ETIOLOGICAL FACTORS IN BRONCHO-PNEUMONIA AMONGST INFANTS IN LONDON

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(With 4 Figures in the Text)

It is only in exceptional years that bronchitis and pneumonia* together fail to be the assigned causes of death for less than one-fifth of all London infants dying under 2 years of age. Sometimes, as can be seen from Table 1, the proportionate mortality from these registered causes of death combined rises to more than a quarter. The serious loss of life amongst infants from these diseases consequently presents a public health problem of the first magnitude.

Table 1. *Mortalities, per* 100,000,† *of infants below the age of 2 years from all causes, and from bronchitis and pneumonia (all forms) combined in the Administrative County of London, from* 1931 *to* 1938

Year	All causes	Bronchitis and pneumonia (all forms)	Proportionate mortality (per cent.)
1931	4088	1141	28·0
1932	4406	859	19·5
1933	3676	732	19·9
1934	4607	1120	24·3
1935	3438	740	21·5
1936	4227	916	21·7
1937	3637	843	23·2
1938	3483	743	21·3

So far as can be seen at present, the solution to the problem of lessening the mortality of infants from bronchitis and pneumonia is unlikely to lie along the lines successfully pursued with some of the more important acute respiratory diseases of childhood. Whereas specific prophylactic measures are now being directed against diphtheria and measles, the micro-organisms responsible for bronchitis and pneumonia are so diverse that the only preventative methods available at the present time for limiting their pathogenic activities are the general hygienic measures which operate indiscriminately against all droplet-borne infections. A knowledge of the relative importance of particular environmental factors that predispose infants to contract bronchitis and pneumonia is thus necessary for the proper planning of measures for the reduction in their incidences and mortalities.

Before examining the possible associations between bronchitis and pneumonia in infants and particular environmental conditions, however, it is necessary to ascertain the extent to which the deaths from certain acute specific respiratory diseases are likely to be confused with those recorded officially as bronchitis and pneumonia (all forms), so that some estimate may be made of their dependability.

* The term 'broncho-pneumonia' will be used in later sections to include both bronchitis and pneumonia (all forms) as employed in the Annual Reports, and bronchitis and broncho-pneumonia as given in the Weekly Returns of the Registrar General.

† In consequence of the error that results from the frequent overstatement of the age of infants in the census returns (see Dunlop, 1916), the populations at these ages have been calculated from recorded births, less deaths at appropriate ages, in the administrative area concerned. This method resembles that described by Farr (1885*a*). Such figures necessarily fail to allow for migration, especially the centrifugal drift from the central Metropolitan Boroughs, but the errors that result from these omissions are probably slight in comparison with that noted above, and in any case are not susceptible of correction. It is of interest as a check upon the present method, that by its use the population, aged 0–2 years, of the Administrative County of London, less the City of London, for 1931, was estimated at 125,749, while the 1931 census figure was 121,876. Were this discrepancy to be due to the overstatement of the ages of certain infants between 21 and 24 months old, it would result from this mistake having occurred in 26% of infants in this trimestrial period. Dunlop estimated that the net overstatement in Scotland in 1911 was 24%. Mistakes in recording ages also apply to deaths, but for the present purposes the resulting error is less serious, because the bronchitis and pneumonia mortalities of infants between 21 and 24 months old are small in comparison with those of infants under 12 months old (see footnote, p. 25).

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Possible errors in the recorded incidence of deaths from broncho-pneumonia amongst London infants through the inclusion of deaths from measles, whooping cough and influenza

Since secondary broncho-pneumonia is a frequent terminal complication of measles, whooping cough and influenza, it is possible for the records of deaths of infants from pneumonia to be exaggerated by the erroneous inclusion of deaths that should properly be attributed to one of these three specific diseases. Such errors of diagnosis might arise, as Smith (1928) has pointed out, from patients only coming under observation after pathognomonic symptoms, such as the rash or the whoop, had disappeared. His comparison of the annual mortalities from measles, whooping cough and broncho-pneumonia in Glasgow between 1920 and 1926 supported his view that such misdiagnoses might not be infrequent, and that under certain circumstances they might lead to considerable inaccuracies in the records of the deaths from primary broncho-pneumonia. Accordingly, the data for London have been examined for this source of error.

Measles. The effect of measles upon the registration of deaths from broncho-pneumonia may be tested in several ways.

(i) The remarkable biennial recurrence of measles epidemics in London during the 16 years of the present study, makes it possible to test for this source of error by comparing the mortalities from broncho-pneumonia for the 8 measles years with those of the immediately succeeding 8 non-measles years.* Although the series is comparatively short, its regularity has the effect of minimizing those chance variations in broncho-pneumonia mortality which might arise from other causes. In the 8 measles years, the average annual mortality from broncho-pneumonia amongst infants under 2 years was 886 per 100,000, while in the non-measles years it was 834. Since the series of measles years was spaced 1 year before that of the non-measles years, and since the estimated annual decrease in the mortality of infants from broncho-pneumonia during this period was about 31 per 100,000 per annum, the figures for comparison should more correctly be 886 and 865. The use of such an estimate, however, can be avoided by comparing the average of the 8 measles years with that of the 7 intervening non-measles years: the comparable figures then are 886 and 880. Thus, with either method of comparison, the excess mortality from broncho-pneumonia in the measles years is found to be small.

(ii) Perhaps the most convincing reason for regarding the records of deaths from broncho-pneumonia as being little affected by erroneous notifications of those from measles is provided by the differing times in the year at which the peaks of mortality of the two epidemics occur. If 5-week moving averages of the mortalities from these two causes of death be calculated for the 8 years in which measles epidemics took place, it is found that the peak for this disease is always later in the year than that for broncho-pneumonia. Table 2 shows in which weeks such peaks occurred, and the intervals which separated them.

In several years the peaks of the epidemics of broncho-pneumonia and measles were separated by intervals of more than 10 weeks, so that by the time that the mortality from measles had reached its maximum, that from broncho-pneumonia had fallen considerably. If the calculated 5-week moving averages of the broncho-pneumonia mortality were continued far past its maximum, no secondary maximum appeared about or shