitted by the by-laws to occupy its cubic space.

Mrs. Pember Reeves has ably investigated family budgets among the poor, and has shown how exiguous is the amount usually available for food. She says :—

> That the diet of the poorer London children is insufficient, unscientific and utterly unsatisfactory is horribly true. But that the real cause of this state of things is the ignorance and indifference of their mothers is untrue. What person or body of people, however educated and expert, could maintain a working man in physical efficiency and rear healthy children on the amount of money which is all these mothers have to deal with ? It would be an impossible problem if set to trained and expert people. How much more an impossible problem when set to the saddened, weakened, overburdened wives of London labourers ? *

Infectious diseases, particularly measles and whooping-cough, are responsible for a considerably higher mortality in urban than in rural districts, but it is not possible to determine with complete certainty whether this is due to a higher case mortality or to greater incidence of these affections in urban areas, since whooping-cough is not notifiable and measles has only been notifiable since 1916. There is no means therefore of determining the numbers of cases in the two types of area. General experience, however, shows that both diseases are wide-spread in every type of locality, and, wherever there is a school, opportunities for infection exist. Scarlet fever and diphtheria are notifiable, and we find that the incidence of these diseases does not differ largely in town and country ; notifications of scarlet fever in 1914 having been 4·74 per 1,000 of the population in the aggregate of county boroughs of England and 3·45 in the aggregate of rural districts, and notifications of diphtheria having been 1·54 and 1·32 respectively. Arguing from analogy, we may infer that measles and whooping-cough do not differ widely in incidence in urban and rural districts.

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* *Round about a Pound a week*, 1913.

5.—Adverse Pre-Natal Influences.

The condition of the mother during pregnancy is generally held to exercise a very important influence upon the state of the infant at birth; and since, as a class, town mothers are less healthy and well nourished than country mothers, it would appear that herein is some explanation of the higher urban rate of infant mortality. This possibility therefore demands very careful examination.

Of definite diseases syphilis is the only one having a greater incidence in towns than in the country, which is sufficiently prevalent to exert any appreciable effect upon the statistics. Syphilis, however, does not appear to be a prominent cause of infant mortality. The recorded mortality under one year of age from this disease in England and Wales in 1914 was 1·5 per 1,000 births, the total mortality from all causes being 104·6. It is well known that the statistics on this point do not represent the full incidence of the disease, but if we double or even treble the recorded figure syphilis still only becomes responsible for a small proportion of the total loss of infant life. This view is supported by the investigations made by Dr. Paul Fildes for the Local Government Board. In an examination of 677 London infants by means of the Wassermann reaction, Dr. Fildes found only 4 syphilitic, of whom only 1 died and 2 showed no symptoms.*

General malnutrition and poor physical development are wide-spread among mothers in the poorer parts of towns. To determine how far these conditions affect the mortality of the offspring we must compare the death-rates in favourably and unfavourably situated classes during the first few weeks of life, and not during the whole of the first year, when the influence of the external environment has been superimposed. If defective pre-natal conditions are the main cause of infant mortality we should expect the difference in these classes to be greatest in the early weeks of life, and to decrease as the child gets older and further from the original injurious influence. On the other hand, if the post-natal environment is responsible, we should expect the difference to increase the longer the children are exposed to it. And this is exactly what happens. The infant mortality rates in the London boroughs afford a good example. The chief medical officer to the London County Council has grouped the boroughs in order of "social conditions," the standard adopted being the percentage of children in each borough who were scheduled for education in the Council schools. Group I, which is the best group, contains boroughs in which less than 82 per cent. of the children were so scheduled; in Group V, which is the worst, 97 per cent. and over of the children were scheduled. The following table shows the deaths per thousand births in each group at various ages for the year 1913 :—

* Reports to Local Government Board on Public Health and Medical Subjects. New Series, No. 105.

Infant Mortality in Relation to "Social Conditions," 1913.

Age—Period.	Groups of Boroughs in order of "Social Condition."				
	I.	II.	III.	IV.	V.
Under 1 week	18·3	22·0	21·3	21·7	19·7
2nd week	5·2	4·6	5·4	4·9	5·0
3rd ,, ...	3·6	4·2	4·0	4·3	5·5
4th ,, ...	1·6	3·2	3·8	3·8	3·4
Under 1 month	28·7	34·0	34·5	34·7	33·6
0–3 months	45·1	51·7	54·5	55·1	56·9
4–6 ,, ...	13·3	18·2	20·0	19·3	27·0
7–9 ,, ...	7·6	13·6	14·6	16·0	22·0
10–12 ,, ...	9·0	13·2	13·6	13·6	19·2
0–12 months	75·0	96·7	102·7	104·0	125·1

It will be noticed that up to two weeks there is practically no difference in the death-rates in any of the groups; indeed, the poorest group actually shows a slightly less mortality than Groups II, III, and IV. After the first fortnight the rate begins to rise in each group in comparison with I, and exhibits the greatest rise in V. At ages 4–6 months the rate in V is twice as great as that in I, and at 7–9 months it is nearly three times as great. It may be of interest to give the corresponding figures for the three boroughs with the lowest yearly rates of infant mortality and the three with the highest rates. These are as follows :—

Infant Mortality in Boroughs with Lowest and Highest Rates.

Age—Period.	Hampstead.	Lewisham.	Woolwich.	Bermondsey.	Finsbury.	Shoreditch.
Under 1 week	21·1	17·0	20·0	19·8	21·2	21·6
2nd week	4·5	5·1	4·2	3·6	5·5	6·5
3rd ,, ...	3·0	4·0	3·8	4·9	8·2	6·8
4th ,, ...	1·5	1·4	3·8	2·5	4·3	2·3
Under 1 month	30·1	27·5	31·8	30·8	39·2	37·2
0– 3 months	44·4	44·3	48·0	55·4	65·2	68·8
4– 6 ,, ...	13·6	13·3	10·0	29·0	29·8	29·9
7– 9 ,, ...	6·8	7·1	12·8	21·3	21·6	28·2
10–12 ,, ...	3·8	10·8	8·3	23·9	20·0	23·9
0–12 months	68·6	76·5	79·1	129·6	136·6	150·8

We see from this table that while the rates in Hampstead and Shoreditch are practically identical during the first week, and Shoreditch only shows an excess of about 25 per cent. in the first month, by the time the period 7–9 months is reached the rate in Shoreditch is more than four times as high as that in Hampstead, and at 10–12 months it is more than six times as high.

Dr. Forbes, the Medical Officer of Health for Brighton, has made a similar investigation in his district, and has found that the death-rate under one week is 20·4 in the poorest class and 20·5 in the well-to-do class, whereas the rates for the whole year are 144 and 67 respectively. He remarks that if his statistics are correct, " then the better feeding, the better housing, the freeing of the mother from manual work and anxiety before the birth of the child, have no effect upon the health of the child at birth."*

Dr. Stevenson, of the Registrar-General's office, included in his report for 1911 a special investigation into the relations between infant mortality and the father's occupation. He did not separate the rates during the first week, but the following are his results for different months :—

Infant Mortality in Relation to Father's Occupation, 1911.

	Under 1 month.	2–3 months.	4–6 months.	7–9 months.	10–12 months.	Under 1 year.
Upper and middle class	30·2	14·9	13·0	9·9	8·4	76·4
Agricultural labourers	36·8	17·9	18·2	13·0	11·0	96·9
Shopkeepers, dealers, etc.	36·5	20·6	20·3	16·3	12·7	106·4
Skilled workmen ...	36·8	21·2	22·1	17·8	14·8	112·7
Intermediate workmen	38·6	22·7	23·8	19·7	16·7	121·5
Textile workers ...	44·4	27·9	32·3	23·6	19·9	148·1
Unskilled workmen ...	42·5	28·6	31·4	26·2	23·8	152·5
Miners	46·5	28·3	33·7	27·5	24·1	160·1

Here again the range of variation in the first month is relatively small compared with that in the later months, particularly the last six months of the year. We shall see later that the difference between the upper and middle classes, and miners, textile workers and unskilled workmen, during the first month, is probably a measure of the post-natal environmental influence during that month.

We have now compared death-rates at periods during the first year in different types of urban areas and in different social classes, and we will complete the investigation by comparing the rates in urban and rural areas, the most important comparison of all in view of the great difference in the yearly rates between these two classes of areas. Unfortunately no recent statistics

* *Jour. Roy. San. Inst.*, December, 1915.

are available showing the rates in the first week, nor for the extremes of conditions represented by the county boroughs of the north and the rural districts of the south. The Registrar-General, however, gives the rates for the county boroughs and rural districts for England and Wales as a whole, and the following are his figures for the year 1914 :—

Area.	Under 1 month.	2–3 months.	4–6 months.	7–9 months.	10–12 months.	Under 1 year.
County Boroughs ...	41·4	22·8	22·2	18·2	16·2	120·8
Rural Districts ...	36·7	14·8	13·4	11·2	9·3	85·4

Here also the difference is small during the first month, but increases steadily as age progresses. Dr. Stevenson says of the figures : "The chances of survival seem to differ but little at birth in town and in country, but the noxious influences of the former soon come into play and make themselves felt to an increasing extent as the first year of life progresses, and to a still greater extent in the second and third years when the urban excess generally approaches 100 per cent., thereafter gradually declining."

The foregoing comparisons show that the death-rate among infants during the first month of life differs but little in different social classes and in different types of environment, but that as the child gets older the mortality rate in unfavourably situated classes becomes progressively higher. This points strongly to the post-natal and not the pre-natal environment being the main factor in the causation of excessive infant mortality. This is not to deny that in each class and in each type of environment a certain number of children die from the pre-natal effects of some deficiency or defect in the maternal organisation, but it will be shown later that this number is remarkably constant and appears to have little relation to the external environment. It would appear that though on the average the town mother is less well nourished than her country sister, she yet has a margin to spare, and Nature takes care that her infant does not suffer. We cannot argue positively from these observations that the children of all classes are born equally healthy, for mortality rates are not the sole index of vigour, but should be supplemented by measurements of physical development ; and on this point not much comparative information is available. We may note, however, Dr. Kerr-Love's observation that the children of the poorest mothers in Glasgow weigh on an average 7·1 lb. at birth, the average weight of a healthy infant being 7 lb.,* and this supports the opinion of various workers among the poor that if the infants of the working classes had the same surroundings as those of the wealthier classes during early life they would develop into equally well-grown and

* Evidence given before the Royal Commission on Venereal Diseases.

healthy children. It is sometimes said that the decline of the birth-rate in the upper classes is leading to increase of population from the " worst stocks," but as far as capacity to survive in early life is concerned the preceding analysis does not support this view.

6.—The Influence of a Polluted Atmosphere upon Infant Mortality.

The preceding comparison between urban and rural conditions does not purport to deal more than broadly with the differences in the two types of environment. But it seems justifiable to believe that, as far as the factors enumerated are concerned, there is not sufficient difference to provide an adequate explanation of the rise in infant mortality from 40 or 50 per 1,000 births in the best rural districts to 180 or more in the worst urban areas. There would appear to be still some factor to be found, and the suggestion may be made that pollution of the atmosphere by the smoke and dust of towns is one of the most important causes of infant mortality. Dirtiness of the air appears to be the one constant accompaniment of a high infant mortality; purity of the atmosphere is the one great advantage which the agricultural labourer of Wiltshire, the Connaught peasant, and the poverty-stricken crofter of the Highlands enjoy over the resident in the town. The highest rates of infant mortality are always found in industrial towns, and it has been estimated that the pall of smoke which hangs over these throughout the year cuts off 20 per cent. of bright sunshine, and as much as 40 per cent. of the total light. The soot emitted from factory chimneys is not carried off by the wind, but falls rapidly in the immediate neighbourhood. A. G. Ruston, for example, has shown that the amount of solid material deposited in the industrial area of Leeds is 1,900 lb. per acre per annum, while three miles north-east of the centre of the town it is only 90 lb., and five miles from the centre it is reduced to 62 lb. per acre.* In such towns if the sanitary services are not of the highest efficiency the atmosphere is further polluted by dust blown up from the dirty streets, back yards and ash-pits, and this appears to contribute particularly to epidemics of enteritis. In correlation with this view it may be noted that infant mortality rates tend to be much lower in towns where there is little industrialism with consequent purity of the atmosphere, although many of the other factors believed to be prejudicial to infant life may be present in these towns. The following towns with their infant mortality rates in 1914 may be cited in support of this statement :—Bath 59, Canterbury 60, Oxford 72, St. Albans 52, Leyton 79, Walthamstow 77, Tunbridge Wells 79, Hornsey 58, East Ham 76. Another group is furnished by seaside towns, *e.g.*, Bournemouth 72, Eastbourne 61, Hastings 64, Southend 69, Poole 77, Dover 76,

* *Jour. Roy. San. Inst.*, 1912.

Folkestone 62, Worthing 60. Most of these towns are built in long strips parallel with the sea, and are thus open to absolutely unpolluted air along their greatest length.

The Committee for the Investigation of Atmospheric Pollution has shown that there are marked variations in the amount of solid material deposited in different parts of a large town. Thus in Birmingham Central the mean monthly deposit amounts to 23·23 metric tons per square kilometre, whereas in the south-west district it is only 6·04 ; in Manchester the monthly deposit is 26·79 tons at Ancoats Hospital, and only 5·69 at Bowden ; in London the measurement is 19·47 tons in the Embankment Gardens, 9·40 at Wandsworth Common, and 8·44 at Ravenscourt Park.* The investigations of the Committee have not yet proceeded far enough to enable a definite attempt to be made to correlate smoke-fall with infant mortality, nevertheless it is significant to note that in most large cities there is a steady rise in the infant mortality rate as we go from the periphery to the central parts which never receive a wind that has not passed over a smoke-laden area. This distribution is well illustrated by London, but in order to study it we must have before us a map of greater London, since we are not concerned with the arbitrary boundary of the London County Council area but with the whole great patch of streets and houses. There is an outlying ring all round London in which the average infant mortality rate was 74 in 1914, and was as low as 48 in Wanstead (66 in 1913 and 47 in 1912), 58 in Hornsey, and 61 in Ilford. Inside this is an inner ring where the average rate in 1914 was 97 ; and in the centre there is an area consisting of Finsbury, Shoreditch, Bethnal Green, City of London, Southwark, Bermondsey, Stepney and Poplar, in which the average is 124, and the highest rate 142 in Shoreditch.†

These differences may be due in part to the outlying and more salubrious districts containing a larger proportion of the wealthier classes, but it is clear that this cannot be a preponderating influence from the fact that the rates in such places as Ilford, East Ham, Walthamstow, Leyton, and Wanstead are as low or lower than that in Hampstead, and lower than those in Kensington, Paddington, and Westminster. When comparing the infant mortality rates in poor and good class parts of a city it must be remembered that the children of the wealthier classes are by no means so continuously subjected to the adverse influence as those of the poor. Not only are there occasional and week-end visits

* *Lancet*, February 26th, 1916.

† The principal districts forming the outer ring are Ilford, East Ham, Barking, Woolwich, Lewisham, Wandsworth, Chiswick, Ealing, Willesden, Finchley, Hampstead, Hornsey, Stoke Newington, Walthamstow, Leyton, and Wanstead.

The inner ring consists of West Ham, Greenwich, Deptford, Camberwell, Lambeth, Battersea, Fulham, Chelsea, Hammersmith, Kensington, Paddington, Marylebone, St. Pancras, Islington, and Hackney.

(B2406—r B1755)

to the country, but a large proportion of the children are taken away from the town during the hottest month of the year, thus escaping a particularly trying period and increasing their power of resisting adverse conditions on their return. It would be interesting to know how much infant mortality in the West End of London would rise, relatively high though it is, if infants and their mothers saw as little of the country throughout the year as most of the mothers of Bermondsey and Shoreditch.

In Liverpool, Manchester, Paris and other large cities the same tendency for infant mortality to increase rapidly as the central and most crowded parts are approached is observable.

7.—Preliminary Conclusions.

The conclusions which the analysis so far leads to are then :—

(1) That excess of infant mortality has very little relation to pre-natal conditions.

(2) That the excess is due to some factor or factors in industrial towns, the centres of large cities, and mining areas, of which possibly the most important is a polluted state of the atmosphere.

Support can now be obtained for these views by another chain of reasoning and another series of statistics derived from study of the pathological causes of infant deaths.

PART II.

INFANT MORTALITY IN RELATION TO PATHOLOGICAL CAUSE.

8.—The Pathological Causes of Infant Mortality.

If we enumerate all the diseases and conditions from which infants die we obtain a fairly long list, but most of these are only of occasional occurrence, and, as a matter of fact, by far the larger part of the mortality is brought about by quite a small number of diseases which fall into the three following sharply-distinguished groups :—

(1) Respiratory diseases, mainly pneumonia and bronchitis, but including measles and whooping-cough, since nearly all fatal cases of these maladies are due to the supervention of pneumonia or bronchitis.

(2) Epidemic diarrhœa and enteritis.

(3) Developmental diseases and malformations, that is—conditions arising from some defect in the child present at birth, a group which will be considered in detail subsequently.

The following table shows the death-rates from these causes in England and Wales, and in the extremes of urban and rural conditions, for the year 1914 :—

Pathological Causes of Infant Deaths, 1914.

Cause of Death.	Deaths under 1 year per 1,000 births.		
	England and Wales.	County Boroughs of North.	Rural Districts of South.
Total respiratory diseases	25·65	35·03	13·86
Pneumonia	10·40	14·03	6·01
Bronchitis	7·75	10·76	4·69
Whooping-cough ...	4·38	5·31	2·14
Measles	2·14	3·77	·27
Pulm. phthisis	·35	·43	·29
Other respiratory diseases	·63	·73	·46
Diarrhœa and Enteritis ...	17·37	23·54	6·11
Developmental conditions	35·97	39·42	28·84
Other diseases	25·63	31·78	16·72
All causes	104·62	129·77	65·53

It will be noticed that the excess of infant mortality in the county boroughs of the north of England over that in the rural districts of the south is mainly due to the great increase in deaths from two causes—respiratory diseases, and diarrhœa and enteritis. The excess from respiratory diseases is 153 per cent., and from diarrhœa 285 per cent., whereas the excess from developmental conditions is only 37 per cent., and from " other diseases " 90 per cent. The class " other diseases " consists mainly of non-pulmonary tuberculosis, rickets, convulsions, and so-called " overlying," and it is probable that a certain number of these deaths might equally well have been certified as due to respiratory causes. The writer has shown elsewhere that a large proportion of deaths attributed to overlying are really due to respiratory diseases. In view of the possibility discussed on p. 11 that the high death-rates from measles and whooping-cough in the county boroughs of the north are due to greater incidence of these diseases owing to increased opportunity for infection, it may be noted that in the county boroughs of the south, where probably the opportunities for infection are just as great but the atmosphere is distinctly purer, the infant death-rate in 1914 from measles was 1·07 and from whooping-cough 3·39.

The criticism may be made that the writer has ignored climatic differences in comparing the warm and dry south of England with the relatively cold and wet north, and it may be urged that the difference is at least partially responsible for the excess of respiratory diseases. To meet this criticism the following

table has been compiled for the northern half of Scotland, where, if cold and wet are important factors in producing respiratory diseases in infants, the greatest effect should be observed. The area dealt with consists of the counties of Orkney, Shetland, Caithness, Sutherland, Ross and Cromarty, Nairn, Aberdeen, Elgin, Banff, Inverness, Kincardine, Argyll, Perth, and Forfar, the total number of births being 11,107 and the year 1914.

Pathological Causes of Infant Deaths in Northern Scotland, 1914.

Cause of Death.	Deaths under 1 year per 1,000 births.
Total respiratory diseases ...	15·50
Pneumonia	6·32
Bronchitis	4·86
Whooping-cough	2·97
Measles	·54
Pulm. phthisis	·18
Other respiratory diseases	·63
Diarrhœa and Enteritis ...	6·12
Developmental conditions ...	26·38
Other diseases	19·08
All causes	67·08

We have here a record of the pathological causes of infant mortality under perhaps the most extreme difference of rural conditions, as compared with the South of England, to be found in the British Isles, yet it will be noticed that the differences in the death-rates are astonishingly small. Deaths from pneumonia, bronchitis, and diarrhœa are almost identical, and the difference in whooping-cough and measles would probably have disappeared if the statistics had been calculated over a term of years.

It seems probable that the excess of deaths from respiratory diseases among infants in large towns is correlated with a smoky condition of the atmosphere. White and Marcy* studied the distribution of mortality from pneumonia at all ages in Pittsburg, and found strong correlation between it and smoke-laden areas. Benner† and Klotz‡ have investigated the pathological effects of smoke, and found it highly injurious. Further research is necessary before we can speak with assurance, but the effect may be due to simple irritation of the respiratory organs by solid particles, rendering them liable to invasion by micro-organisms,

* "Study of the Influence of varying Densities of City Smoke on the Mortality from Pneumonia." Trans. of 15th Int. Cong. on Hygiene, Washington, 1912.

† "How and why Smoke is Injurious." Ib.

‡ "Pulmonary Anthracosis; a Community Disease." *Amer Jour. of Pub. Health.*

or it may be due to other constituents of smoke. The infant death-rate from respiratory diseases rises rapidly in the winter months, and it is possible that this is not due to the cold to which we generally attribute it, but to the increased pollution of the atmosphere from the larger number of fires, and the precipitation of solid material in foggy weather. It is interesting to note that the death-rate from respiratory diseases does not appear to be at all affected by the annual average temperature. Thus, in the very hot year 1911, the infant mortality in England and Wales from respiratory diseases was 26·67, the rate from all causes being 130 ; and in the exceptionally favourable year 1912, when the lowest rate from all causes was established, viz., 95, the death-rate from respiratory diseases was 26·34. It would be difficult to find two years of more strongly contrasted meteorological conditions, and yet the death-rate from respiratory diseases was the same in each.

Diarrhœa and enteritis is clearly also a feature of urbanisation, but in addition it is markedly influenced by temperature. In 1911 the infant death-rate for England and Wales from this cause was 36·20 and in 1912 it was 7·72, thus accounting for more than three-quarters of the total difference between the two years. The special effect of urbanisation can best be demonstrated by setting out the deaths in different quarters of the year. Figures are not available for infant deaths separately in quarters of the year, and the following table gives the deaths at all ages ; but since two-thirds of these are in the first year and three-quarters in the first two years, the argument is not thereby seriously affected. Statistics, too, are only available for the aggregate of districts for England and Wales as a whole.

Deaths from Diarrhœa in Quarters of Year 1914.

Aggregate of	Population.	Deaths in				
		1st Quarter.	2nd Quarter.	3rd Quarter.	4th Quarter.	Whole Year.
County Boroughs	11,865,815	961	962	5,933	2,068	9,924
Rural Districts	7,892,817	483	400	1,419	719	3,021

Comparing the first quarter with the third the rise in the county boroughs is 517 per cent., whereas in the rural districts the rise is only 189 per cent. If we had figures exclusively for infants the difference would probably be greater.

What the factor is which produces the excess of infant mortality from diarrhœa in industrial towns we do not precisely know. Artificial feeding is undoubtedly an important cause, but

it cannot alone explain the great difference in the urban and rural death-rates. It may be noted that diarrhœa is responsible for the highest mortality in the second and third months of life, although the proportion of breast-fed infants is appreciably higher then than in later months, and the death-rate falls steadily from the fourth month onwards. Decomposition of milk is also a factor, but it is difficult to believe that the quality of the milk in rural districts, though undoubtedly higher, is so much better as to explain the difference in the death-rates. Dr. Newsholme and others have clearly established that dust blown up in hot weather from dirty streets, privies, and ash-pits, in towns where scavenging is inefficient, is at least one important factor in causing the disease.

9.—Deaths from Developmental Conditions.

Consideration of these will afford lessons of equally great but entirely different character. The tables given show that the range of variation in the mortality from developmental conditions does not approach in any degree that exhibited by other causes of death, leading to the remarkable and apparently paradoxical result that in rural districts, although the mothers are the healthiest, developmental conditions form by far the largest single cause of infant mortality, accounting for more than 40 per cent. of the total deaths in the first year. In Berkshire and Oxfordshire, the two counties in which the rural infant mortality was lowest in 1914, no less than 111 out of a total of 243 infant deaths were due to developmental conditions.

The range of variation in the death-rate due exclusively to developmental conditions is, however, even smaller than that shown in the tables, since the latter includes a small proportion of deaths which are really due to the influence of the post-natal environment. In order to bring out this fact, and demonstrate the constancy under all circumstances in the death-rate from conditions present at birth, we must analyse this group more fully.

The group " developmental " conditions includes the following subdivisions :—

Premature birth ;
Congenital malformations ;
Atrophy, debility, and marasmus.

The first two of these subdivisions are clearly due to causes operating before birth ; the third is less definite. It is applied to conditions of wasting and feebleness observed in young infants, not due to definitely recognisable disease, but to some cause the exact nature of which is often not fully understood. In the first month deaths from atrophy, etc., appear almost always to

be due to some deficiency existing at birth, but in the later months it is impossible to distinguish with certainty between the influence of the environment and congenital influences. In order therefore to eliminate as far as possible this element of uncertainty we must measure deaths from developmental conditions, not by the mortality in the whole year, but by that in the first month. The following table shows the distribution of deaths from all three causes according to months of the first year :—

Infant Mortality from Developmental Conditions per 1,000 *Births,* 1914.

Cause of Death.	Under 1 month.	2–3 months.	4–6 months.	7–9 months.	10–12 months.	Under 1 year.
Premature birth ...	17·88	1·37	0·24	0·03	0·01	19·73
Congenital malformations	2·47	0·73	0·40	0·18	0·11	3·89
Atrophy, debility, and marasmus ...	6·55	3·01	1·79	0·70	0·37	12·42

The two influences, pre-natal conditions and post-natal environment, really interdigitate to some extent, but the above figures show that by drawing the line at the end of the first month we obtain a fairly sharp line of division ; for in those deaths even certified as due to premature birth or congenital malformations, which occur after the first month, we cannot positively exclude the effect of the environment, while, on the other hand, we know from the earlier investigations that the influence of the post-natal environment in causing mortality during the first month is small.

We will now compare the death-rates from developmental conditions in the first month under various conditions. The comparison between urban and rural districts is the most important, but unfortunately statistics are not available to enable the rates in the county boroughs of the north and rural districts of the south to be compared ; the Registrar-General, however, gives the following figures for London, the county boroughs, other urban districts, and rural districts, for England and Wales as a whole. We can introduce into the same table another element of variation by including the figures for 1911 as well as those for 1914. The year 1911 was one with a summer heat of almost tropical intensity, and infant mortality in England and Wales rose to 130 ; 1914 was a comparatively cool year, and the rate was only 105.

Deaths from Developmental Conditions, under one month, per 1,000 *Births.*

Area.	Premature Birth.		Congenital Malformations.		Atrophy, Debility, and Marasmus.	
	1911.	1914.	1911.	1914.	1911.	1914.
London	16·43	16·14	2·58	2·14	5·24	4·41
County Boroughs ...	19·66	19·30	2·21	2·45	7·98	6·78
Other Urban Districts	18·21	17·76	2·43	2·64	8·07	6·84
Rural Districts ...	17·09	16·77	2·12	2·44	8·49	7·06
All Urban Areas ...	18·51	18·16	2·36	2·47	7·58	6·42

We note in this table the small range of variation in deaths from developmental conditions in the first month, whether we compare different types of area or years of very different meteorological conditions. On the other hand, deaths from pneumonia and bronchitis during the first month, though causing only a small mortality, are 60 per cent. more in London and in the county boroughs than in the rural districts. The small advantage shown by London in deaths from developmental conditions is probably due partly to difference in diagnosis. It should be noticed that deaths under one month in London certified as due to syphilis, pneumonia, and atelectasis, though causing in the aggregate only a small mortality, are all higher in London than in any other part of the country.

We have yet another system of classification which admits of further comparisons, viz., social classes. The death-rates from developmental conditions in the first month according to social class were tabulated as part of the special investigation undertaken by the Registrar-General in 1911, and the following are his figures :—

Deaths from Developmental Conditions, under one month, in Social Classes, 1911.

Social Class.	Premature Birth.	Congenital Malformations.	Atrophy, Debility, and Marasmus.
Upper and middle class ...	13·8	2·3	5·6
Shopkeepers, dealers, etc.	16·6	2·0	6·3
Agricultural labourers ...	16·9	2·2	8·1
Skilled workmen	17·1	2·4	6·6
Intermediate workmen ...	17·7	2·4	7·0
Unskilled workmen ...	19·0	2·4	8·2
Textile workers	19·1	3·0	8·7
Miners	20·3	2·3	9·9

In this table we notice that though the range of variation is small between all classes but the upper and middle class, the latter do appear to have a distinct advantage over the worst class, miners, as regards deaths from prematurity and from atrophy. It would be impossible to determine, however, whether the increased mortality among infants of miners is really due to adverse conditions acting upon the mother before birth, or to the adverse post-natal environment killing off some prematurely born infants in the first month who would have survived, either permanently or until after the first month, if they had received the care and attention they are likely to receive in the upper and middle classes. Statistics showing the mortality during the first week, and still more during the first day, in different social classes would materially assist to determine this point, but, as has been stated, they are not available. The smaller number of premature births in the upper and middle classes may also in part be due to some premature births being regarded as still-births, for in those cases in which an infant dies very shortly after birth, perhaps having only made a few movements or convulsive gasps for breath, it is a very fine line which divides live-birth from dead-birth. It is a fact of some psychological interest that many mothers are less distressed at having a miscarriage than giving birth to an infant which dies immediately, and the slight straining of the law to spare the mother's feelings is perhaps more apt to occur among a class where births are mainly attended by doctors than in a class where they are principally attended by midwives.

The most significant feature of the table is the agreement of the rates among agricultural labourers with those in other classes of manual workers, although, as we have seen, they have so great an advantage over other classes in all other causes of infant mortality.

We have now compared deaths from developmental conditions during the first month, in urban and rural areas, in years of different meteorological conditions, and in different social classes, and we find a remarkably constant rate running throughout. Mortality from this cause appears to bear almost no relation to the external environment of the mother—a very hot year does not send it up, rural conditions do not bring it down; and even if we assume that the statistical difference between the upper and middle classes and miners represents a real difference, the effect of the best social circumstances over the worst is far smaller than that apparent in other causes of infant mortality. To the writer these facts seem to lead to the conclusion that the great bulk of these deaths are due to some obscure internal derangement of normal processes in the mother or infant which are either independent of the external environment or are due to some factor or factors in the external environment

equally common among all classes and under all circumstances. It would appear that the structural or physiological defects leading to these deaths really fall into the same category as those minor defects, such as moles, nævi, contracted foreskins, etc., which are exhibited by a certain proportion of children, but do not characterise any particular class or environment and do not appear to have any recognisable relation to external conditions. We can write off a small proportion of these deaths in large towns as due to syphilis, but we know that this is an inappreciable cause of prematurity in country districts. A few others are due to acute illness or accidents to the mother; but of by far the greatest number of deaths from developmental conditions we do not know the cause, and we do not know how to prevent this mortality. Just as in every packet of seeds there are some that do not germinate, and in the young of every flock there are some that do not survive, so it may be suggested that these deaths represent Nature's failures, and man with his present knowledge cannot hope to prevent this loss. The deaths from developmental conditions in the first month appear to range from 25 to 30 per 1,000 births, and this probably represents the real natural death-rate which was postulated at the beginning of this paper. We see here natural selection in operation, uncontrolled and uninfluenced by man's efforts, steadily eliminating the unfit, and we realise how shallow is the argument sometimes brought forward that by preventing infant deaths we are in the long run injuring the national physique by interfering with natural processes.

10.—Still-births.

An investigation of infant mortality to be comprehensive should include examination of the number and causes of still-births, but statistics are too incomplete and unreliable for definite conclusions to be drawn regarding these questions. Syphilis undoubtedly plays a larger part here than in infant mortality, but the current view that some 50 per cent. of still-births are due to this disease appears to be much exaggerated. The statistics of Dr. Whitridge Williams, who found syphilis responsible for 14 per cent. of fœtal deaths among white women admitted to the John Hopkin's Hospital, probably much more nearly represent the truth. While further investigation is needed there are reasons for believing that a large proportion of still-births, as those of infant deaths in the first month, are due to natural and seemingly unpreventable causes.

PART III.

THE DECLINE OF INFANT MORTALITY, AND MORTALITY IN EARLY CHILDHOOD.

11.—The Decline in Infant Mortality.

Infant mortality has declined appreciably during recent years, and this has been generally attributed to such measures as the Midwives Act, the Notification of Births Act, and the establishment of pre-natal clinics, schools for mothers, infant consultation centres, etc. But if this claim is justified it follows that maternal ignorance and lack of care is a larger factor in the causation of infant mortality than the writer has been disposed to admit in the preceding pages, and it correspondingly reduces the importance which has been attached to atmospheric pollution. It is necessary therefore to ascertain how far the relation of cause and effect can be established between the special measures which have been taken to reduce infant mortality and the decline in that mortality.

The following table shows the movements in infant mortality since 1880 in England and Wales :—

Infant Mortality in England and Wales, 1881–1915.

Year.	Deaths, under 1 year, per 1,000 births.	Year.	Deaths under 1 year per 1,000 births.
1881–1885	139	1907	118
1886–1890	145	1908	120
1891–1895	151	1909	109
1896–1900	156	1910	105
1901	151	1911	130
1902	133	1912	95
1903	132	1913	108
1904	145	1914	105
1905	128	1915	110
1906	132		

It will be seen that there has been by no means a constant downward trend. The rate for the period 1891–1900 was for some unknown reason high as compared with the rate in 1881–1885. Thereafter the fall has occurred mainly in two periods. There was an abrupt decline in 1902, and then, with some rise in 1904, the rate remained constant until 1906. Two years of intermediate mortality are followed by another abrupt fall in 1909, and again, with an exceptional rise in 1911 and an exceptional fall in 1912, the rate has remained nearly constant to the present year.

It is impossible to correlate these movements with legislative and administrative measures. The Midwives Act was passed in 1902, but did not come into force until 1905, and it did not produce an abrupt change, as it took in all midwives then in *bona fide* practice, and it is estimated that even in 1913 more than 50 per cent. of practising midwives were untrained women who came in at the beginning. The Notification of Births Act, which is the foundation of modern methods, was passed in August, 1907, but it was then an adoptive Act, and several years elapsed before it was at all widely adopted by local authorities. Even by the end of 1913 the Act was not in force in 13 county boroughs, 159 municipal boroughs, and 1,230 urban and rural districts, with a total population of nearly fifteen millions. The Act cannot be held to account for the abrupt fall in 1909, for if its very partial adoption during the first two years produced so great an effect why has not this effect continually increased in subsequent years with the steadily increasing extension of the Act? The growth of schools for mothers, infant clinics, ante-natal clinics, and visiting by health visitors has occurred almost entirely since 1910, and has increased with each year, but the effect on the infant mortality rate seems to have been *nil*.

It is perhaps fairer to test the value of these methods, not by reference to the infant mortality rate for the whole country, but by the rate in a district where they have been most zealously applied. Bradford affords a good instance for this purpose. The city was one of the first to adopt the Notification of Births Act, and it has deservedly earned a high reputation for the energy it has shown in providing for the care of infant and maternal life. It possesses an ante-natal clinic and maternity hospital, an infant clinic with hospital attached, a system of supplying nursing and expectant mothers with food in order to encourage breast feeding, a municipal milk depôt, and a staff of health visitors who are in touch with all the departments of the child welfare scheme. What effect now have these measures had upon the infant mortality record of Bradford? We will examine the rates for the same years as in the previous table.

Infant Mortality in Bradford, 1881–1915.

Year.	Deaths, under 1 year, per 1,000 births.	Year.	Deaths under 1 year per 1,000 births.
1881–1885	160	1907	124
1886–1890	170	1908	143
1891–1895	176	1909	116
1896–1900	165	1910	127
1901	168	1911	140
1902	139	1912	99
1903	148	1913	128
1904	167	1914	122
1905	144	1915	123
1906	152		

Comparison with the previous table shows that infant mortality in Bradford has varied almost exactly as it has in England and Wales as a whole. There was a high rate from 1891 to 1901 ; an abrupt fall in 1902, which continued to 1906 except for a rise in 1904 ; and a further abrupt fall in 1909, which has continued to 1915, broken only by the rise in 1911 and the fall in 1912. It is obvious that these variations have not been due to local efforts, but to changes in conditions which have prevailed more or less uniformly over England and Wales. When we recall that there are reasons for thinking that a natural death-rate need not exceed 30 per 1,000, and that wide areas in all parts of the country exhibit a rate which does not exceed 60 per 1,000, it is clear that, even if we ascribe the whole decline in Bradford to the efforts made, these efforts are merely touching the fringe of the problem.

We will complete this investigation by showing at what periods in the first year infant mortality has declined. Unfortunately the Registrar-General did not tabulate deaths in the first month previous to 1905, though we can get earlier statistics for the first three months together. The following table shows the information available for England and Wales :—

Infant Mortality according to periods of year, 1898–1914.

Year.	Under 1 month.	2–3 months.	Total under 3 months.	4–6 months.	7–12 months.
1898	—	—	75·1	35·2	50·1
1899	—	—	76·9	35·7	50·0
1900	—	—	74·2	32·7	47·3
1901	—	—	74·8	32·0	44·5
1902	—	—	68·4	25·8	38·7
1903	—	—	67·6	26·2	37·8
1904	—	—	70·9	30·1	44·3
1905	41·8	24·8	66·6	24·8	36·8
1906	41·9	25·7	67·6	27·0	37·9
1907	40·7	23·3	64·0	21·3	32·3
1908	40·3	24·2	64·4	23·6	32·4
1909	39·7	20·4	60·1	19·2	29·4
1910	38·5	20·0	58·5	18·8	28·2
1911	40·6	24·8	65·4	26·1	38·5
1912	38·4	17·6	56 0	14·8	23·9
1913	39·4	20·3	59·7	19·8	28·9
1914	38·5	19·4	57·9	18·8	28·0

It will be seen that during the first month the death-rate has been *almost constant for nine years*. In the second and third months it has fallen about 20 per cent. comparing 1905 with 1914. In the fourth, fifth, and sixth months it has fallen 24 per cent. in the same period, and nearly 50 per cent. if we go back to 1898. In the period including the seventh to the twelfth month the rate has fallen 24 per cent. comparing 1905 and 1914, and again nearly 50 per cent. as compared with 1898. Similar

tables for urban and rural districts separately present exactly the same features. In the county boroughs of England and Wales the average rate in the first month during the four years 1911–1914 was 42·0, while in the rural districts it was 38·0, again showing how limited is the special effect of an urban environment during the first month. We see then that, though much the larger part of our special efforts to reduce infant mortality have been directed against adverse conditions prevailing during the first few weeks, the greater part of the fall in the death-rate has occurred in the last half of the first year.

Dr. Dudfield has analysed the statistics for Paddington, and his figures under one month go back to an earlier year than those of the Registrar-General. He has shown that the death-rate under one month in that district was 42·69 in the quinquennium 1891–95, and 37·53 in the quinquennium 1906–10. He remarks: "It may be accepted as demonstrated that the present methods employed for combating infant mortality are of comparatively little effect upon those causes of mortality which are operative during the earliest days of extra-uterine life."*

12.—Death-rates in Early Childhood.

The fall in mortality has not characterised the first year of life alone, but has been even more marked in the immediately succeeding years. The following table shows the death-rates in the second year since 1880:—

Mortality in Second Year of Life, England and Wales, 1881–1914.

Year.	Deaths per 1,000 living at age 1 to 2.	Year.	Deaths per 1,000 living at age 1 to 2.
1881–1885	53·1	1907	37·2
1886–1890	53·4	1908	34·9
1891–1895	52·2	1909	33·5
1896–1900	48·8	1910	30·7
1901	43·3	1911	42·2
1902	41·1	1912	31·6
1903	39·1	1913	33·4
1904	44·1	1914	32·8
1905	37·7		
1906	37·8		

Similar tables for the third, fourth, and fifth years show that in each year the mortality has declined by approximately 50 per cent. since 1881–1895, the largest part of the decline having occurred since 1900. The improvement at these ages is particularly noteworthy since no special efforts have been made by the

* "Still-births: The Case for their Compulsory Registration and their Definition." Pro. Roy. Soc. of Med., January, 1914.

State for these children, and they only share to a limited extent in the special provision for infants and do not come under the school medical service. It is evident that certain factors have been exercising a favourable influence upon life in young children at all ages during the last twenty years or so, and the decline in infant mortality is only a part, and even the smaller part, of this process. A separate investigation would be necessary to determine the real causes of the decline in infant and child mortality, but probably the greatest factor has been the clearing of slum areas. A remarkable series of cool wet summers has also played a considerable part.

When we examine the distribution of mortality in young children we find it presents precisely the same features as that of deaths in the first year. The following are the rates per thousand living at each age group in the extremes of urban and rural conditions for the year 1914 :—

Second Year.

County Boroughs of the North	55·71
Rural Districts of the South	11·71
Third, Fourth, and Fifth Years.	
County Boroughs of the North	13·50
Rural Districts of the South	3·80

Analysis of the pathological causes of these deaths shows that the excess in urban districts is due in greatest measure to increase of deaths from respiratory conditions and diarrhœa. The following table shows the causes of death in the second year of life :—

Death-rates in Second Year*, 1914.

Cause of Death.	County Boroughs of North.	Rural Districts of South.
Respiratory Diseases	33·27	5·86
Diarrhœa and Enteritis	8·21	·97
Other causes	14·23	4·89
All causes	55·71	11·72

In the period 3–5 years the proportion of deaths due to other conditions increases, but the urban excess of deaths from respiratory diseases and diarrhœa is even more marked, as shown in the following table :—

* The Registrar-General points out that death-rates at this age are not entirely reliable, owing to uncertainty in the statements of age.

Death-rates, Third to Fifth Year, 1914.

Cause of Death.	County Boroughs of North.	Rural Districts of South.
Respiratory Diseases	7·09	1·18
Diarrhœa and Enteritis	·86	·12
Other causes	5·55	2·50
All causes	13·50	3·80

It will be observed that while respiratory diseases are six times, and diarrhœa seven times, as high as in the rural districts, the mortality from all other causes is only slightly more than doubled. It may be noted that neither this nor the preceding table gives an absolute separation of all deaths in which respiratory conditions played a part, for "other causes" includes deaths from scarlet fever, diphtheria, and other conditions, the most frequent complications of which, as shown by the Registrar-General's secondary classification, are bronchitis and pneumonia.

18.—General Conclusion.

It appears, then, that under the term "infant mortality" we are classing together two radically different types of deaths, which are brought about by different causes and are governed by different influences. The first type consists of deaths due to developmental factors which vary but little from place to place, year to year, and class to class, and appear to be caused by fundamental influences which we do not fully understand, and at present seem unable to control. The second type consists of deaths mainly due to respiratory diseases and enteritis caused by influences in the post-natal environment, most prevalent in crowded, smoky, industrial and mining districts, and probably entirely preventable.

These two types of deaths overlap somewhat in time, but the end of the first month gives us a fairly sharp line of division. Some 75 per cent. of all deaths before that line are due to developmental conditions, though the proportion among miners, textile workers, and unskilled labourers is rather less. On the other side of the line the proportion of deaths due to developmental conditions is small. Some three-quarters of mortality in the first month represents a bedrock loss of life which we have hitherto failed to reduce, and may continue so to fail indefinitely. Mortality after the first month is part and parcel of the general mortality of childhood, due apparently to the same causes, and

demanding for its reduction the same measures. The use of the term "infant mortality"—applying only to deaths in the first year—is apt to be misleading, since it tends to concentrate attention upon that year, and obscure the fact that the same influences are acting upon all young children after the first month and producing the same variations and tendencies. It might be an advantage to drop this term and speak of those in the first month as "birth mortality," and those from the end of the first month to say the end of the third year as the "mortality of early childhood." The great centres of deaths in infancy and early childhood are overcrowded industrial cities, and the measures which will benefit all classes of the community—clearing of slum areas, provision of open spaces, segregation of factories as at Letchworth, and prevention of atmospheric pollution—are also those which will reduce infant mortality.

The Causes of Infantile Mortality.

By Leonard Findlay, M.D., D.Sc. (Glasgow).

CONTENTS.

THE CAUSES OF INFANTILE MORTALITY.

(Preliminary Communication.)

By Leonard Findlay, M.D., D.Sc. (Glasgow).
Physician, Royal Hospital for Sick Children, Glasgow.

Much has been said lately of the desirability of Government action towards the inauguration or encouragement of ante-natal and post-natal cliniques, milk depôts and similar institutions. It is very doubtful, however, if the good that will accrue from institutions of this kind will be at all commensurate with the expectations that have been aroused or with the expense that would be entailed. Prof. Donald, of Manchester, has recently written ("Brit. Med. Jour.," July 8th, 1916) to show how little real progress in the study of ante-natal mortality and in the knowledge of the diseases of the pregnant woman can be expected from these measures, and I am inclined to be equally pessimistic regarding the effect of the post-natal cliniques and child-welfare societies in seriously reducing the infantile death rate. Mortality at birth and in childhood would seem to offer much more complex problems than is commonly imagined, and to have its roots more deeply situated than can be touched by the proposed schemes.

I.—The Effect of Infant Welfare Schemes on Infantile Death Rate.

During the past ten or fifteen years several municipalities have inaugurated schemes for Milk Depôts or for Infant Cliniques, with the hope of reducing the infantile mortality. A study of the infantile death rates in towns where such measures have been adopted, *e.g.*, Liverpool, Bradford, Poplar, and Glasgow, does not, however, support the contention that these methods are of much value in seriously decreasing the evil.

If one examines the infantile death rates of England, Scotland, and Ireland generally, and of these various towns, it will be seen that about the year 1900 there set in all over the kingdom a decline in the death rate, and that the various curves follow practically the same course and are unaffected by the introduction of the measures above mentioned. (*See* Charts 1 and 2.)

The Medical Officer of Health of Liverpool, in his Annual Report for 1914, speaks enthusiastically of the effects of the Milk Depôt which was started in 1901. According to the figures in the Report the Depôt did not become popular for some years, though the decline in the death rate set in contemporaneously with its opening. In Glasgow a similar depôt was opened in 1904, but the curve for this town shows, just as in Liverpool, a decline commencing in the year 1900 with no acceleration of the fall after 1904 and continuing till 1912, although the depôt was abandoned in 1910. An Infant Clinique was started in

Bradford in 1912, and certainly the infantile death rate for that year shows a marked fall; but, as will be seen from the various curves, the death rate all over the country for 1912 was the lowest ever recorded until that date.

The various charts show from year to year a wonderful uniformity in the behaviour of the different curves. In fact, it is most striking how in such widely separated towns as London and Glasgow the apices and dips of the curves coincide, so that one is hardly justified in ascribing any result, which is so general, to the adoption of a particular measure in any individual town.

Recently there appeared the following paragraph in the London correspondence column of the "Glasgow Herald" concerning the Infant Welfare Scheme of Poplar:—

"It is remarkable and disappointing that in Poplar the death-rate [infantile] has continued to rise, and has gone up from 83 to 117 per thousand ever since the inauguration of the baby-saving campaign. The chief lady health visitor is quite candid, admitting that the increase has come about despite the amount of money and energy spent by the various organisations working directly and indirectly for the preservation of infant life. She thinks that sometimes there is too much visiting, and observes: 'I myself was unfortunate enough to be the fifth to call on one mother, and the number of visitors who might call is positively staggering when you try to reckon them up.'"

II.—The Influence of Wages.

The decline of the infantile death rate during 1916 concurrent with the high wages earned has been suggested as evidence that it is in great part a question of wages. This, of course, is an old idea and one that has often been expressed, but a critical study of the available data shows how unwarranted such an assumption is.

After the declaration of war the death-rate at first rose, but during 1916 it fell considerably, and in most places has been the lowest ever recorded. (*See* Chart 3.)

In 1915 the working and labouring classes were quite as prosperous—in fact, their purchasing power was really greater (Miss Ferguson, Proc. Roy. Soc., Edin., Vol. XXXVII., pt. 2, No. 8), so that the fall in 1916 is more probably due to some other factor, *e.g.*, a diminution in the severity of epidemics of such diseases as measles and whooping cough. The importance of this factor is well exemplified in one town in the West of Scotland (Coatbridge), where, although as in the West of Scotland generally, there has been increased prosperity, the death rate has increased. A survey of the death returns for this town as depicted in Chart 4 shows that an epidemic of measles was the contributing factor, whereas in Scotland generally, and in Glasgow particularly, deaths from this disease were during 1916 unusually few. (See Charts 5 and 6.)

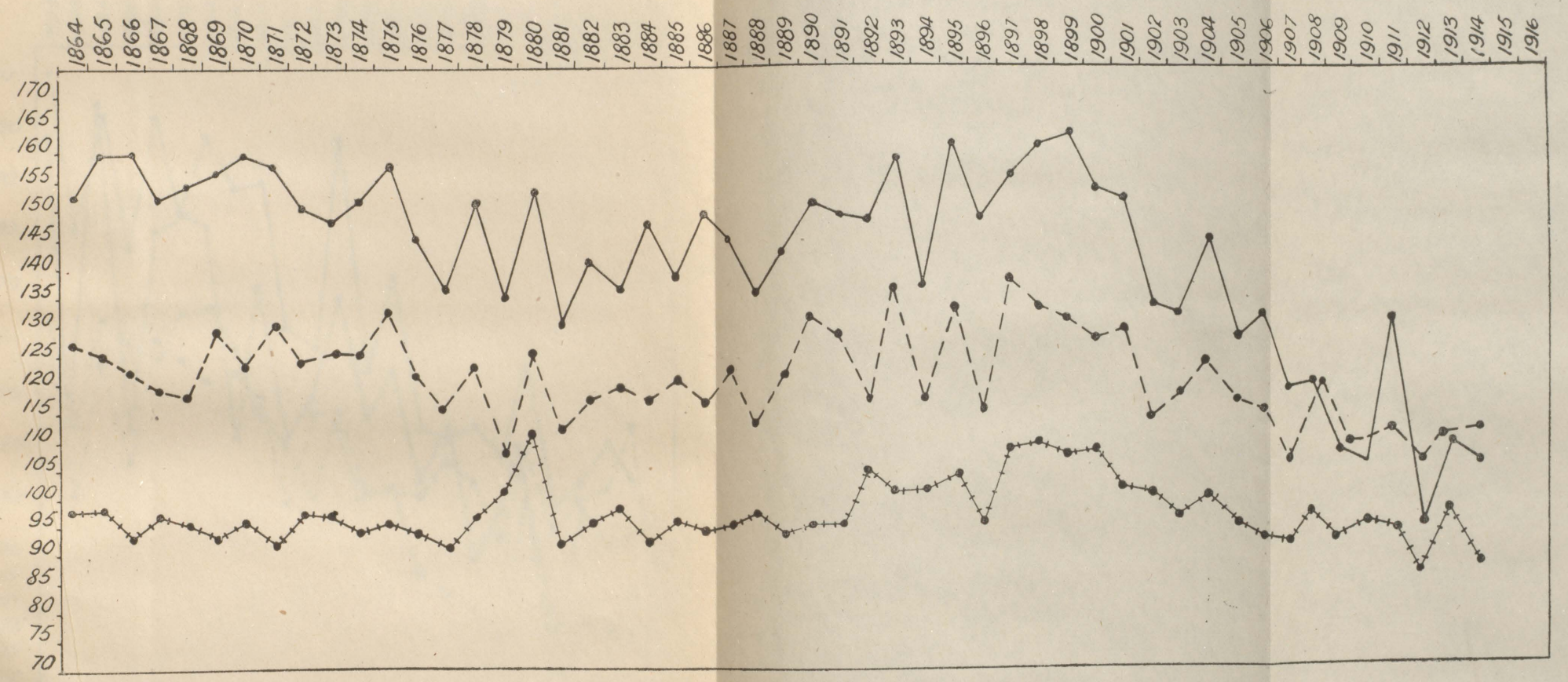


CHART I. Infant Mortality Rate of England —— Scotland - - - - and Ireland ⊣⊣⊣⊣⊣⊣⊣ from 1864.
From Annual Report of R.G. of Ireland, 1914.

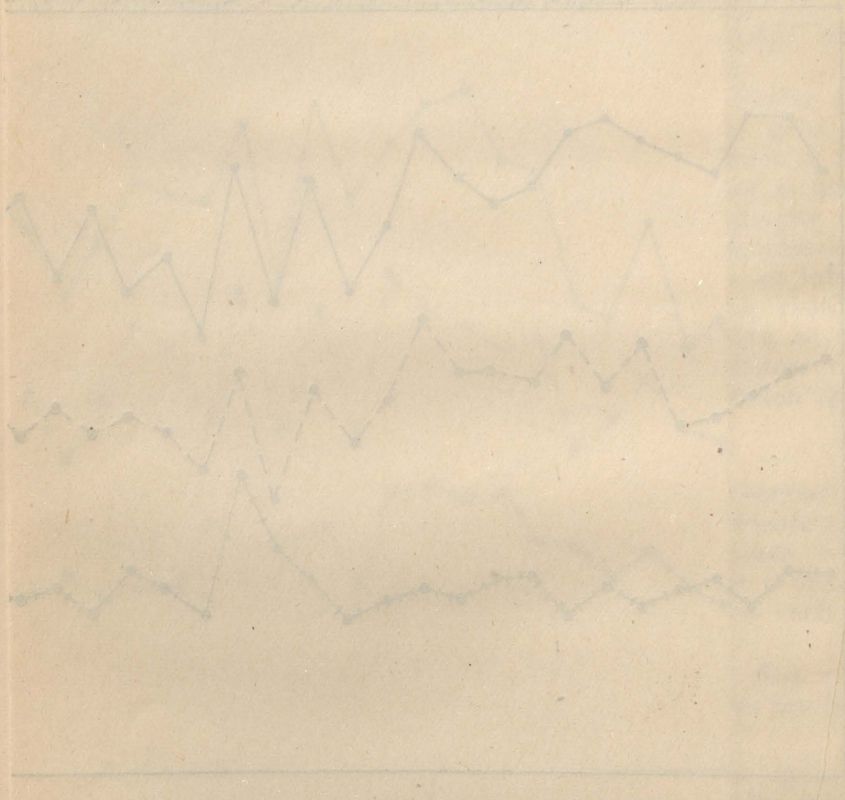
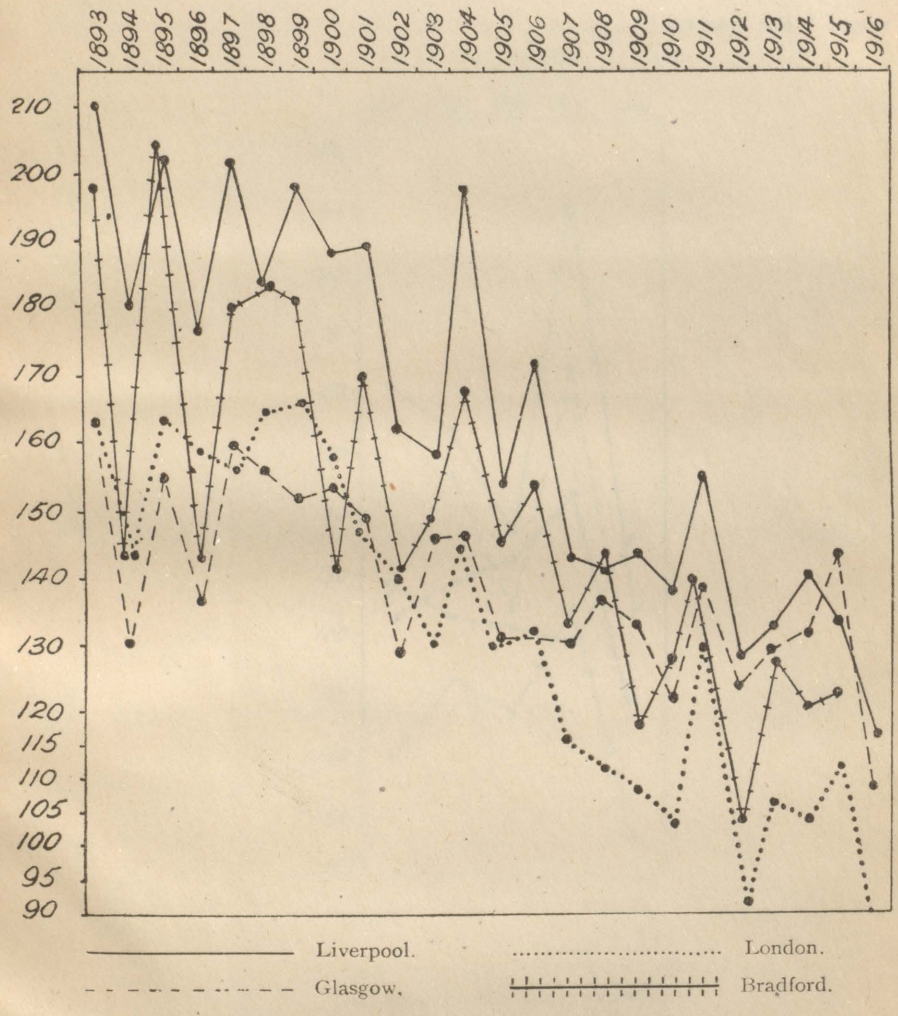


CHART II.

Infantile death rates of Liverpool, London, Glasgow and Bradford from 1893 till 1916.



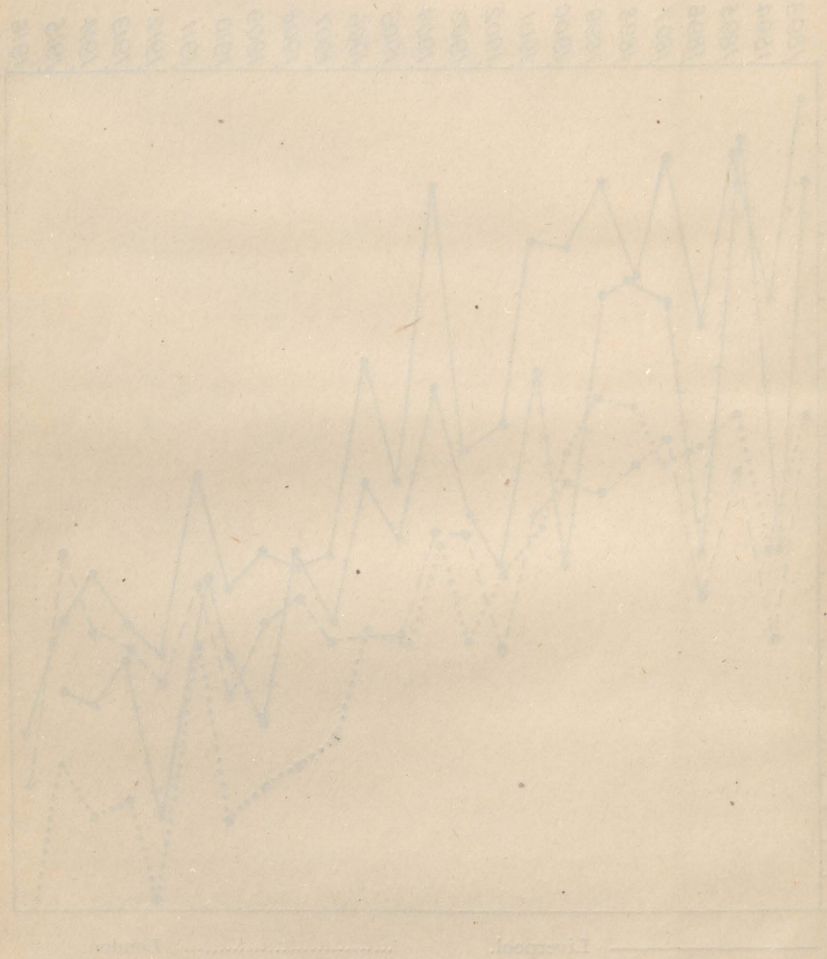
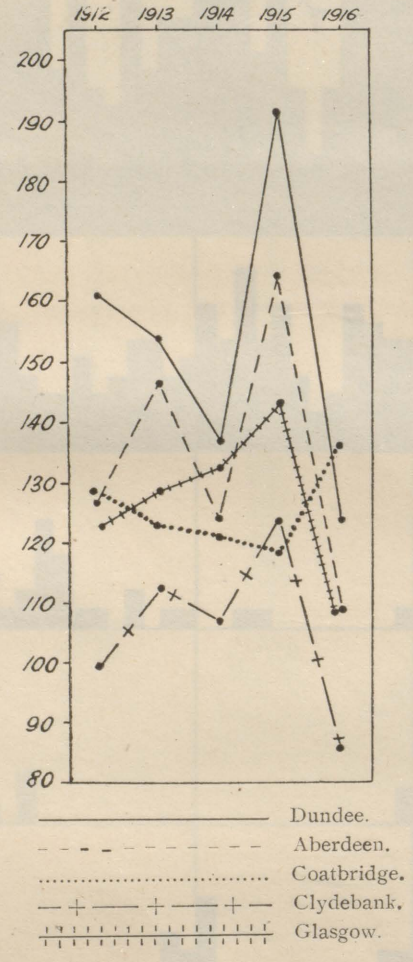


CHART III.

Infantile death rates in Dundee, Aberdeen, Coatbridge, Clydebank and Glasgow from 1912 till 1916.



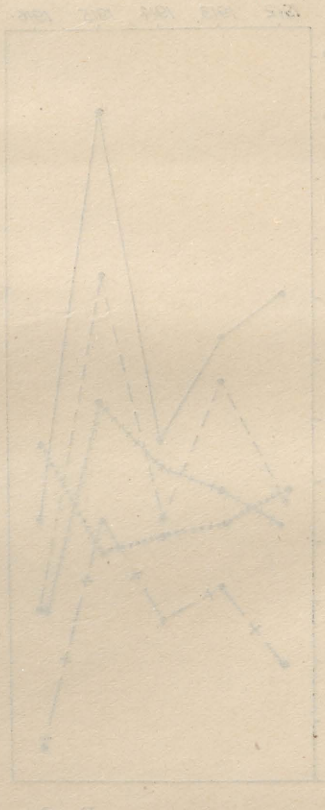
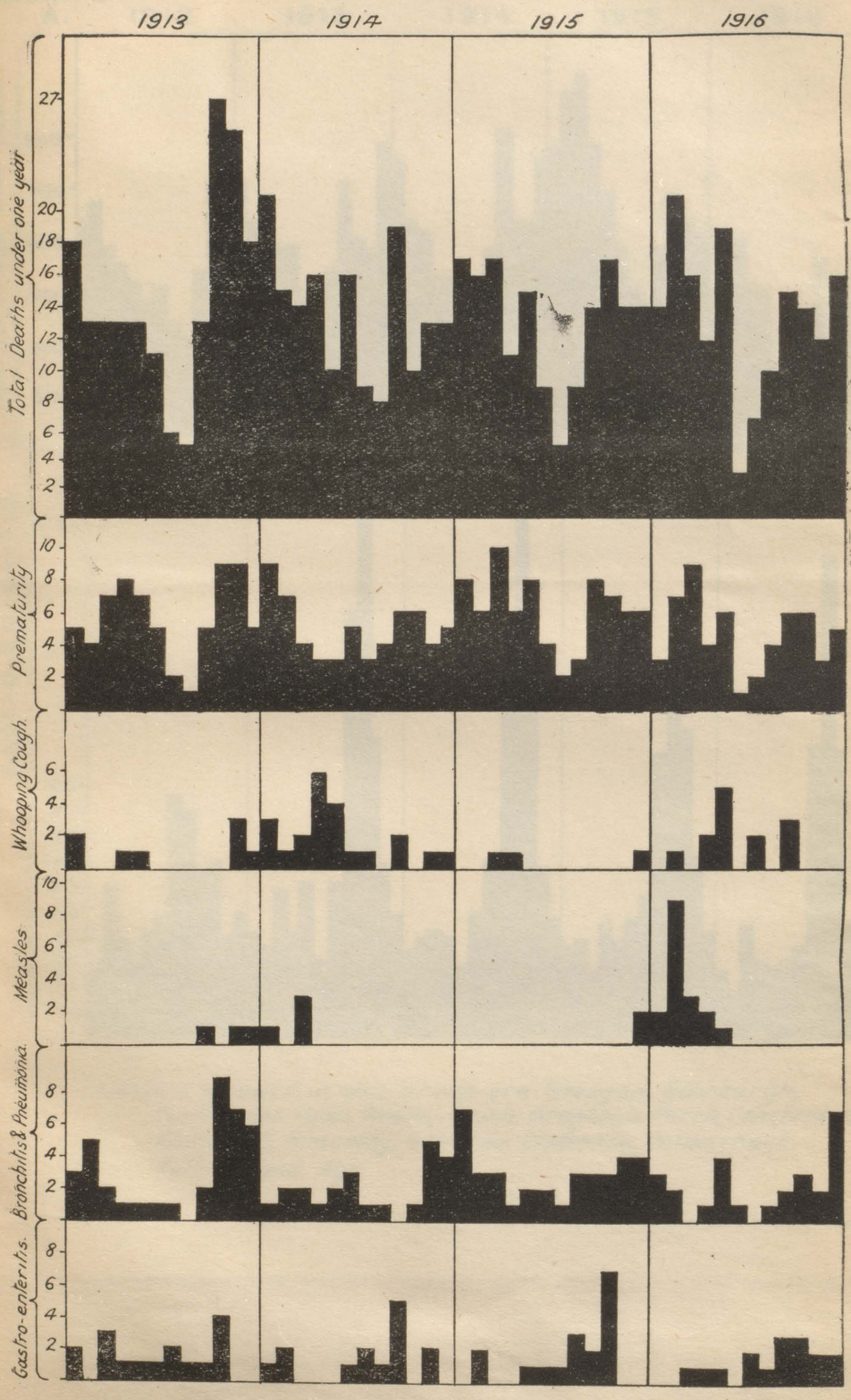
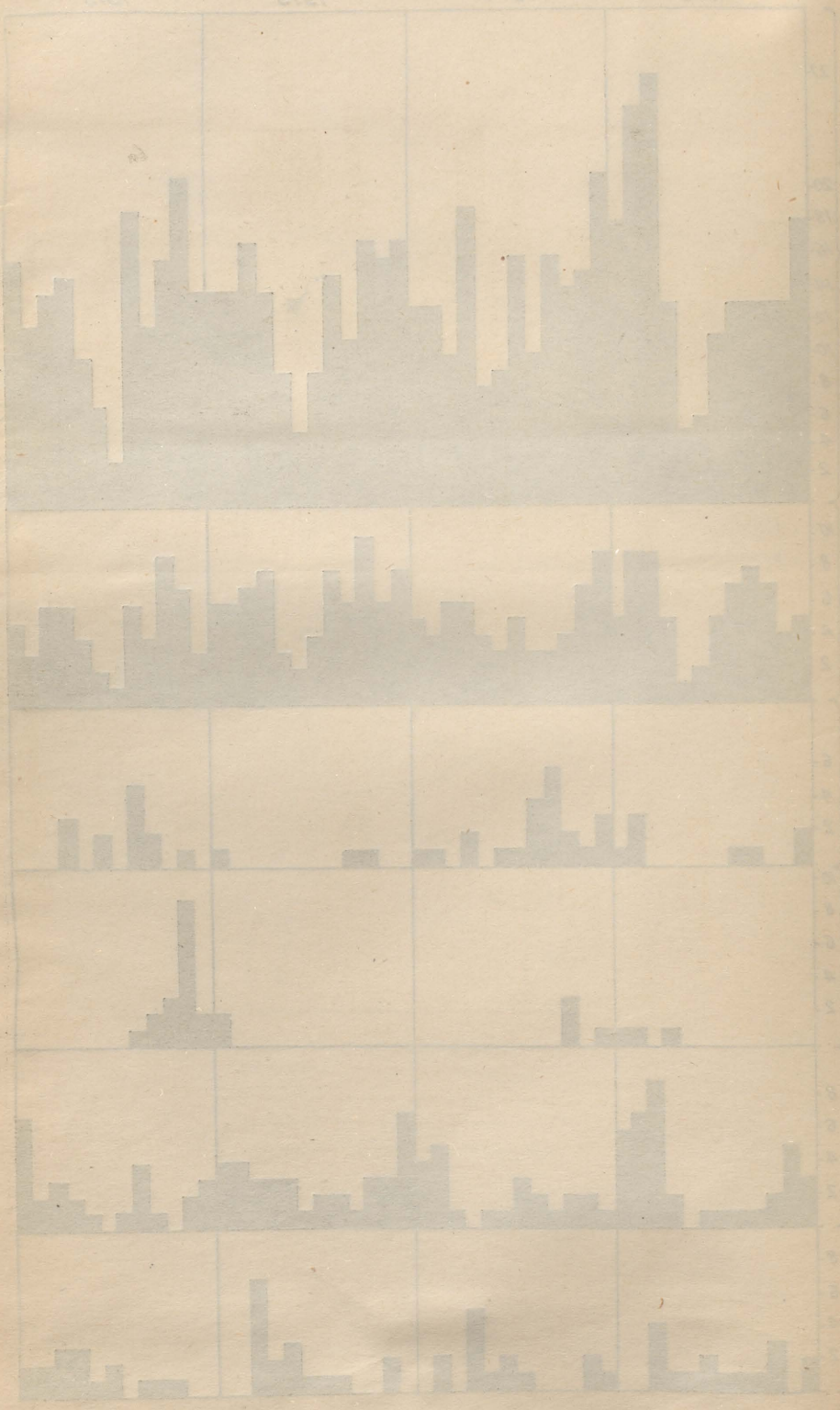


CHART IV.

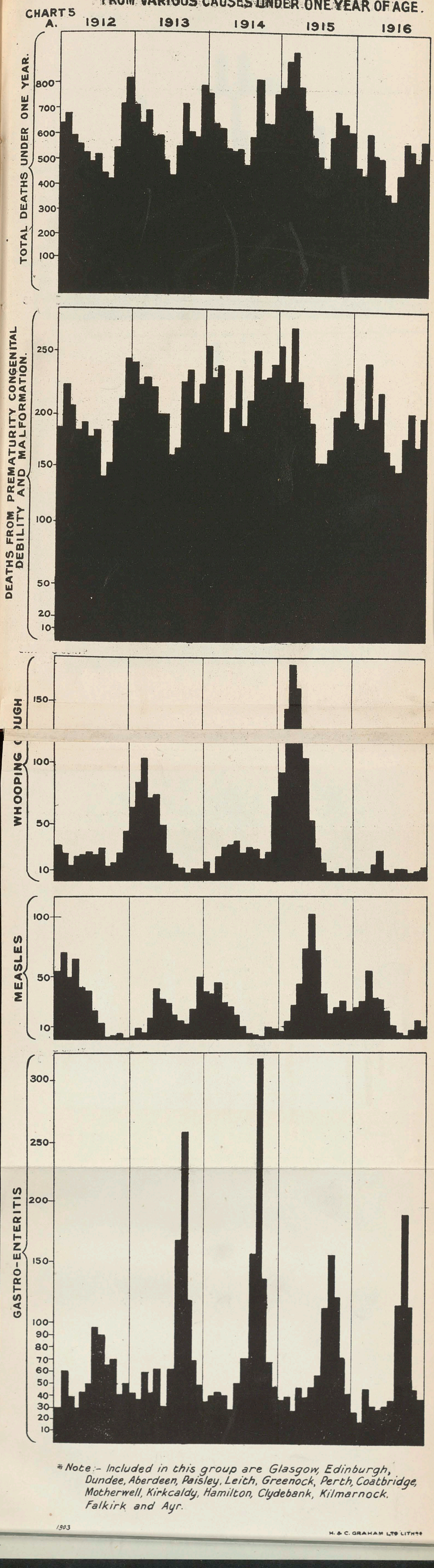
COATBRIDGE: SHOWING DEATHS OCCURRING MONTHLY FROM VARIOUS CAUSES UNDER 1 YEAR.





16 CHIEF TOWNS OF SCOTLAND. SHOWING DEATHS OCCURRING MONTHLY FROM VARIOUS CAUSES UNDER ONE YEAR OF AGE.

CHART 5 A.



* Note:- Included in this group are Glasgow, Edinburgh, Dundee, Aberdeen, Paisley, Leith, Greenock, Perth, Coatbridge, Motherwell, Kirkcaldy, Hamilton, Clydebank, Kilmarnock. Falkirk and Ayr.

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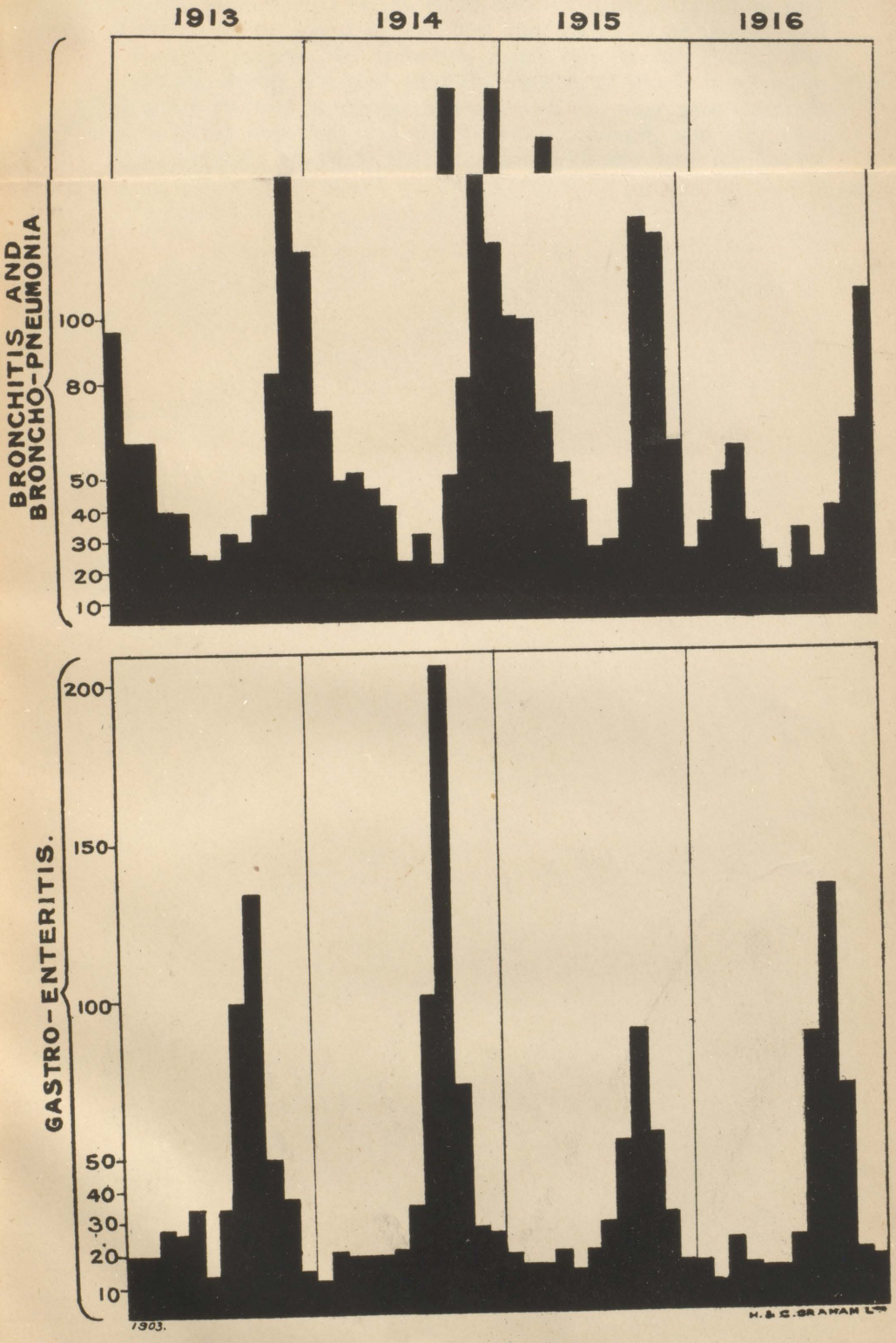
CHART 6. GLASGOW. SHOWING DEATHS OCCURRING MONTHLY FROM VARIOUS CAUSES UNDER ONE YEAR OF AGE



The unlikelihood of the wage element being a factor of any moment is supported by the fact that in times of famine and industrial trouble the infantile death rate usually falls. For example, during the year 1912 the number of people involved in disputes causing stoppage of work and the aggregate duration of working days lost was the highest on record, and yet, with the exception of 1916, the infantile mortality was the lowest ever recorded in most of the chief towns of Scotland and England.* (*See* Charts 1 and 2.)

III.—The Zymotic Diseases.

The importance of the zymotic diseases and their complications as a cause of death during the first year of life cannot be over-estimated. For example, in Glasgow during 1914, 23·6 per cent. of all the deaths under one year were due to measles, whooping cough, and gastro-enteritis, and 18·4 per cent. were due to bronchitis and broncho-pneumonia many cases of which were no doubt complications of these diseases.

Charts 5 and 6, showing infantile deaths occurring monthly for the sixteen chief towns of Scotland collectively, and for Glasgow individually, demonstrate this point most strikingly. From these it is also seen how the mortality from these various diseases may cause a variation in the general infantile death rate. They shew, apart from the seasonal variations, a certain swing, suggesting periodicity over a longer period than the charts represent. This is best illustrated in that portion showing deaths from bronchitis and broncho-pneumonia. Again, in the year 1912 the deaths from gastro-enteritis were comparatively few; in 1913 they were more numerous; in 1914 they reached their maximum, and declined in 1915; and in 1916 rose again slightly. Whooping cough also is seen to recur every second year.

Brownlee has frequently drawn attention to the periodicity of epidemics of the zymotic diseases, and therefore it would not be surprising to find that there prevails a certain periodicity in the death rates from these same diseases. One cannot expect the curves of the death rates, more especially when these are limited to the case of children under one year, to obey the same mathematical laws so accurately as the curves referring to the incidence of the disease in the general population. Nevertheless, the behaviour of the curves for the few years I have chosen is so striking as to arrest attention and to warrant further investigation. Should the law of periodicity of deaths from these

* During 1912 there was a prolonged coal strike. It commenced on 26th February, and by 4th March 1,000,000 workers were on strike and 1,000,000 idle in consequence. This strike was settled on 8th April. From 25th May till 10th August there was the Port of London strike. ("Annual Register," 1912, New Series.) In 1912 there was also the lock-out in the cotton trade, which commenced in 1911. The coal strike of 1912 accounted for the loss of 30,000,000 working days. ("Hazell's Annual," 1914.)

causes during infancy be substantiated it will be necessary to consider this factor in estimating the benefit of any scheme for diminishing our infantile mortality. In this connection it is difficult to see how the institution of centres, where large numbers of children aggregate, can act otherwise than as foci for the dissemination of infectious disease in addition to those afforded by schools.

IV.—Housing Conditions.

A recent investigation on the Etiology of Rickets carried out in Glasgow under the auspices of the Medical Research Committee seems to indicate that among the most important determining factors are bad housing and over-crowding, with deficient opportunity for open-air life. This naturally suggests the bigger question in how far these same factors are also responsible for much of the infantile mortality. Rickets itself indirectly plays a part in a certain proportion of the infantile deaths in so far as it increases not only the frequency, but also the mortality, of the respiratory sequelæ of such diseases as measles and whooping cough.

A consideration of the housing conditions of the poorer classes lends support to the idea that they play a prominent rôle in the causation of infantile deaths. The mortality rate is higher in the town than in the country, *e.g.*, in 1913 it was for Scotland generally 110, for the sixteen largest towns 125, and for the rural areas 92 ; in 1914 the corresponding figures were 111, 124, and 92. The death rate is highest in the most densely populated districts of the large towns and higher in a city such as Liverpool than in its industrial suburb Port Sunlight.

	Liverpool.	Port Sunlight.
1911	154	52
1912	125	81
1913	132	104
1914	139	74
1915	133	101

It has been shown, too, how renovation of a slum area may diminish considerably the infantile death rate. The following is a quotation from the Report of the M.O.H. of Liverpool on the Infant and Welfare Scheme for 1916, p. 25 : "The work of the Corporation in clearing the slum areas has resulted in great benefit not only to the general health of the population, but more particularly to that of infants and young children. The Housing Committee have erected nearly three thousand dwellings on sites formerly occupied by insanitary property, and these dwellings now house a population of 11,000 persons. It was shown at the enquiries relating to the demolition of the houses that the general death rate averaged nearly 40 per 1,000 and the infantile mortality 300 per 1,000 births. The people who were

displaced now inhabit the dwellings erected by the Corporation, and the general death-rate of the population of these dwellings has been reduced to 28 per 1,000, and the infantile mortality rate to 167 per 1,000 births."

It hardly seems likely that any number of visits to infant cliniques will ameliorate the health of the infant so long as it has to spend its time in unhygienic surroundings. This is well exemplified in hospital practice. Not infrequently children are admitted to hospital suffering from marasmus, enteritis, or broncho-pneumonia and recuperate, and are given back to the parents almost normal children, only to return with a relapse in a matter of a month or even less. Again recovery may take place, but it is less likely; and should the child be dismissed well, it may even return a third time, when it will almost certainly die.

It must be admitted that ignorance on the part of the parents may play a certain part in bringing about such results, and in the direction of educating the parents the Infant Welfare Scheme and Infant Cliniques may and ought to do some good.

V.—Prematurity and Marasmus.

One of the most striking features of the various groups of charts accompanying these notes is the constancy of the deaths which are ascribed to prematurity and congenital defects. In Glasgow these conditions were responsible in 1914 for 30·9 per cent. of all the deaths under one year of age. This class, however, is the most unsatisfactory chapter in all infantile vital statistics. Undoubtedly, all are not born into the world possessed of equal physical powers any more than of similar mental endowments, and many die as a result of some inherent weakness of constitution or error in their make up. Congenital heart disease and malformations of the gastro-intestinal tract may be cited as good examples.

Unfortunately, however, there are included under this heading deaths from so-called marasmus and chronic gastro-intestinal catarrh. It is certainly true that many examples of marasmus or wasting are due to some inherent error of metabolism—assuredly a congenital defect of a kind; but it is equally true that many of the children are the victims of some adverse circumstance—either culpable or accidental—of their environment. The first example that occurs to one's mind in this connection is the case of a child contracting tuberculosis from the ingestion of tuberculous milk. There is, indeed, much evidence that many cases of wasting or marasmus are not examples of immaturity, but are in reality due to tuberculosis, chronic pneumonia, and infection of the urinary tract.

One gets, I think, an erroneous impression of the frequency of death due to congenital defects from the accompanying charts, which are made up from figures published by the Registrar General. In the Royal Hospital for Sick Children, Glasgow, from 1903 till 1913 the deaths under one year from congenital affections varied from 7·5 per cent. to 16 per cent., a very different figure from the 30 per cent. above quoted. When one recollects, too, that no infectious cases are admitted to such a hospital the difference between these former percentages and those of the Registrar General becomes even greater.

VI.—Conclusions.

This short paper is of the nature of a preliminary communication to focus attention on certain points of this difficult question of infantile mortality.

(1) The apparent periodicity in the death rates from the various zymotic diseases, which seems to explain not only the variations in the death rate from year to year, but in different parts of the country at the same time.

(2) The importance of environment (housing, &c.) as a factor in causing the present high infantile mortality.

(3) The necessity for a more thorough study of that class of case called "Prematurity or Congenital Defect."

(4) The need for a more scientific investigation of the results following schemes of Infant Welfare to determine their true effects.

The Changes in the Physiological Processes of the Developing Child as shown by its Response to different Diseases.

By John Brownlee, M.D., D.Sc.

(*Director of the Statistical Department, Medical Research Committee*).

CONTENTS.

THE CHANGES IN THE PHYSIOLOGICAL PROCESSES OF THE DEVELOPING CHILD AS SHOWN BY ITS RESPONSE TO DIFFERENT DISEASES.

By JOHN BROWNLEE, M.D., D.Sc.

I.—INTRODUCTION.

The following pages contain a first study of some of the data relating to infantile mortality. The subject is presented statistically, but the opinions expressed must not be considered as mere deductions from figures apart from clinical experience. Many of the conclusions are the result of twenty years of observation of children's diseases, not, indeed, in a special children's hospital, but in the City of Glasgow hospitals for infectious diseases. These hospitals have a character of their own, inasmuch as the class, infectious diseases, has been interpreted in no narrow manner, and many cases, elsewhere refused entry to such hospitals, have been freely admitted. The large number of cases of whooping-cough and measles also gives exceptional opportunity for the observation of disease in young children. In no year have I had, under my direct supervision, fewer than 2,000 cases of disease in children under five years of age.

With regard, however, to children under three months of age my clinical experience is much more limited. I have seen, indeed, cases, more or less numerous, of all the diseases or defects which commonly cause death at this period, but not in sufficient numbers to enable me to decide how far the conclusions advanced are justified. With regard to this age period, therefore, these conclusions must be considered purely tentative. From the age of three months and upwards, however, this reservation is not made, and the opinions expressed are offered as considered opinions whether they be right or wrong. These remarks have been made because I think a purely statistical treatment of the diseases of childhood from the data at present in existence, apart from considerable clinical experience on the part of the writer, is likely only to increase the obscurity with which, in many places, the subject is surrounded.

The processes underlying and determining mortality during childhood are very complex. Diseases truly infantile persist into childhood, and diseases as truly diseases of childhood have their beginnings in the first year of life. It seems to me that the age of ten should be chosen as representing more nearly the end of the special physiological developments of childhood.

Up to this point the death-rate continuously decreases ; after this point it begins to increase again. It must not, of course, be assumed that at the age of ten the causes producing death are simple, but this age probably marks the point in the whole of life at which the fewest disturbing factors exist.

There is one great difficulty, however, in making an effective study of the changes taking place. Only rarely, as in the case of the notifiable diseases, are the statistics of actual cases of disease available in large numbers, and consequently the inferences must be made from the records of deaths alone. Thus the changes in the physiology of the child with each period of growth are less easily traced, and much is obscure which might be readily understood if more information was available.

The growth of a child is on the whole a continuous process, and, especially after birth, seems, apart from interruption due to illness, to proceed in a perfectly regular manner. Observation, however, reveals the fact that under this appearance of regularity numerous discontinuities exist.

The first great discontinuity is the act of birth. This discontinuity is associated with the greatest disturbance. The rate at which death takes place during the first day after birth is equivalent to 4,000 per 1,000 per annum, a figure which means that if the same death-rate persisted through the first three months of life there would be no survivors at the end of this period. Though this death-rate very rapidly falls it still remains extremely high throughout the first week of life. This incident of birth is obviously a thing by itself ; at no period in after life can there be anything like the shock which occurs at this time. With regard to three of the great systems—respiration, digestion, and heat regulation—there is an instantaneous alteration of the physiological processes, and the failure of the child to meet the new requirements in any one of these three can only result in death. It is not in these physiological processes alone, however, that discontinuities occur at this time. Evidence of others will be given later.

The second obvious physiological discontinuity is at the sixth month, a period associated with the appearance of the first teeth. Of course the process of dentition has been continuous before this date, but the irritative effects are most marked during the actual eruption of the teeth through the gums. This phenomenon must be regarded, however, as only a visible sign giving evidence of the presence of other profound changes. Thus, with regard to digestion, a great development of the pancreatic gland takes place about the age of five months, while at the same time the amount of ptyalin in the saliva is generally stated to increase. Other more subtle changes are observed in addition. With measles and scarlet fever it is found that the severity of the disease rapidly increases, the dividing line seeming to be definitely situated between the age of five and

six months. In scarlet fever, indeed, the change is so rapid as to be almost instantaneous. Such a change seems to imply the rapid formation of some substance which affords the attacking organism the opportunity of producing some product which greatly enhances the severity of the disease. An increase in the infectibility to these diseases occurs at the same time, a phenomenon also observed with regard to cerebro-spinal meningitis. These alterations in the character of the resistance made by the child to infectious diseases must be taken as accidents of development. The fact that the susceptibility to disease and death alters must be the result of the production or destruction of substances required by the physiology of growth. These instances of physiological change just noted represent almost the whole sum of our knowledge. Their discovery is the result of the fact that these diseases are notifiable. They, therefore, probably constitute but a fraction of those changes which are taking place during this early part of life.

The third obvious physiological discontinuity is the act of weaning. This commonly takes place about the age of nine months, and is in certain children marked by gastric disturbances. With the bulk of children, however, as far as my experience goes, the process of weaning is a gradual one, begun often about the sixth month. There is no evidence that this discontinuity produces any effect on the death-rate.

It is the intention in this note to place the facts of development during the first ten years of life as far as possible in line with the observations of bio-chemistry. It is now well known that when certain foreign substances are introduced into an organism, protective "anti-bodies" are formed. Thus the introduction of the enteric bacillus leads to the formation of agglutinins. When the amount of such anti-bodies present in the blood is measured at suitable intervals it is often found that the observations are capable of being described by a simple mathematical formula. Sometimes the formula is a simple geometrical progression, in which case, in the interpretation of physical chemistry, the anti-body decays according to a process which is termed a unimolecular reaction, or a mass action in which single molecules are involved. The molecules in this case are somewhat unstable, and the internal vibrations of each individual molecule brings the molecule sooner or later into a position which leads to its change into some more stable substance. One of the best known examples is the formation of urea by heating ammonium isocyanate. Both substances contain exactly the same amounts of carbon, hydrogen, etc., but the internal structural arrangements of the molecules are quite distinct. In this case the rate at which the change takes place is identical with that obtaining in many of the anti-bodies just referred to. In other cases the experimental data can be closely described by a common formula of physical chemistry, but the resulting

expressions suggest that fractions of a molecule take part in the reaction. As I have elsewhere shown, it is probable that in such cases a mixture of mono-molecular reactions takes place. Such a phenomenon might be regarded as specially probable during the early years of life, where the rapidity of growth and of change is so special a feature.

To summarise, the method employed in this paper is to consider the developing organism as a complex physico-chemical mechanism. Direct investigation of the different processes of this mechanism is in most cases possible only to a limited extent, but nature has provided a large number of interfering agents in the shape of infective organisms, each with special properties. As the same agent acts over a considerable range of ages it is possible in some measure to trace out the changes which take place in the processes of development and growth as age increases. The experiments thus made by nature are on the whole not simple, but in many instances sufficiently simple to demonstrate the progress from the instability of the infant to the comparative stability of the young adult.

II.—ON THE GRADUATION OF STATISTICS BY MATHEMATICAL FORMULÆ.

Statistical information is often recorded in a form not directly suitable for immediate use. Data relating to facts which are essentially different are frequently grouped together. Again, so much similarity may exist between two sets of phenomena that it is practically impossible to refer each individual observation to its proper class. This difficulty, to take an example, is specially notable with regard to bronchitis and broncho-pneumonia among children. Many deaths from bronchitis are registered as broncho-pneumonia and *vice versa*.

In discussing such data the application of a graduating curve to the statistics is often of very considerable value, as by this means new light can be thrown on the nature of the data. The method proceeds on the assumption that in a developing organism such as a growing child the changes which are taking place do not vary in an arbitrary manner, but according to some regular law. From this assumption it can be inferred that, if children of different ages are attacked by the same infecting agent, the attack—rates or death-rates will increase or decrease from age to age in a regular manner. As a rule it is not to be expected that a disease will cause a large number of deaths at one age, a small number at the immediately succeeding age and a large number in the age following. If such a result appeared in any statistics the value of such statistics would at once be questioned, and unless the phenomenon were observed to occur in a large number of cases the differences found would be attributed

to chance. An example of this can be seen by referring to the table (Table IV) in which the death-rates from scarlet fever are given. It will be noticed that when the actual and theoretical death-rates are compared between the ages of four and five years there is a great defect in the number of deaths in the Glasgow statistics. This defect, however, though great in amount, is shown to be accidental by comparing the figures for Glasgow with the corresponding figures for Manchester, where the theoretical curve used to graduate the observations is in accord with the facts. The assumption that the death-rate varies from age to age in a regular manner is in this instance justified.

The simplest method of graduating statistics is first to make a graph of the data on squared paper and then to draw a freehand curve through the observations so as to give a clear representation of the manner in which the death-rates vary. Reference to Diagram VIII, which represents the death-rates from bronchitis and pneumonia in children under three years, will illustrate this point. These two diseases have been grouped together in this diagram, as it is comparatively easy to say whether a child dies of a lung disease or not. So, though differential diagnosis may be difficult, the total number of deaths certified as due to lung diseases must be close to the truth. Through the actual death-rates, as shown in the diagram, a curve has been drawn to represent the progression as closely as possible. The first part of the curve, namely, that referring to the first year of life, is easily drawn, as the observations are given in months. When the second year of life is reached, however, such data do not exist, only the total number of deaths in the year being recorded. In drawing a graduating curve in this part of the diagram it is necessary to see that this total number of deaths is kept to its true value : to achieve this the area above the line of observations in the first portion of the year must be kept equal to that below the line of observations in the second portion. For the succeeding years the same care is necessary. The curve drawn in this manner indicates that the total mortality from lung diseases decreases at first rapidly, more slowly during the second six months of life, and again very rapidly in the first part of the second year. These changes in the curvature must represent either some discontinuity in the physiology of the child or, as seems more probable in this case, indicate that a mixture of two or more diseases is contained in the data, for though any specified disease may show a regular change in its death-rate with increasing age the combination of two or more diseases may give rise to great irregularities. A good example of a change in mortality with age, according to a definite law, is given by the death-rate from convulsions (Diagram V). In this case a simple mathematical expression is found to give a most accurate representation of the facts.

In the subsequent discussion of the data, in place of a simple

graduation by freehand, mathematical methods have in all cases been employed. These are described in detail in notes in the appendix with special reference to the sections in which they are used. It must be pointed out, however, that the line of argument can be completely understood without any reference to the special mathematics. A sufficient examination of the diagrams will enable the non-mathematical as well as the mathematical reader to estimate whether the deductions made in the text are probable or the reverse. The special advantage that a mathematical process possesses is that it enables us, having once determined a form of curve likely to be useful, to make a general application of the curve and decide the cases to which it may apply; but when once the process has been applied the results can be expressed so as to be easily intelligible. It will be shown that the use of graduating curves often permits us to test how far a hypothesis suggested by the figures is justified, and sometimes also to place the arguments on a slightly firmer basis.

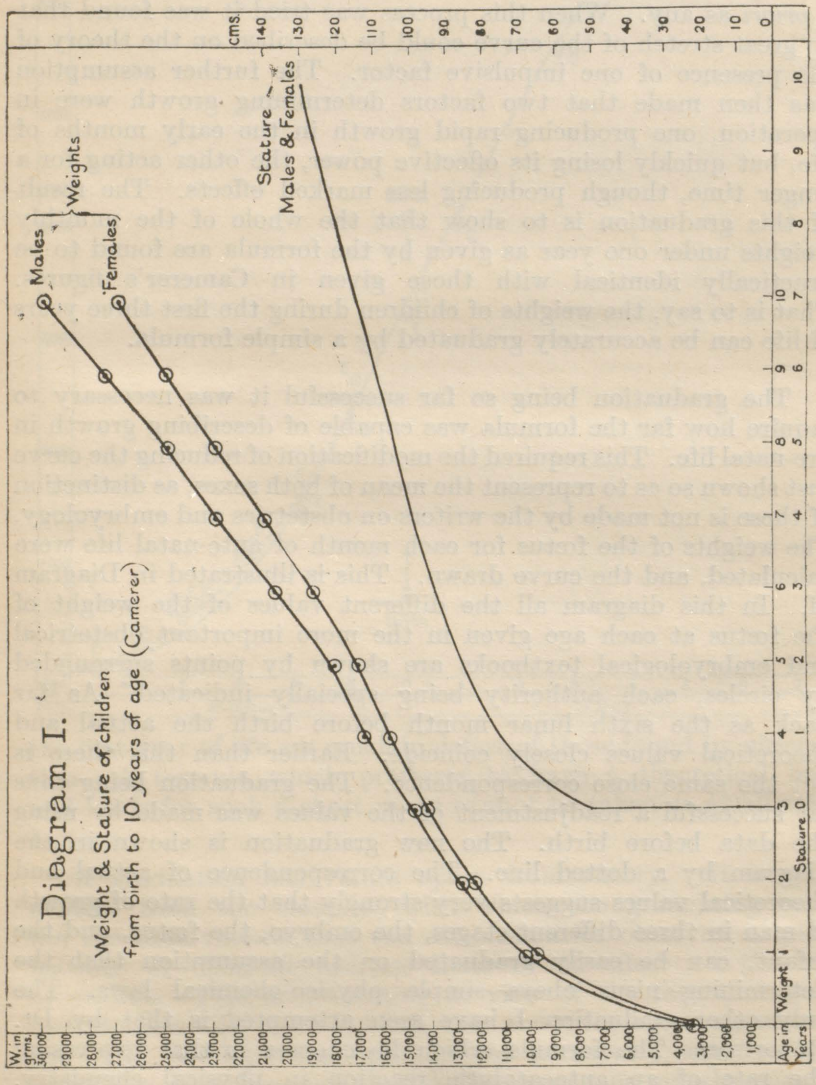
III.—GROWTH IN CHILDHOOD.

It is impossible to consider mortality in childhood without some reference to its relation to growth. The data for this are of two kinds. One method, the ideal, is to measure the rate of growth of a considerable number of persons from birth onwards at different ages. This was first carried out by Quetelet, but much more fully and completely by the Camerers, elder and younger. The second method is to measure a sufficiently large number of persons between definite ages, *e.g.*, children at school between the ages of five and six years. This is not so satisfactory, but has been fairly largely employed. When results obtained by these two methods are compared it must always be kept in mind that with the first method the age is definitely specified and represents the beginning or end of a year of life, whereas in the second the averages refer to the mid year. In some instances comparisons have been made between the results obtained by these two methods of measurement and erroneous conclusions drawn because the different methods of measurement used were not fully realised.

With regard to growth under one year of age many observations have been made in infant clinics and the rate of growth at this period is fairly well known, but it would be much more satisfactorily known if those who make the measurements would systematically publish their observations. During the second year of life only one observer, so far as I can find, Dr. Griffith, has published the results of monthly measurements. From this epoch till school ages data are not so numerous, but at this period of life many measurements have been made, chiefly by the second method.

What exactly happens during growth is not yet agreed upon.

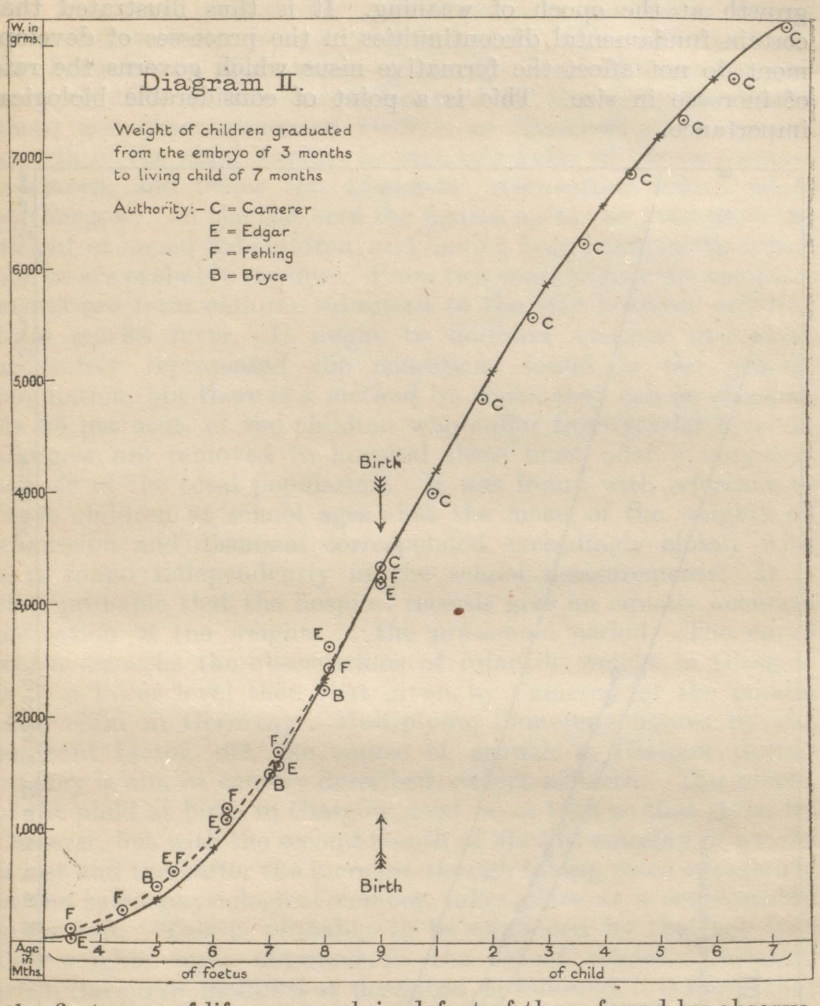
One or two points are quite clear. If the course of growth, as represented by increase in weight and stature with age, illustrated for both sexes in Diagram I, is examined, it will be observed that from birth onwards to the age of four years the increase is continuous, but that the rate of growth gradually lessens. After the age of four years some new impulse of growth must take place, as the rate of growth definitely increases. A similar impulse again occurs with the approach of puberty. The discussion of this part of the subject is, however, beyond the scope of this note.



The curve of growth cannot be fully considered without the application of some method of graduation, and with a view to discover the best method some experiments were made. The

measurements selected were the average weights of male children at birth and at the end of the first, second, third and fourth years as given by Camerer. For the measure of the rate of growth at any epoch the percentage increase in size was chosen rather than the actual increase. It was further assumed that at any point the impulse to growth present at any epoch decays at a rate to be described by the terms of a geometrical progression. There is nothing inconceivable in this supposition on the one hand, nor on the other hand is there any theory with which it is incompatible. It seems to offer as good a graduation formula *a priori* as any. When this process was tried it was found that no great stretch of the curve could be described on the theory of the presence of one impulsive factor. The further assumption was then made that two factors determining growth were in operation, one producing rapid growth in the early months of life, but quickly losing its effective power, the other acting for a longer time, though producing less marked effects. The result of this graduation is to show that the whole of the monthly weights under one year as given by the formula are found to be practically identical with those given in Camerer's figures. That is to say, the weights of children during the first three years of life can be accurately graduated by a simple formula.

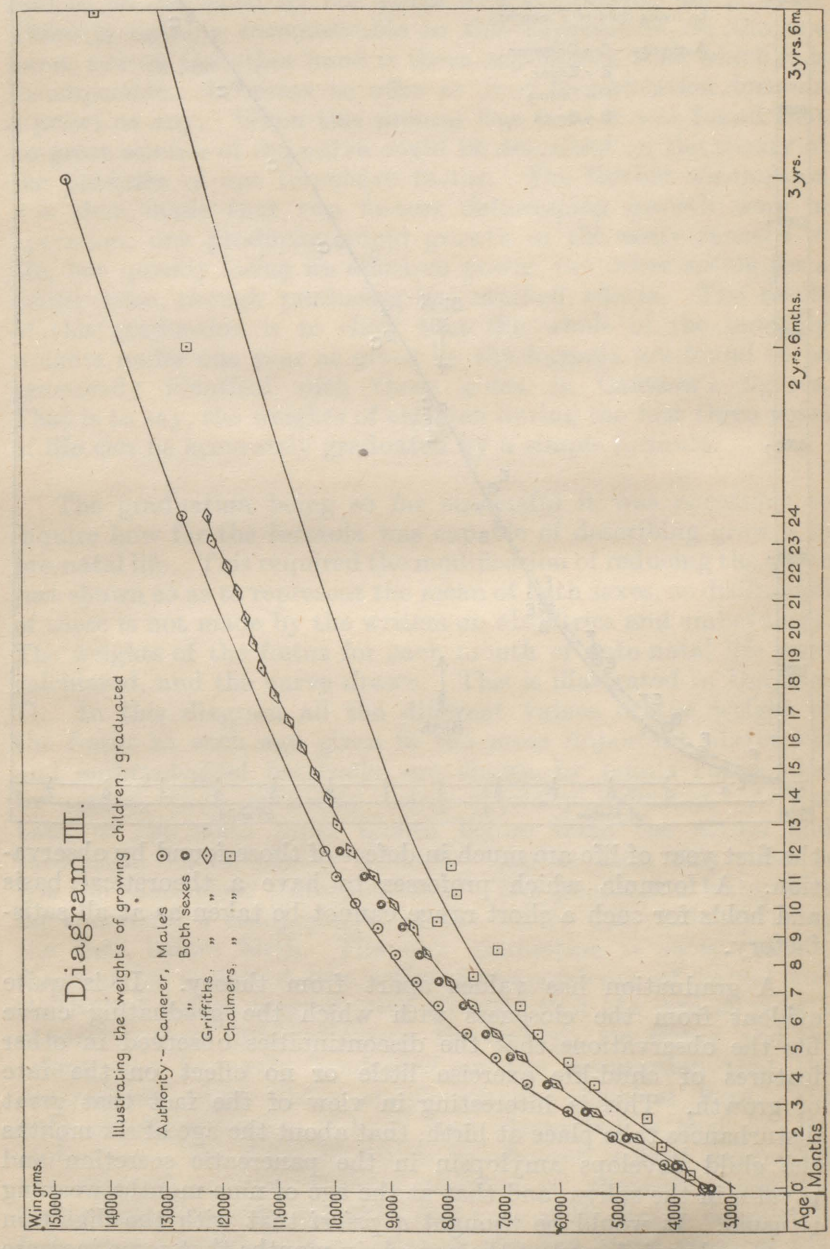
The graduation being so far successful it was necessary to inquire how far the formula was capable of describing growth in pre-natal life. This required the modification of reducing the curve just shown so as to represent the mean of both sexes, as distinction of these is not made by the writers on obstetrics and embryology. The weights of the fœtus for each month of ante-natal life were calculated, and the curve drawn. This is illustrated in Diagram II. In this diagram all the different values of the weight of the fœtus at each age given in the more important obstetrical and embryological textbooks are shown by points surrounded by circles, each authority being specially indicated. As far back as the sixth lunar month before birth the actual and theoretical values closely coincide. Earlier than this there is not the same close correspondence. The graduation being thus far successful a readjustment of the values was made by using the data before birth. The new graduation is shown in the diagram by a dotted line. The correspondence of actual and theoretical values suggests very strongly that the rate of growth of man in three different stages, the embryo, the fœtus, and the infant, can be easily graduated on the assumption that the determining nisus obeys simple physico-chemical laws. The only other graduation I have seen attempted is that by Dr. Robertson. The formula which he chooses is that expressing the rate of an autocatalytic reaction in physical chemistry. This graduation suffices for the first year of life, but it completely fails when carried further. Taking the first three years of life, and fitting the figures to such a curve, the values obtained for



the first year of life are much in defect of those found by observation. A formula which professes to have a theoretical basis and holds for such a short range cannot be taken as at all satisfactory.

A graduation has values apart from theory. It is quite evident from the closeness with which the graduating curve fits the observations that the discontinuities observed in other features of child-life exercise little or no effect on the rate of growth. This is interesting in view of the fact that great disturbances take place at birth, that about the age of six months the child develops amylopsin in the pancreatic secretion and ptyalin in the saliva, and that at the age of nine months weaning is usual. It would be thought *a priori* that with the digestion so strongly reinforced at the age of six months that some increase in growth would follow, but there is no evidence of this, nor in like manner is there evidence of any considerable lessening of

growth at the epoch of weaning. It is thus illustrated that certain fundamental discontinuities in the processes of development do not affect the formative nisus which governs the rate of increase in size. This is a point of considerable biological importance.



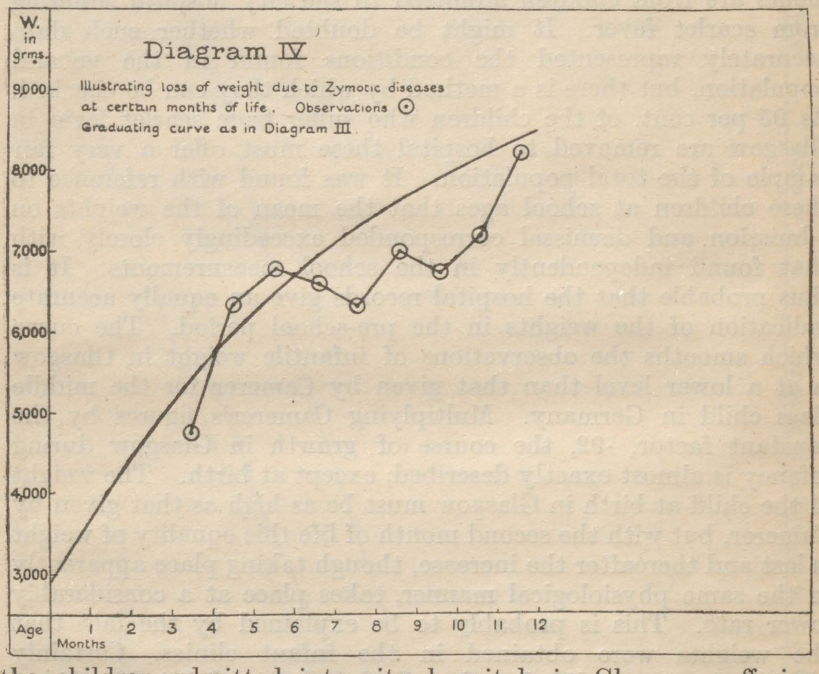
Having thus formed a criterion, it is interesting to see how far this describes other observations. In the accom-

panying diagram (Diagram III) certain data are shown for the first four years of life. The graduation curve derived as already described is shown as a continuous line for males alone and also for both sexes. The values given by Camerer's observations are indicated by dots set within circles. For comparison with these the observations of Griffith as illustrating the typical growth of the child during the first two years of life in America is shown, and below this Chalmers' observations which relate to Glasgow. In the last case the figures up to one year show the weight of breast-fed children, and having been made in the infant clinics are probably too low. From two years to four the measurements are from children admitted to the city hospital suffering from scarlet fever. It might be doubted whether such data accurately represented the conditions found in the general population, but there is a method by which they can be checked. As 95 per cent. of the children who suffer from scarlet fever in Glasgow are removed to hospital these must offer a very fair sample of the total population. It was found with reference to these children at school ages that the mean of the weights on admission and dismissal corresponded exceedingly closely with that found independently in the school measurements. It is thus probable that the hospital records give an equally accurate indication of the weights in the pre-school period. The curve which smooths the observations of infantile weight in Glasgow is at a lower level than that given by Camerer for the middle class child in Germany. Multiplying Camerer's figures by the constant factor, ·92, the course of growth in Glasgow during infancy is almost exactly described, except at birth. The weight of the child at birth in Glasgow must be as high as that given by Camerer, but with the second month of life this equality of weight is lost and thereafter the increase, though taking place apparently in the same physiological manner, takes place at a considerably lower rate. This is probably to be explained by the fact that the weights were obtained in the infant clinics. Certainly when the curve, modified as described, is followed, it is found that the observations for the ages 2–3 and 3–4 obtained in the City Hospitals, as shown in the diagram, indicate a greater weight than would be expected if the curve describing the weights during the first year of life held for the next three years.

It has been stated generally that the growth of healthy children on the average is continuous. This, however, is not strictly true. There is the loss of weight following birth which occurs in so many cases that it must be considered physiological. Though not present in all cases, such a loss of weight would seem to mean simply that the child takes a few days to adjust itself to its new mode of life. When growth begins recovery of weight is rapid, so that by the end of the first month the same weight is attained as would have been expected from the graduating curve had the rate of growth not been interrupted. This phenomenon is allied to the condition observed in children where

increase in the rate of growth is interrupted by illness. The moment the illness passes, there is for a time a very rapid increase until the normal weight for the age is reached or passed. It would seem as if in general there exists for each age some kind of balance between the capacity of nutrition and the actual weight of the body, and though in illness the vital agencies, digestion, etc., may be temporarily thrown out of gear, these are capable, the moment the disturbing causes disappear, of rapidly restoring the balance of nutrition in the organism.

In this connection a very interesting observation (Diagram IV) by McGregor must be referred to. For eighteen months



the children admitted into city hospitals in Glasgow suffering from scarlet fever, measles and whooping-cough were weighed and measured on admission and dismissal. The number of children under one year was not large, but some information was obtained. It was found that in the fourth and fifth months the average weight of the child admitted to the hospital was not greatly different from that found in the infant clinics in the city. After six months of age, however, there was a great defect. The manner in which infectious diseases become more severe at this period has already been mentioned. The difference of weight found has probably something to do with this phenomenon. McGregor explains the difference on the ground that the children who take measles, whooping-cough, and scarlet fever at these ages are probably of less weight than the average child. I doubt this explanation on the ground that it is unlikely that such a defect of weight only appears in a limited range of ages. I

think it more likely that the greater severity of the diseases in the second six months of life has more to do with causing the loss of weight. I also think it possible that, if the analysis of the growth of young children can be accepted as more than a hypothesis, the impulse to growth which is purely infantile may be interfered with at the ages which show such great changes in the physiology of the child. It is interesting at least to inquire as to what effect such an interference would cause. In the accompanying diagram (Diagram IV) McGregor's observations regarding the children in the City of Glasgow hospitals are compared with the curve of increase of weight obtained in the infant clinics.

With regard to the manner of growth from four years of age and upwards there is not much to discuss. The curve, as has already been shown, becomes practically a straight line between the ages of four and ten years, the limit of discussion in this note. This change in the curvature implies, as before mentioned, that a new impulse to growth takes place at about the ages of four or five years. It is interesting to note that this phenomenon has been recognised from a different point of view. Thus Dr. McGregor in the summary of his paper, using height as a criterion in preference to weight as less likely to be affected by illness, says : "It would appear that between the ages of two and four the influence on height of poor surroundings is most marked, but it was also to be noted that some recovery of physical vigour is apparent when the school period begins at the age of five years and that without any probable betterment of the conditions of life (a fact also noted by Eichholz)." The new impulse to growth about the age of four years is thus apparently a real phenomenon.

Table I. showing the Weights of the Fœtus at the end of each Lunar Month, from different authorities, all reduced to grammes.

Lunar m'ths.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	—	1·3–2·3	—	—	—	—	·08	·50
2	—	22–25	—	4	—	4–5	1·36	4·6
3	—	30	5–20	20	—	5–20	11·6	26·0
4	110	120	55–120	120	—	10–120	63·3	97·5
5	300	273	280	285	—	75–500	194	270
6	650	680	634	635	500	375–1280	484	591
7	1100	1100	1200	1220	—	785–2250	966	1082
8	1625	1571	1600–1900	1700	1500	1095–2400	1632	1729
9	2350	2640	1700–2600	2240	2000–2500	1500–2900	2434	2487
10	3220	3200	3000–3600	3250	—	3000–3600	3360	3360

(1) Zangemeister. Zeits : *für Geb und Gyn*, Vol. 69, 1911, p. 131. Authority—His own observations.
(2) Edgar. *Practise of Obstetrics*, 4th Ed., London, 1913, p. 68–72.
(3) Ditto, p. 70. Authority—Droysen and Göttangar.
(4) Child. *Senescence and Rejuvenescence*, p. 449. Authority—Fehling.
(5) Bryce. *Quain's Anatomy : Embryology*, p. 92.
(6) Webster. *Text-book of Obstetrics*, 1903, p. 75. Authority—Not given.
(7) Calculated by formula—first graduation.
(8) Ditto—second graduation

Table II. of Weights in Grammes of Children during the first two years of Life.

	Camerer.				Griffith.		
Age Lunar Months.	Boys.	Girls.	Both Sexes.	Both Sexes artificially fed.	Both Sexes.	Age Lunar Months.	Both Sexes.
Birth	3,480	3,240	3,360	3,390	3,450	14	9,980
1	4,170	3,810	3,990	3,730	3,900	15	10,200
2	5,080	4,560	4,820	4,340	4,650	16	10,430
3	5,870	5,270	5,570	4,930	5,400	17	10,610
4	6,580	5,900	6,240	5,610	6,080	18	10,840
5	7,140	6,520	6,880	6,270	6,670	19	11,022
6	7,650	6,920	7,320	6,900	7,140	20	11,290
7	8,140	7,380	7,710	7,300	7,570	21	11,450
8	8,540	7,800	8,170	7,750	7,980	22	11,560
9	8,900	8,090	8,500	8,130	8,390	23	11,750
10	9,220	8,400	8,810	8,270	8,570	24	11,910
11	9,650	8,720	9,190	8,650	8,960	25	12,020
12	9,970	8,970	9,470	8,910	9,300	26	12,250
13	10,210	9,660	9,930	9,980	9,750		

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(1) Camerer, 1908. "Children's Growth in Weight and Height." Translated by A. Amberg, in "Diseases of Children," by Pfaundler and Schlossman. Vol. I., Philad., pp. 409–424.

(2) Griffith, 1899. "The Weight in the First Two Years of Life, with Description of a New Weight Chart." *New York Med. Journal*, Vol. LXIX., January-June.

(3) McGregor, 1909. "Physique of Glasgow Children: An Inquiry into the Physical Condition of Children admitted to the City of Glasgow Fever Hospital, Belvidere, during the years 1907-1908." From the *Proceedings of the Royal Philosophical Society, April 21st.*

(4) Nobecourt, 1916. "Memoires Originaux; V. 'Des Hypotrophies et Des Cachexies Des Nourrissons; Etiologie; Physiologie Pathologique Anatomie Pathologique; Pathogenie (1).'" *Archives de Medicine des Enfants*, Tome XIX., 9 No., 3 March.

(5) Robertson, 1915. "Studies on the Growth of Man. 1. 'The Pre- and Post-Natal Growth of Infants.'" *The American Journal of Physiology*. Vol. XXXVII., No. 1, April 1st.

(5A) Robertson, 1915. "Studies on the Growth of Man. II., 'The Post-Natal Loss of Weight in Infants and the Compensatory Over-Growth which Succeeds it.'" *The American Journal of Physiology*, Vol. XXXVII., No. 1, April 1st.

(5B) Robertson, 1916. "Studies on the Growth of Man. III. 'The Growth of British Infants during the First Year Succeeding Birth.'" *The American Journal of Physiology*, Vol. XLI., No. 5, Nov. 1st.

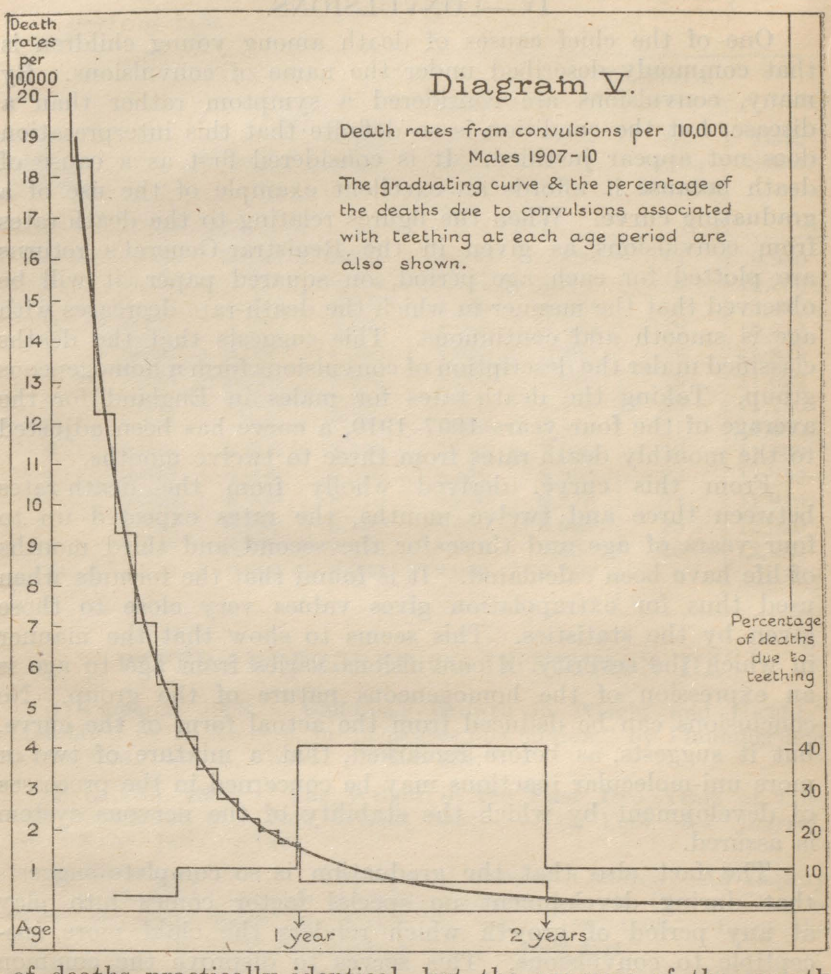
(5C) Robertson, 1916. "Studies on the Growth of Man. IV. 'The Variability of the Weight and Stature of School Children and its Relationship to their Physical Welfare.'" *The American Journal of Physiology*, Vol. XLI., No. 5, Nov. 1st.

IV.—CONVULSIONS.

One of the chief causes of death among young children is that commonly described under the name of convulsions. By many, convulsions are considered a symptom rather than a disease, but the condition is so definite that this interpretation does not appear justified. It is considered first as a cause of death because it affords an excellent example of the use of a graduating curve. When the figures relating to the death-rates from convulsions as given in the Registrar-General's returns are plotted for each age period, on squared paper, it will be observed that the manner in which the death-rate decreases with age is smooth and continuous. This suggests that the deaths classified under the description of convulsions form a homogeneous group. Taking the death-rates for males in England for the average of the four years 1907–1910, a curve has been adjusted to the monthly death-rates from three to twelve months.

From this curve, derived wholly from the death-rates between three and twelve months, the rates expected up to four years of age and those for the second and third months of life have been calculated. It is found that the formula when used thus for extrapolation gives values very close to those given by the statistics. This seems to show that the manner in which the severity of convulsions varies from age to age is an expression of the homogeneous nature of the group. No conclusions can be deduced from the actual form of the curve, but it suggests, as before remarked, that a mixture of two or more uni-molecular reactions may be concerned in the processes of development by which the stability of the nervous system is assured.

The fact also that the graduation is so complete suggests that during development no special factor comes into play at any period of growth which renders the child more susceptible to convulsions. This serves to disprove the common association of convulsions with teething, since with growth the stability of the nervous system continuously increases. In the accompanying diagram (Diagram V) illustrating the progress of the death-rate from convulsions, the proportion of deaths from convulsions certified as associated with teething is also shown. There is obviously no evidence of any change in the slope of the curve representing the death-rate from convulsions at the ages of teething, a change which would seem to be necessary if teething really exercised a marked effect in producing the condition. Convulsions, therefore, though a reflex phenomenon due to a variety of intoxications, alimentary or other, are really an index of the condition of the nervous system at each point of growth, and the change in their frequency with advance of age must be taken as a measure of the change in the physiology of the child. This is illustrated when the death-rates from convulsions for the urban and rural counties are compared. These rates are almost identical in both sets of statistics. Not only is the total number



of deaths practically identical, but the progress of the growth of immunity against convulsions is also identical for town and country. Thus convulsions do not depend on environment to any extent, a very remarkable fact when it is considered that they are among the chief causes of infantile death, accounting for a twelfth of the whole deaths under one year of age.

One word further is necessary. In the first month after birth convulsions are specially common. The deaths in this month, however, I do not think comparable in character to those taking place in the following months. During the first month of life the infant is still suffering from the shock of birth, and consequently much more easily affected by adverse influences.

The curve of the death-rate from convulsions is the most definite example of a mortality which decreases uniformly from birth onwards. Convulsions must thus be considered as a purely infantile cause of death, though they affect to some extent the early years of childhood. After four years of age they are

very uncommon, and it is interesting to note, without pressing the point, that this is the age at which, according to the hypothesis previously given, the original impulse to growth ceases.

Table III., showing the Graduation of the Death-rate from Convulsions for Males in England and Wales, 1907–1910, *at different ages, to a formula, and showing a comparison of the Death-rates in both sexes for Urban and Rural Counties,* 1905–1910.

	Death-rate, males, 1907–1910.		Death-rate, both sexes, 1905–1910.	
			Counties.	
	Actual.	Theoretical.	Mainly Urban.	Mainly Rural.
Weeks.				
0–1	—	—	—	—
1–2	99·5	—	—	—
2–3	80·1	62·2	—	—
3–4	62·5	56·2	—	—
Months.				
1–2	183·7	177·4	185·2	169·8
2–3	127·5	125·9	127·2	137·8
3–4	93·0	93	97·7	97·0
4–5	71·0	70·4	72·5	75·7
5–6	56·4	54·8	56·0	53·5
6–7	43·0	43·5	44·2	43·7
7–8	35·2	35·2	35·8	33·8
8–9	28·0	28·8	26·3	29·7
9–10	23·2	24·1	23·5	24·7
10–11	20·7	20·1	20·0	21·8
11–12	16·5	17·1	17·3	17·7
Years.				
1–2	101·5 (88·8)	94·8	111·1	100·3
2–3	32·2 (28·2)	28·6	33·5	30·8
3–4	13·5 (11·8)	12·2	15·2	13·2
4–5	5·5 (4·8)	6·4	6·8	4·8

NOTE.—The figures in brackets are those which must be compared with the theoretical figures being calculated per 1,000 births. Those not in brackets are calculated by the Registrar-General as per 1,000 living at the beginning of each year and are therefore not comparable with those relating to the last months of the first year of life.

V.—WASTING DISEASES

Among the most important causes of death in children under one year are the wasting diseases; they include premature births, congenital defects, want of breast milk and atrophy, debility and marasmus. This class of disease introduces a good deal of difficulty into the problem of measuring the infantile death-rate. Of the deaths under one month nearly a half are due to premature

birth, and of that half a like proportion die on the day of birth. This relationship to total deaths under one month holds equally for the town and for the country. Even as regards the total number of deaths, on an average of five years the deaths from premature birth in the counties mainly urban is only 10 per cent. greater than in the counties mainly rural. The deaths due to premature birth are quite clearly in a different category from those occurring among children born at full time. As, however, the proportion to the number of births is much the same in town and country, no great error is introduced if this fact is remembered when the death-rates are discussed.

The number of premature births may be capable of being reduced by ante-natal care of the mother, but in recent years this number shows no sign of diminishing. Thus Dr. Moore, Medical Officer of Health for Huddersfield, a town in which great attention has been paid to the subject of infantile mortality, finds that during the last few years an increase has occurred in the number of deaths ascribed to prematurity, with a somewhat larger fall in the number of deaths from wasting diseases. The death-rate ascribed to premature births extends through the first six months of the first year of life, but sixteen-seventeenths of the deaths occur in the first month. As the proportion of prematurely born infants is unfortunately not known the actual death-rate due to such births cannot be adequately measured. It would seem, however, that if a prematurely born child survives the first month it has a fair chance of life. In the normal development of the child the mechanism of digestion is efficient at birth. In the child prematurely born this is often not the case, both fat and protein digestion being markedly defective. It would seem thus to follow that there may be very great difficulty in giving food, and, if the child survive the shock of birth, with the consequent loss of heat, starvation may be its natural fate. Of course this is not always the case; in many instances, if proper warmth is maintained and breast milk available, almost immediate increase of weight ensues.

The diseases included under the heading of atrophy, debility, and marasmus must be manifold. Of the earlier period of the region of life in which these diseases occur, as already stated, I hesitate to speak. From three months and upwards I have had, however, a considerable experience in children's diseases—an experience in some ways complementary to that of the physicians in children's hospitals. To the latter, only children who are suffering from some disease are admitted. To the hospitals of which I had charge, the same of course is true, but the disease for which the children were admitted was in many instances trifling. In the wards devoted to the treatment of whooping-cough this was specially the case, as this disease frequently causes little or no constitutional disturbance. I was thus able to observe the effects of different methods which

had been adopted in feeding infants, not merely in those who were ill, but also in those who were well. This experience has led me to hold views upon certain points regarding the nutrition during the first year of life which will presently be stated.

Examining the course of the death-rates by the method employed in considering the death-rates due to convulsions, and fitting a graduation curve of the same type, it is found that when the formula is used for extrapolation, and the number of deaths is calculated under one month and for over one year of age, values in excess of those actually existing are found. The formula thus fails. This seems to indicate that in the middle months of the first year of life there is an excess in the number of deaths over those to be expected if the class were as homogeneous as that of convulsions has been found to be. This finding is in direct opposition to the idea that immaturity at birth governs the death-rates in this class. The shock of birth is extreme, and the number of deaths occurring in the first weeks should be in excess of that given by any graduation formula. As this is not found to be the case with this group of deaths, it is unlikely that many deaths of truly premature children are included in this class, though of course there must be some admixture.

What the group of atrophy, debility, and marasmus actually contains demands further investigation, but as far as my clinical experience goes I think that the three chief causes of death may be grouped under the headings, *immaturity* (with which unsuitable feeding is associated), *debility*, and *infectious disease*. With the class of (*a*) immaturity I include that of congenital defects, as I am very sceptical as to whether it is possible to separate the deaths from immaturity from those said to be due to congenital defects. A congenital malformation of the heart gives rise to an obvious condition which can be easily diagnosed. A defect, however, of some essential constituent in intestinal secretions can only be ascertained with the help of a biological chemist, but is just as much a congenital defect as imperfect closure of the *foramen ovale*. Of those children born immature probably the majority who die in the early days suffer from want of capacity to maintain the body temperature, from some defect in the mechanism of the nutrition, or from physical inability to expand the lungs properly. Among these children it is probable that many could be tided over the initial period of difficulty. It is not a matter here of town versus country, because the absolute death-rate in both is practically identical. It is rather a question of care during the earliest weeks of life. That such is the case is, I think, shown by the fact that there has been quite a remarkable fall in the death-rate ascribed to these causes, and a fall which is not, so far as I can make out, associated with any change in nomenclature of disease. Between 1907 and 1913 the deaths ascribed to these diseases have fallen from about 15·5 per 1,000 to 13 per 1,000.

It is not merely a question, however, of a child being born immature, that is to say, with some fundamental property imperfectly developed, a condition which with the lapse of time disappears, but it is also certain that immaturity may occur at any period during development. Of this form of immaturity during recent years many investigations have been made, and there is now a large literature dealing with children in whom various organs, the thyroid glands, kidneys, etc., do not develop their functions properly. In these cases for the most part the defect is permanent and not transitory. I am of opinion, on the other hand, that there are many derangements in development causing disturbances or disease for a longer or shorter period, which become ultimately adjusted, so that the individual can live a healthy or very nearly healthy life.

To emphasise the point a short discursus is necessary. The difficulty of feeding children, at least after the age of three months, seems to me greatly exaggerated by most writers. Many alterations and preparations of cows' milk are recommended, but as far as my experience goes there are very few children over three months of age who cannot be healthily reared on fresh cows' milk. Of the few who cannot take such milk alone the great majority find it perfectly digestible when a suitable proportion of barley water is added. Children who require to be specially dieted have been in my experience rare. I think the difficulty experienced in so many places in feeding children on cows' milk is due to the milk not being clean, and that where clean fresh milk is available, as in the City of Glasgow hospitals, most of the difficulty disappears. It was the custom with healthy children over three months to wean on admission to the hospital, and this custom has been found to act satisfactorily, not only with healthy children, but even in cases where constitutional disturbance was present. Not only is this the case, but the ordinary healthy child will stand, and actually does stand, being fed on a most varied diet. I have had many perfectly healthy children admitted to hospital whose diet at home consisted of the "run of the hoose," and have had many arguments with anxious parents who insisted that because the children were receiving nothing but milk foods in the hospital they were not obtaining sufficient nourishment. I have also observed the difficulty experienced by the nurses in training such children to be content with such food, their education having led them to expect more appetising morsels. To say, therefore, that a child is suffering from atrophy because it has been badly fed is an incomplete argument. Feeding in itself is, I think, not the chief cause.

With regard to many of these cases my own impression is that the normal developments of the nutritional mechanism have not taken place in due order, and that therefore temporary difficulties in assimilation have arisen. These may be associated

with cessation of growth or even loss of weight, a condition which presently disappears when the various processes of the body become readjusted.

It is difficult to obtain data to prove this, but the following figures giving the weight of the pancreas in a number of children at different ages will illustrate quite clearly how the average child may be capable of digesting a considerable quantity of food, though many healthy individuals at the same age require more careful feeding. From these figures there seems to be a rather sudden increase in the size of the pancreas between four and five months of age. Even at eight months, however, one child is found with a pancreas weighing less than that observed in children under four months, namely, 3·5 grammes as against 10 or 15 grammes in the other two cases examined at the same age. Such differences can hardly but be associated with great differences in the digestive capacity, and such delays in development represent immaturity just as much as premature birth. Such delay in development persists to later ages. Thus the weight of the pancreas between one and two years of age varies extensively. In the six observations the weight in one set of three observations is almost exactly half that in a second set, a fact indicating very considerable variations in the probable digestive power. It is not pretended that power of digestion is in absolute relation to the weight of the pancreas, but differences such as those found must express differences in the power of accommodating the digestion to unsuitable diet.

SIZE OF PANCREAS IN CHILDREN.*

Age.	*Weight in Grammes.*
Five days	5
Two months	1·9, 2·5
Three ,, ...	4·5
Four ,, ...	2·5, 3
Five ,, ...	8, 17
Six ,, ...	10
Eight ,, ...	3·5, 10, 15
Nine ,, ...	15, 40
Twelve ,, ...	15, 20
One to two years	12, 13, 15, 22, 25, 30
Five years..	20
Seven ,, ...	40

(*b*) *Debility* is also a term difficult to define. I think it distinct from immaturity inasmuch as the debility persists through life. There are a large number of people who seem to have a very low vitality from birth to death. Everyone has seen such persons. Some of these are characterised by great mental ability, which they exercise with difficulty owing to want of

* "Maladies des Enfants," Vol. III. "Maladies du Pancreas," Paris, 1909.

physical power. Others, individuals of only average or less than average brain power, pass their life without ever doing a full day's work, not from want of intention, but from sheer physical incapacity. Every workshop has a tail of such persons, only employed during times of emergency, and the first to be turned off the moment the emergency has passed. The same type of child is well known, and, as an infant, falls a victim to various diseases. Such children seem to have very little stamina.

The third cause of death (*c*), *infection*, is not fully discussed by writers on children's diseases. My own impression is that there are a considerable number of infectious diseases which have not hitherto been properly described, but which are to my mind quite definite clinically. One of these which is associated with persistent vomiting renders children extremely atrophic in a short time, and runs a course of from three to four weeks. The convalescence is usually rapid, and sometimes as astonishing as that often seen in children recovering from a severe specific fever. This type of case was in my early hospital years comparatively common. One of the forms of marasmus, from the constancy of the symptoms, also seems to me to be a specific infectious disease. The illness, however, may not be due to the direct action of a specific infection. Imperfect development of the digestive powers gives rise to disordered secretions, and disordered secretions afford an admirable medium for the growth of many kinds of organisms, some pathogenic in themselves, others merely secondarily so, producing their effects by giving rise to the formation of acids or other toxins in the alimentary canal. The easy induction that these cases are cured by proper dieting does not seem to me any more clinically justified than that a typhus fever patient is cured by dieting. Of course dieting is necessary. Nourishment must be given in the form most easily assimilable, but the redintegration of function which follows intelligent dieting is not instant in action, and in most cases the improvement may be as much due to the production of protective substances against infective organisms as to the fact that the physiological powers of the child have in the interim developed so as to be in correspondence with the needs of nourishment.

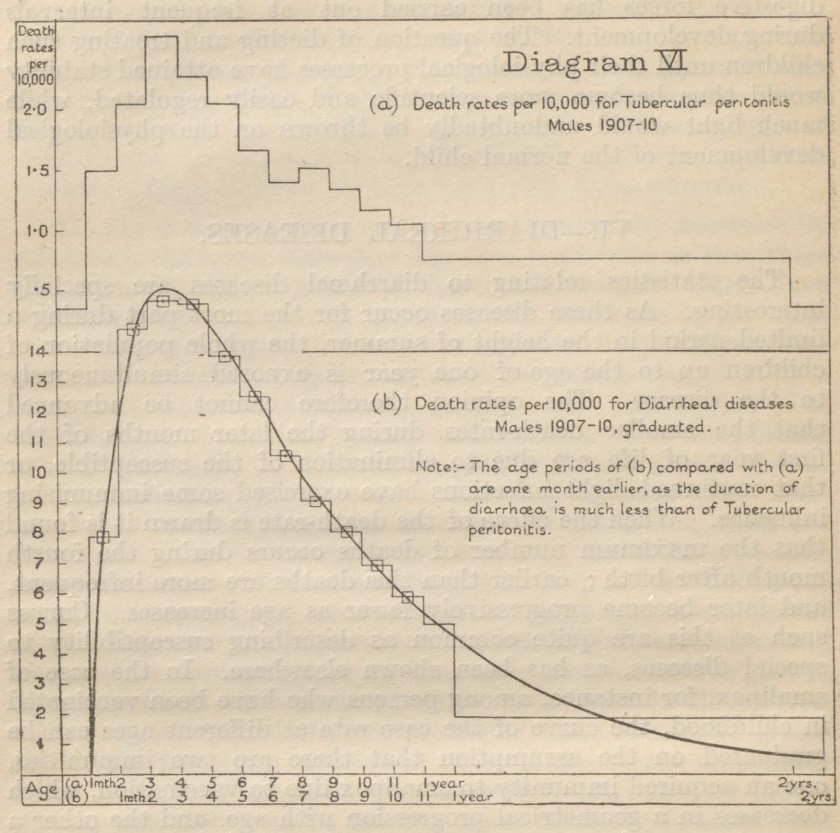
I think this group of diseases would repay some statistical medical investigation. I have no doubt that the physicians in the children's hospitals are thoroughly well acquainted with the different varieties of disease which are classed under this head. They have not, however, made any attempt to apply their knowledge so as to bring it into line with the facts as given by the Registrar-General.

For the whole group of wasting diseases it is exceedingly important that measures should be taken to collect histories from birth to the end of school age. These histories should refer to cases in which proper chemical examination of the

digestive forces has been carried out at frequent intervals during development. The question of dieting and treating such children until their physiological processes have attained stability would thus become more scientific and easily regulated, while much light would undoubtedly be thrown on the physiological development of the normal child.

VI.—DIARRHŒAL DISEASES.

The statistics relating to diarrhœal diseases are specially interesting. As these diseases occur for the most part during a limited period in the height of summer, the whole population of children up to the age of one year is exposed simultaneously to the disease. The opinion therefore cannot be advanced that the smaller death-rates during the later months of the first year of life are due to elimination of the susceptible, or that continued slight infections have exercised some immunising influence. When the curve of the death-rate is drawn it is found that the maximum number of deaths occurs during the fourth month after birth ; earlier than this deaths are more infrequent, and later become progressively fewer as age increases. Curves such as this are quite common as describing susceptibility to special diseases, as has been shown elsewhere. In the case of smallpox, for instance, among persons who have been vaccinated in childhood, the curve of the case rate at different ages can be graduated on the assumption that there are two immunities, one an acquired immunity to smallpox due to vaccination, which decreases in a geometrical progression with age, and the other a natural immunity to the disease which increases with age according to the same law. Similar conditions might possibly exist with regard to diarrhœa, the child at birth being unsusceptible to the disease owing to the presence or absence of some property which develops later, and which lowers an initial natural immunity. Graduation on this hypothesis has, however, been quite unsuccessful. A second possibility, however, must be remembered. If with development some substance is formed according to a mono-molecular reaction, and decays as it is formed according to a similar reaction, but at a different rate, and if the presence of this substance predisposes to a fatal issue, a curve of the death-rate of a definite form would necessarily be found. Such phenomena are frequent in the reactions of organic chemistry. It has been found by trial that the death-rates from summer diarrhœa from birth to the age of three can be graduated almost perfectly upon this hypothesis (Diagram VI). In such a reaction it is obvious that the process must begin at some definite epoch. When the epoch at which the chemical or pseudo-chemical change begins is calculated from the form of the curve, it is found that the origin is at about ·08 months before birth, a figure which strongly suggests that birth itself is the period at which the phenomenon appears. We thus have an indication that with

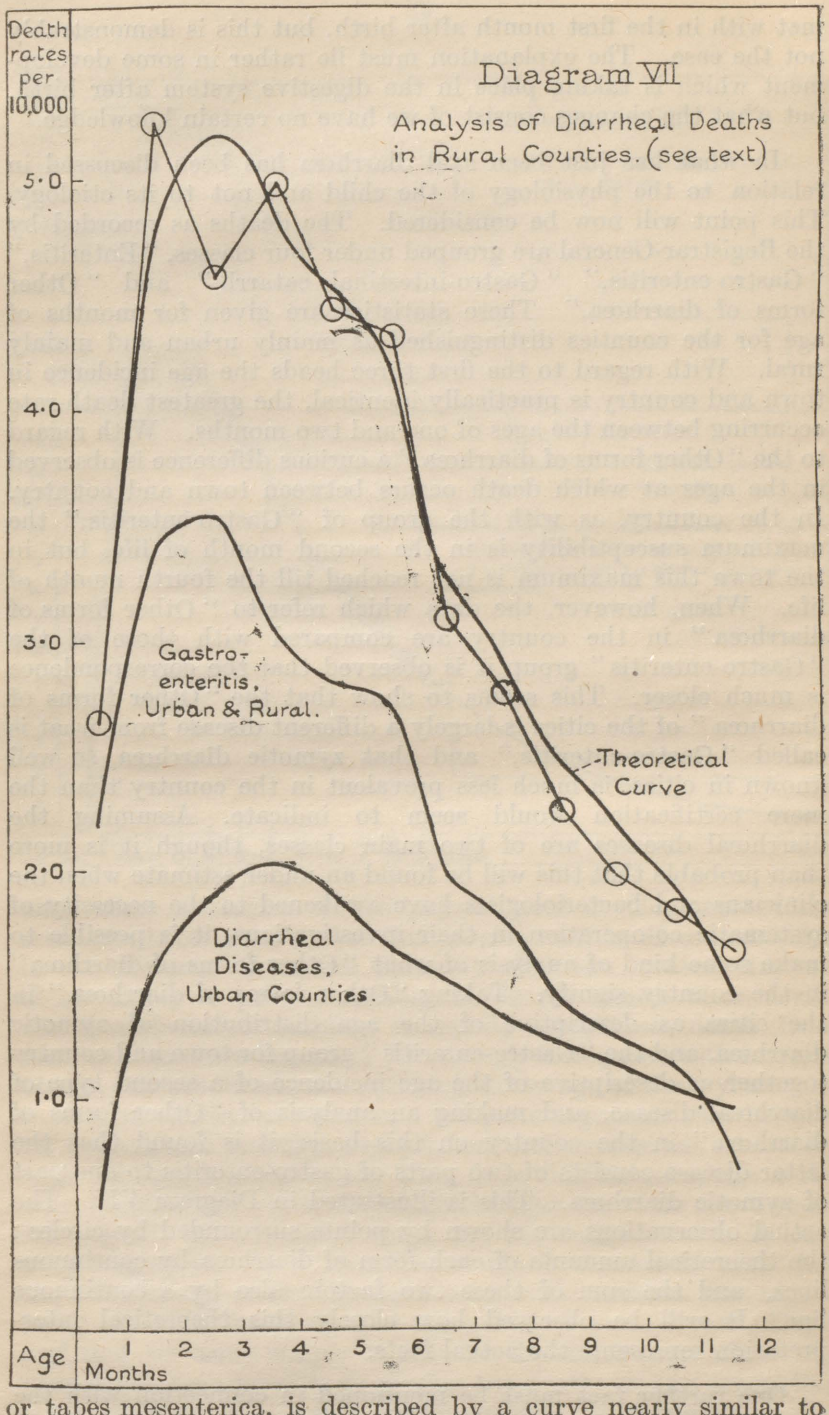


birth some alteration of the physiological development of the intestines takes place ; that this development leads to instability in the presence of certain poisons ; that the greatest amount of instability is present during the fourth month after birth, and that thereafter stability is rapidly established, death from diarrhœal diseases becoming increasingly infrequent with increase of age, and practically disappearing at the age of three years. It cannot, of course, be taken as a complete argument that because the curve which describes a certain reaction corresponds accurately with the figures given by the data, as in this instance, this is the only explanation. It is not suggested that the same curve could not possibly arise in other ways, but the coincidence is at least very suggestive. It is therefore of much interest to note that the calculations in this instance were made without any regard being taken to the portion of the curve above one year of age, and that by using simply figures for the death-rates under one year it has been possible to predict the deaths in two succeeding years of life. This curve again suggests a physiological discontinuity at birth. Such a physiological discontinuity might be expected since the method by which the child receives its nutriment is instantaneously changed. If such a change were the sole explanation, diarrhœal diseases should be most commonly

met with in the first month after birth, but this is demonstrably not the case. The explanation must lie rather in some development which is taking place in the digestive system after birth, but what the changes consist of we have no certain knowledge.

In what has just been said diarrhœa has been discussed in relation to the physiology of the child and not to its etiology. This point will now be considered. The deaths as recorded by the Registrar-General are grouped under four classes, "Enteritis," "Gastro-enteritis," "Gastro-intestinal catarrh," and "Other forms of diarrhœa." These statistics are given for months of age for the counties distinguished as mainly urban and mainly rural. With regard to the first three heads the age incidence in town and country is practically identical, the greatest death-rate occurring between the ages of one and two months. With regard to the "Other forms of diarrhœa," a curious difference is observed in the ages at which death occurs between town and country. In the country, as with the group of "Gastro-enteritis," the maximum susceptibility is in the second month of life, but in the town this maximum is not reached till the fourth month of life. When, however, the data which refer to "Other forms of diarrhœa" in the country are compared with those of the "Gastro-enteritis" group it is observed that the correspondence is much closer. This seems to show that the "Other forms of diarrhœa" of the cities is largely a different disease from what is called "Gastro-enteritis," and that zymotic diarrhœa, so well known in cities, is much less prevalent in the country than the mere certification would seem to indicate. Assuming the diarrhœal diseases are of two main classes, though it is more than probable that this will be found an under estimate when the clinicians and bacteriologists have awakened to the necessity of systematic co-operation in their investigations, it is possible to make some kind of analysis of what "Other forms of diarrhœa" in the country signify. Taking "Other forms of diarrhœa" in the cities as descriptive of the age distribution of zymotic diarrhœa, and the "Gastro-enteritis" group for town and country together as descriptive of the age incidence of a second type of diarrhœal disease, and making an analysis of "Other forms of diarrhœa" in the country on this basis, it is found that the latter disease consists of two parts of gastro-enteritis to one part of zymotic diarrhœa. This is illustrated in Diagram VII. The actual observations are shown by points surrounded by circles; the theoretical amounts of each form of diarrhœa by continuous lines, and the sum of these two factors also by a continuous line. It will be observed how closely this theoretical interpretation represents the actual facts.

One further fact must be mentioned in connection with the death-rate from diarrhœal diseases. Though the consideration of tuberculosis has been definitely excluded from this note it is to be observed that the death-rate from abdominal tuberculosis,



or tabes mesenterica, is described by a curve nearly similar to that of diarrhœa; in other words, the changes in the abdominal viscera during growth do not merely affect the stability of this system in the presence of the organisms of diarrhœal diseases

alone, but also towards certain other organisms. The curve illustrating the susceptibility to tabes mesenterica is shown in the diagram (VI) above that illustrating the death-rates of diarrhœa. The similarity is obvious.*

*Dr. Stevenson points out that there is a correlation from year to year between the death-rates from tuberculous peritonitis and diarrhœa. The variation in the amount of tuberculous-peritonitis from year to year is not, however, sufficient, I think, to invalidate the argument advanced in relation to instability during development. Apart from confusion in diagnosis it is, in addition, quite probable that the two diseases mutually predispose to each other.

VII.—SCARLET FEVER AND MEASLES.

With regard to certain diseases a marked change both in the susceptibility and the case mortality takes place in children roughly at about the age of six months. Under five months of age children are as a rule very insusceptible to infection from measles or scarlet fever. When nursing mothers were admitted, suffering from scarlet fever, to the City of Glasgow Hospital it was quite usual to admit the child to the scarlet fever ward if its age were under three months, and in no instance did such a child contract the disease. The case mortality also differs, changing from 10 per cent. during the first six months of life to 30 per cent. during the second six months. This change takes place with apparent suddenness. During the age period between one and two years of age the mortality of scarlet fever is still high. From that time, however, it decreases until the age of 10 years is reached, the decrease in case mortality being capable of graduation by a geometrical progression. Thus the mortality between two and three years of age is three-quarters of that between one and two years of age, between three and four three-quarters of that between two and three. This ratio applies to the figures of Glasgow, Manchester and Aberdeen, even although the severity of disease in these three towns has been different.

Table IV. showing the Case Mortality at Ages from 1 Year to 10 Years in the City of Glasgow Fever Hospital, Belvidere, for Measles, and Scarlet Fever, with a like Table added for Comparison for Scarlet Fever in Manchester.

Age Period.	Measles.		Scarlet Fever.			
			Glasgow.		Manchester.	
	Actual C.M.%.	Theor. C.M.%.	Actual C.M.%.	Theor. C.M.%.	Actual C.M.%.	Theor. C.M.%.
1–2	26·1	25·0	24·3	22	19·3	19·3
2–3	15·5	16·0	16·5	16·5	14·7	14·2
3–4	10·4	10·2	12·6	12·4	12·2	10·6†
4–5	5·0	6·5†	9·1	9·3	8·7	7·8
5–6	4·3	4·2	7·0	7·0	5·7	5·8
6–7	2·7	2·7	4·1	5·2†	4·5	4·3
7–8	1·4	1·7	3·6	3·9	3·4	3·2
8–9	1·9 { 1·5	1·1 } 1·8	3·1	2·9	2·2	2·3
9–10	1·9 { ·4	·7 } 1·8	2·2	2·2		

†Ages at which divergence of fact from theory is greatest.

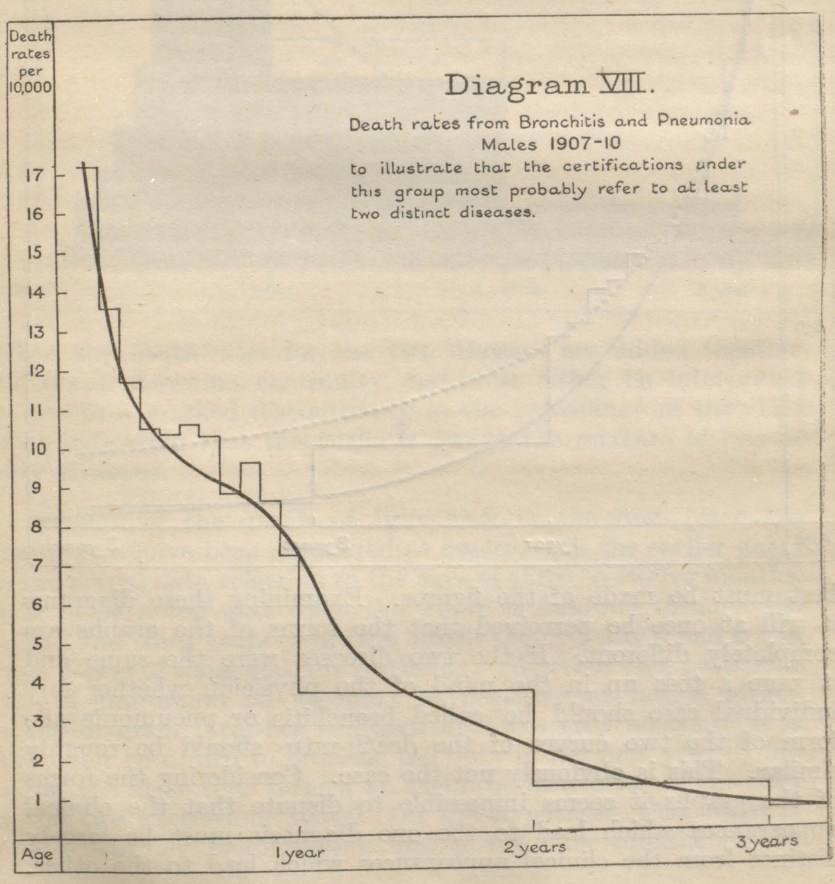
The phenomena with regard to measles are nearly similar. Under five months of age the number of children exposed to infection who contract the disease is very small. In the next seven months of life, however, the number is very great. Dr. Hay's figures for Aberdeen which refer to notification make this quite certain. The third quarter of the year, six to nine months, is the period of the greatest susceptibility. As with scarlet fever, the case mortality is higher in the second half of the first year. During the second to the tenth year of life the mortality progressively declines. In Glasgow this decrease is measured by a geometrical progression of ratio, ·65, but this does not apply to Dr. Hay's figures. It may be noted, in addition, that the same phenomenon regarding susceptibility to attack is found in cerebro-spinal meningitis, the number of cases occurring in the first six months of life being much smaller than in the succeeding six months. There is thus clear evidence of profound differences existing between the first and second halves of the first year of life. Dr. Dale suggests that the change which takes place at the sixth month may be due to gradual weaning since in this way the child may cease to receive from the mother's milk certain protective anti-bodies. In the complete absence of evidence it is obviously impossible to express an opinion on this point. Argument from analogy in questions of immunity is useless, as I hope to show elsewhere.

VIII.—PNEUMONIA AND BRONCHITIS.

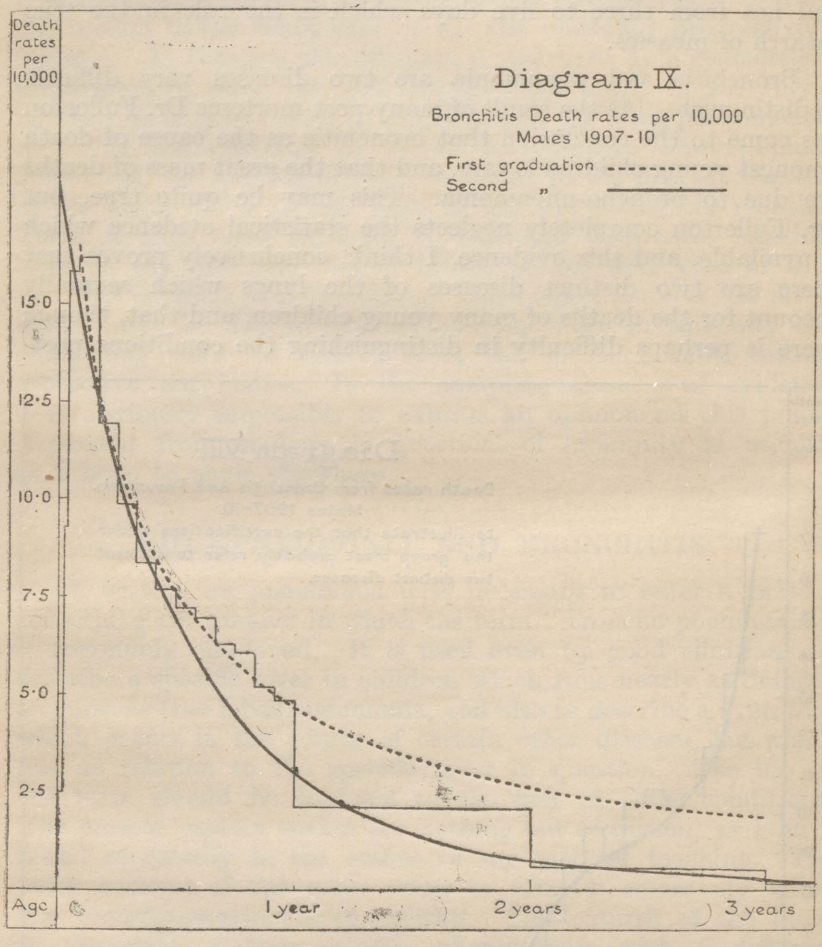
In writing on pneumonia it is necessary to enter a protest concerning the manner in which the term " broncho-pneumonia " is commonly employed. It is used even by good clinicians to describe a specific fever in children which runs nearly as definite a course as true lobar pneumonia, and also to describe a symptom which occurs in the course of certain other diseases, but which has no relation to the specific fever in question. The use of the term should be confined to the first of these conditions. The present custom makes for nothing but confusion, as I have found repeatedly in the course of my medical teaching. The chief instance of this error refers to what is commonly called the broncho-pneumonia of measles. This catarrh of the lungs is, however, a true measles phenomenon with a different clinical appearance from true broncho-pneumonia. I have been in the habit of calling it " the suffocative catarrh of measles," not that I think this a perfect description, but to make sure that the distinction is observed. The specific fever, broncho-pneumonia, does in certain cases, it is true, follow measles. This combination occurs in some epidemics. During recent years in Glasgow, however, this combination has been far from common, the catarrh of the lungs present being in practically all cases due to the organism of measles. This is proved by the fact that the symptoms occur regularly at the same stage in this

disease. Even in severe cases with extreme dyspnœa and rapid pulse the symptoms often disappear within a day if the child lives, the whole course of the attack of measles from commencement to the end of the pyrexia being no more than eight or nine days, even although the patient may for the latter part of that period be in extreme danger. It is true that broncho-pneumonia may kill with great rapidity, but it is a disease which in my experience runs a course of from twelve days to three weeks, and not from three to five days which is the rule in the true catarrh of measles.

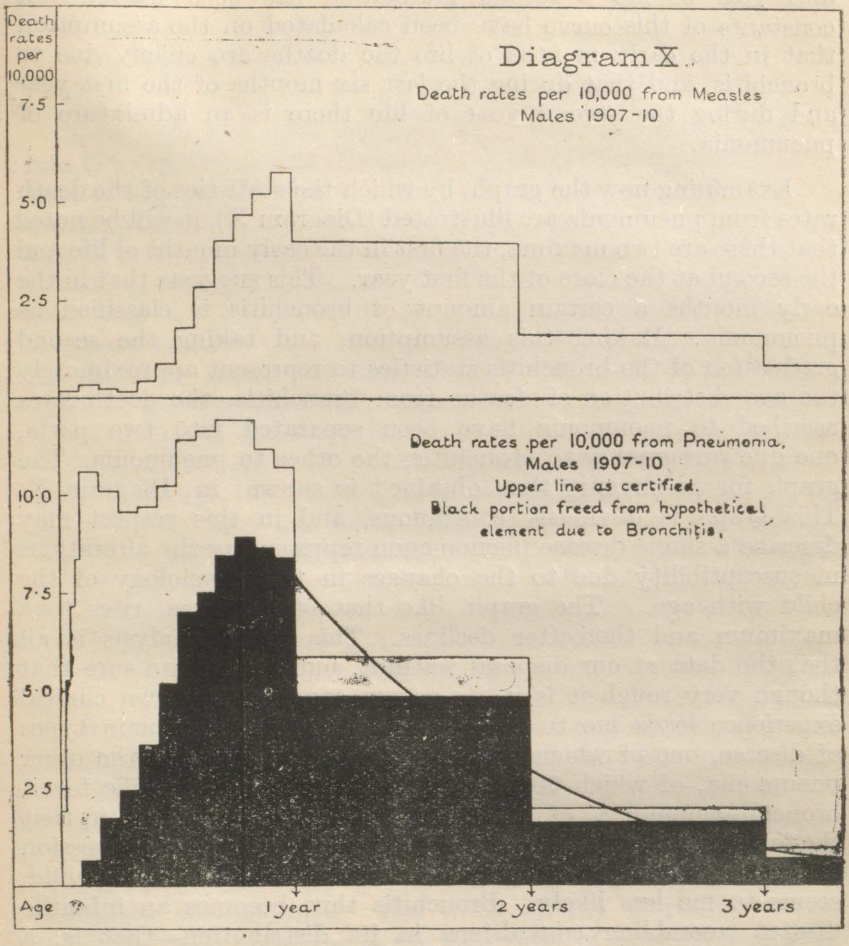
Bronchitis and pneumonia are two diseases very difficult to distinguish. As the result of many post-mortems Dr. Fullerton has come to the conclusion that bronchitis as the cause of death amongst young children is rare, and that the great mass of deaths are due to broncho-pneumonia. This may be quite true, but Dr. Fullerton completely neglects the statistical evidence which is available, and this evidence, I think, conclusively proves that there are two distinct diseases of the lungs which severally account for the deaths of many young children, and that, though there is perhaps difficulty in distinguishing the conditions post-



mortem, the clinical differences are such as to ensure that the two diseases are roughly sorted out. In the accompanying diagrams (Diagrams VIII, IX, X) the death-rates from pneumonia and from bronchitis are shown, for the first four years of life, at monthly intervals during the first year, and yearly thereafter. It would have been much better if we could have had the monthly data for the second year of life, but in the absence of this the



best must be made of the figures. Examining these diagrams it will at once be perceived that the forms of the graphs are completely different. If the two diseases were the same and it were a toss up in the mind of the physician whether any individual case should be called bronchitis or pneumonia the form of the two curves of the death-rates should be roughly similar. This is obviously not the case. Considering the forms of the graphs it seems impossible to dispute that the clinical appearances which lead to the one diagnosis must be largely distinct from the clinical appearances which lead to the other.



When the death-rates for the two diseases are added together the graph shows no continuity, and must either be interpreted as due to a marked discontinuity in the physiology of the child or as indicating that the curve is due to the mixture of two or more diseases.

Examining the graph of bronchitis in the first place the death-rates have been graduated as described in the earlier pages to the actual data referring to the ages of three to twelve months. It is to be noted that when this curve is followed through the second and third years of life the deaths theoretically found are in great excess of those actually occurring. Whether this particular type of graduation be accepted as probable or not, a glance at the diagram furnishes sufficient evidence that no continuous curve can be drawn to describe the data in the first year of life and at the same time furnish an accurate description of the data in the two succeeding years. On the hypothesis that there is some disturbing factor acting during the later months in the

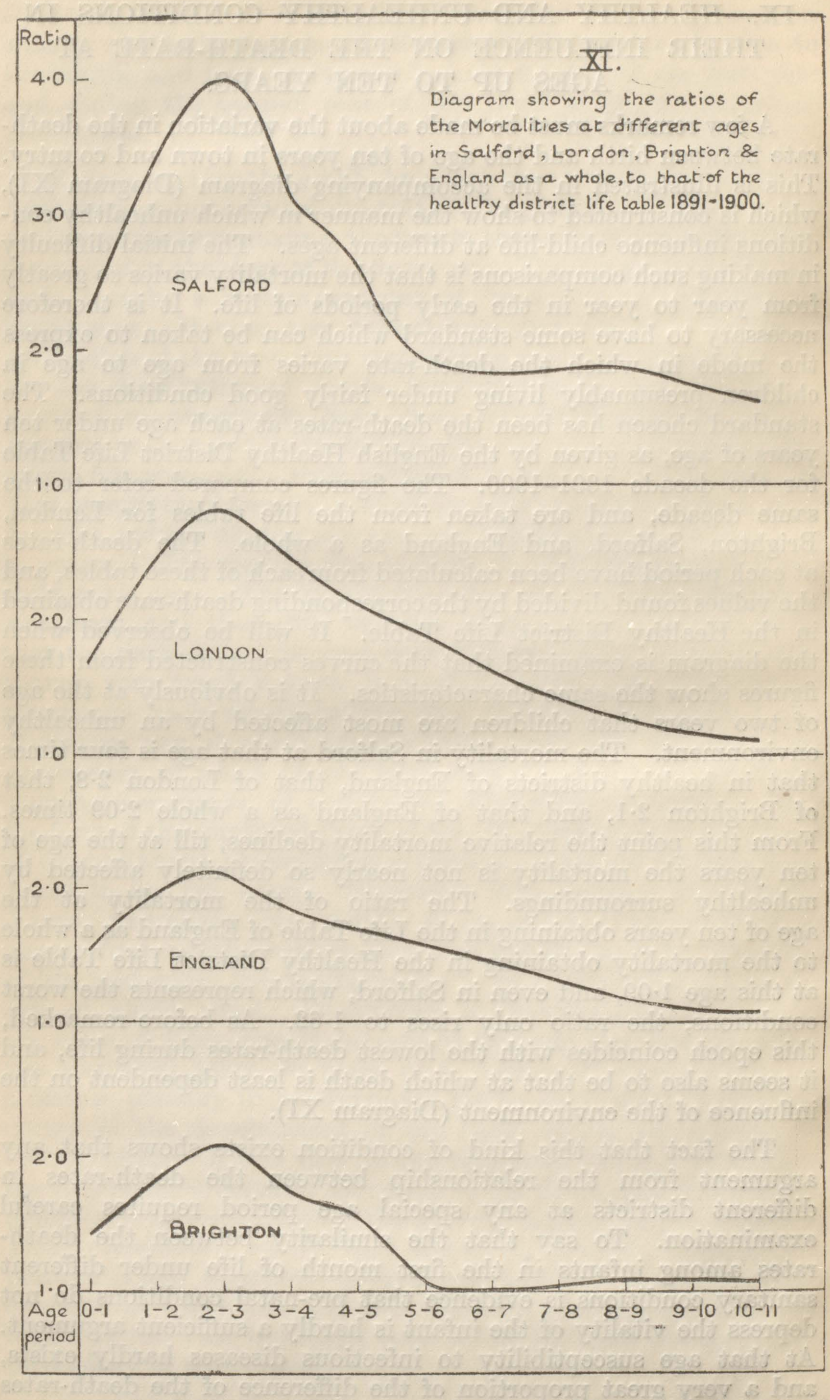
first year of life a second graduation has been made. The constants of this curve have been calculated on the assumption that in the early months of life the deaths are chiefly due to bronchitis, and that during the last six months of the first year and during the second year of life there is an admixture of pneumonia.

Examining now the graph, by which the statistics of the death rates from pneumonia are illustrated (Diagram X), it will be noted that there are two maxima, the first in the early months of life and the second at the close of the first year. This suggests that in the early months a certain amount of bronchitis is classified as pneumonia. Making this assumption, and taking the second graduation of the bronchitis statistics to represent approximately the age distribution of deaths from bronchitis, the death-rates ascribed to pneumonia have been separated into two parts, one due presumably to bronchitis, the other to pneumonia. The graph for pneumonia thus obtained is shown in Diagram X. This graph is obviously continuous, and in this respect may describe a single disease phenomenon representing the alterations in susceptibility due to the changes in the physiology of the child with age. The graph, like that of diarrhœa, rises to a maximum and thereafter declines. This rough analysis is all that the data at our disposal warrant, but I am quite sure that though very rough it is in its nature correct. My own clinical experience leads me to believe that there are two main types of disease, one of which may be called bronchitis and the other pneumonia, of which 90 per cent. consists of the specific fever, broncho-pneumonia, of childhood. The other explanation, that the form of the combined graph of the two diseases is an expression of discontinuous physiological condition in the developing child, seems to me less likely. Bronchitis thus becomes an infantile disease resembling convulsions in its distribution—that is, a disease from which death is most common in the earliest months of life, and which ceases practically to be a cause of death at the age of three years. Pneumonia or broncho-pneumonia (for the cases of lobar pneumonia are at this age too few to affect the statistics) takes its place as a disease of early childhood, a disease possibly to be accounted for by some instability which occurs in the development of the lungs during the second six months of life. If this view be correct special interest attaches to the resemblance between the graph of the death-rates from pneumonia and measles, graphs which are compared in the diagram. This resemblance recalls that obtaining between tuberculous peritonitis and diarrhœal diseases, and furnishes another possible example in which two different diseases affecting specially one organ, in this case the lungs, both reveal the same changes in the physiology of that organ.

IX.—HEALTHY AND UNHEALTHY CONDITIONS IN THEIR INFLUENCE ON THE DEATH-RATE AT AGES UP TO TEN YEARS.

A few remarks must be made about the variation in the death-rate between birth and the age of ten years in town and country. This is illustrated in the accompanying diagram (Diagram XI), which is constructed to show the manner in which unhealthy conditions influence child-life at different ages. The initial difficulty in making such comparisons is that the mortality varies so greatly from year to year in the early periods of life. It is therefore necessary to have some standard which can be taken to express the mode in which the death-rate varies from age to age in children presumably living under fairly good conditions. The standard chosen has been the death-rates at each age under ten years of age, as given by the English Healthy District Life Table for the decade 1891–1900. The figures compared refer to the same decade, and are taken from the life tables for London, Brighton, Salford, and England as a whole. The death-rates at each period have been calculated from each of these tables, and the values found divided by the corresponding death-rate obtained in the Healthy District Life Table. It will be observed when the diagram is examined that the curves constructed from these figures show the same characteristics. It is obviously at the age of two years that children are most affected by an unhealthy environment. The mortality in Salford at that age is four times that in healthy districts of England, that of London 2·8, that of Brighton 2·1, and that of England as a whole 2·09 times. From this point the relative mortality declines, till at the age of ten years the mortality is not nearly so definitely affected by unhealthy surroundings. The ratio of the mortality at the age of ten years obtaining in the Life Table of England as a whole to the mortality obtaining in the Healthy District Life Table is at this age 1·09, and even in Salford, which represents the worst conditions, the ratio only rises to 1·62. As before remarked, this epoch coincides with the lowest death-rates during life, and it seems also to be that at which death is least dependent on the influence of the environment (Diagram XI).

The fact that this kind of condition exists shows that any argument from the relationship between the death-rates in different districts at any special age period requires careful examination. To say that the similarity between the death-rates among infants in the first month of life under different sanitary conditions is evidence that pre-natal conditions do not depress the vitality of the infant is hardly a sufficient argument. At that age susceptibility to infectious diseases hardly exists, and a very great proportion of the difference of the death-rates between the country and the town is due to the difference of the death-rates from those diseases. Thus in 1913, between one and three months, the death-rates in the rural and urban districts were



XI.

Diagram showing the ratios of the Mortalities at different ages in Salford, London, Brighton & England as a whole, to that of the healthy district life table 1891-1900.

15·27 and 21·58 per 1,000 respectively, a difference of 6·31, of which more than half was due to the ordinary infections of childhood, including bronchitis and pneumonia. This difference

between the town and country death-rates, small at birth, is seen to be again almost negligible at the age of ten years, yet no one could say that a child brought up in a large town during the whole of its early years of life was on an average as healthy as a similar child brought up in the country. Death-rates must therefore be considered in relation to the physiology of development, and not as independent numbers which can be used for comparison without giving consideration to the physiological stability of the growing child.

X.—SUMMARY AND CONCLUSIONS.

In the preceding pages the nature of the physiological changes which take place in the growing child have been discussed in so far as these changes can be inferred from the manner in which disease acts on the growing child during successive periods of life. The results may be briefly summarised.

First, it has been shown that the growth of the child is a continuous process from a period at least six months prior to birth to the age of about four years, a process not interrupted either by the act of birth or by the act of weaning.

Second, with regard to convulsions, it has been shown that the death-rate from this condition diminishes in a perfectly definite manner from the age of two months to the age of four years. Convulsions are usually considered as a symptom of disease, and there is no doubt that this is true. This statement, however, as usually interpreted, lays too little stress upon the fact that the essential factor is the nervous instability of the child. Thus, I have never been able to satisfy myself that there is any clinical distinction between convulsions associated with pneumonia and convulsions associated with enteritis. It is not only with regard to the tendency towards convulsions that changes take place in the growing child. The growing stability of the nervous system during the first few years of life is shown in many ways —for instance, the tendency in children towards paroxysmal rage disappears with age in the same kind of manner. In view of these facts I feel inclined to believe that convulsions are more a pathological entity than they are commonly regarded at the present moment.

Third, it has been suggested that in the group of premature births and wasting diseases some considerable saving of infantile life is possible. This saving of life may be expected from better care at certain critical stages of development.

Fourth, the group of diarrhœal diseases has been found to be a homogeneous statistical group, and as these diseases undoubtedly include several definite specific infections, it seems obvious that the reasons for the frequency of these diseases at the ages of life at which they are found must be sought for in the development of the child and not specially in the type of parasite. This is rendered more probable as it has been seen

that the variation of the death-rate from tuberculous peritonitis with age bears a very close correspondence to that from diarrhœal diseases.

Fifth, with regard to scarlet fever and measles it has been remarked that as the second half of the first year of life is reached both the infectibility by the parasite of the disease and the susceptibility to death are markedly higher. In both these instances the curve of the death-rate can be represented by the same curve as that which has been used to graduate the death-rate in diarrhœal diseases. The evidence for this has not been given, as the data are not sufficient to do more than offer the suggestion that this is the explanation. There is no doubt, however, about the manner in which the death-rates decline in these diseases with increase of age. For this change it seems to me most useful to seek the explanation from the side of physical chemistry and to assume that some substance in the body which predisposes to a severe attack of the disease develops rapidly and then gradually disappears during the growth of the child. This explanation seems more probable than the complementary explanation, namely, that the increase of the severity of the disease at the age of six months is due to a loss of one protective substance, and that the recovery of the protection is due to the development of a second protective substance. This is, however, a matter in which direct animal experiment might be made, once a suitable animal and a suitable disease were found. The final solution of this question will be obtained either in the laboratory or by direct observation in one of the larger fever hospitals.

Sixth, it has been shown that the statistics of bronchitis and pneumonia suggest that these are two diseases of different etiology : the one bronchitis, an infantile disease, and the other, pneumonia, a disease causing the greatest number of deaths during the latter half of the first year of life. With regard to the broncho-pneumonia of measles and true broncho-pneumonia, the view has been advanced that these are two separate diseases, though the pathological and bacteriological findings have been hitherto considered almost identical. The clinical differences are quite sufficiently marked to warrant the conclusion that there is an etiological difference.

Lastly, the general conclusion is advanced that the physiological processes of the growing child offer a great field for study, and that systematic enquiry resulting in the correlation of the evidence obtainable by the physiologist, clinician and the bacteriologist would lead to very valuable results.

APPENDIX.

Note to Section III. Growth in Childhood.

In this section the assumption has been made that the rate of infantile growth may be explained by the presence of two separate impulses to growth in the embryo, each of which decays in a geometrical progression. This gives rise to the equation that, if y be the weight at any instant, x the age, and a, b, c_1 and c_2 constants to be determined from the statistics that :—

$$\frac{1}{y}\frac{dy}{dx} = ac_1 e^{-c_1 x} + bc_2 e^{-c_2 x}$$

which, when integrated, gives the equation of weight with age as :—

$$y = Ke^{-ae^{-c_1 x} - be^{-c_2 x}}$$

This equation is easily solved in any individual instance by choosing a suitable set of values of the weight at equal intervals of age. The values chosen for calculation are the mean weight at birth, at one, two and three years of age, and a slightly modified value at four years of age to allow for the secondary increase of growth which begins about that time. Taking logarithms of both sides and denoting log K by C, and e^{-c_1}, e^{-c_2}, by l and m respectively, we have—

Weight.	Log W.
3·4	·5315 = C − a − b
10·2	1·0086 = C − al − bm
12·7	1·1038 = C − al^2 − bm^2
14·7	1·1673 = C − al^3 − bm^3
16·4	1·2135 = C − al^4 − bm^4

The easiest method of solving these equations is to eliminate the three variables C, a and b from the two consecutive groups of four equations. This elimination gives rise to two determinant equations :—

$$\begin{vmatrix} ·5315 & 1 & 1 & 1 \\ 1·0086 & 1 & l & m \\ 1·1038 & 1 & l^2 & m^2 \\ 1·1673 & 1 & l^3 & m^3 \end{vmatrix} = 0$$

$$\begin{vmatrix} 1·0086 & 1 & 1 & 1 \\ 1·1038 & 1 & l & m \\ 1·1673 & 1 & l^2 & m^2 \\ 1·2135 & 1 & l^3 & m^3 \end{vmatrix} = 0$$

By simple reduction these give rise to the simultaneous equations,

$$·4771\ lm - ·0952\ (l + m) + ·0635 = 0$$
$$·0952\ lm - ·0635\ (l + m) + ·0462 = 0$$

Taking as independent variables lm and $l + m$ these can be immediately solved ; l and m are then found to have the values ·72978 and ·02362. It is now easy to deduce the values of a, b and C, which are—

$$a = ·43985$$
$$b = ·36691$$
$$\text{C} = ·13383$$

The theoretical values calculated from this formula are shown in Diagram III plotted against the observations. The formula modified so as to apply to the mean weights of both sexes is also shown in Diagram III. The weights before birth were then calculated, and the results of this calculation

are graphically illustrated in Diagram II, by the continuous line. It will be noticed that the weights of the fœtus as given by the formula are somewhat smaller than those given by the observations; a correction was therefore made, and the new value of l found. The corrected curve is indicated in the diagram by the dotted line. The closeness of the graduation is easily seen.

NOTE TO SECTION IV.—CONVULSIONS.

The graduation of the death-rate from convulsions has been made to the formula,

$$y = \frac{a}{(b+t)^n}$$

where y is the death-rate and t the age, while a, b and n are constants to be determined from the statistics. In the formula, if $\frac{a}{b}n$ is the amount of a substance present at the beginning of a chemical reaction in which $\frac{n+1}{n}$ molecules take part ($\frac{n+1}{n}$ being in physical chemistry a whole number), then the amount of the substance present at any future time is $\frac{a}{(b+t)}n$. As I have shown elsewhere the formula also describes very accurately what is found when two or more mono-molecular reactions of different velocities are taking place simultaneously. It is on this ground that it has been applied in this instance.

In this case the formula has been fitted to the death-rates between three and four months, seven and eight months, and eleven and twelve months. In the case of the latter figure, a slight adjustment has been made, as it is obvious from the diagram that the figure for the death-rate between ten and eleven months is somewhat too large and that for eleven and twelve correspondingly somewhat too small. The adjustment amounts to increasing the death-rate of the latter by ·6, which is equivalent to decreasing the death-rate between ten and eleven months by a like amount. The working then is as follows. Taking logarithms of both sides in the above formula,

$$\log y = \log a - n \log (b+t)$$

so that we have the three equations :—

$$\log 93{\cdot}0 = 1{\cdot}96848 = \log a - n \log (b + 3{\cdot}5)$$
$$\log 35{\cdot}2 = 1{\cdot}54654 = \log a - n \log (b + 7{\cdot}5)$$
$$\log 17{\cdot}1 = 1{\cdot}23300 = \log a - n \log (b + 11{\cdot}5)$$

the value of y, the death-rate, occurring in the left-hand side of the equation and the mean value for each month of life in the right hand side. The solution of these equations is simple. By subtraction, we have :—

$$\cdot 42194 = n \left\{ \log (b + 7{\cdot}5) - \log (b + 3{\cdot}5) \right\}$$
$$\cdot 31354 = n \left\{ \log (b + 11{\cdot}5) - \log (b + 7{\cdot}5) \right\}$$

and by division we have :—

$$1{\cdot}345729 = \frac{\log (b + 7{\cdot}5) - \log (b + 3{\cdot}5)}{\log (b + 11{\cdot}5) - \log (b + 7{\cdot}5)}$$

With the help of a table of logarithms we find :—

$$b = 6{\cdot}269$$

whence $n = 2{\cdot}8308$

and $\log a = 4{\cdot}77055$

so that finally :—

$$y = \frac{5{\cdot}8959}{(6{\cdot}269 + t)^{2{\cdot}8308}}$$

NOTE TO SECTION VI.—DIARRHŒAL DISEASES.

The graduating curve used in this section is that which arises if two consecutive uni-molecular reactions follow each other, one substance being formed according to the law and thereafter decaying according to the same law, but with a different velocity.

The formula in this case is,

$$y = ae^{-c_1 x} - be^{-c_2 x}$$

where y is the amount of the substance, x the age, a and b constants, and c_1, c_2, represent the velocities of the reactions. If the origin of the curve is known, a is equal to b.

The formula may also be written :—

$$y = al^x - bm^x$$

l and m being less than unity. The method of fitting in this case is exceedingly simple, and will at once be understood from the annexed table. In the first column the death-rates from diarrhœa are shown for each month of age. If these death-rates follow the law in question the ratios between the death-rates in each successive month of life in the latter months of the year must be approximately constant. These ratios have been calculated for the last six months of the first year. The ratios are given in column (2) ; the mean value of these ratios is 1·16. Taking the last death-rate, namely, 167, and multiplying this number by 1·16 and continuing the process, the numbers in the third column are obtained. The differences between these calculated numbers and the numbers in the first column are given in the fourth column. In this case it will be noticed that the successive figures are approximately in a geometrical progression, of which the ratio is one-half. The ratios between the first and second and second and third numbers are given in column five (5) ; taking the mean of these and taking 679 as the starting number, the numbers given in the sixth column are obtained. These numbers fall to be subtracted from those found in the third column, and the result is in the seventh column of the table. When this column is compared with the first the differences are seen to be comparatively small. Having once obtained an approximation such as this it is not difficult, by trying slightly different values of the ratios and the initial numbers, to obtain a closer fit.

The equation found is evidently :—

$$y = 853 \cdot \left(\frac{1}{1{\cdot}16}\right)^x - 679\ (\cdot 4746)^x$$

If $y = 0$,

we have :—

$$\log 853 - x \log 1{\cdot}16 = \log 679 + x \log \cdot 4746$$

or

$$\log 853 - \log 679 = x \left\{ \log 1{\cdot}16 + \log \cdot 4746 \right\}$$

or,

$$\cdot 09908 = x + (-\cdot 25921)$$

which gives :—

$$x = -\cdot 38$$

As the origin is at the middle of the first month in the calculation this places the commencement of the developmental change at ·12 of a month after birth.

Graduation of the Death-rate from Diarrhœa.

Month of Age	(1) Death rates 1000 × 4	(2) Ratio I.	(3)	(4) Excess of (3) (1)	(5) Ratio II.	(6)	(7) Graduated Values.	(8) Diff: act: and Theor.
0–1	174		853	679	·4712	679	174	0
1–2	415		735	320	·4781	322	413	+ 2
2–3	481		634	153		153	481	0
3–4	481		547	66		73	474	+ 7
4–5	445		472	27		35	437	+ 8
5–6	396		407	11		17	390	+ 6
6–7	350	1·1705	351			8	343	+ 7
7–8	299	1·0872	303			4	299	0
8–9	275	1·1506	261			2	259	+ 16
9–10	239	1·1831	225			1	224	+ 15
10–11	202	1·2095	194				194	+ 08
11–12	167		167				167	
		mean 1·16			mean ·4746			

The graduation just given is not the one used in the construction of the diagram, the papers containing the previous calculations having gone amissing, but the new values differ little from the old. The principle of the method is quite clear, and the application involves nothing but a little elementary arithmetic.

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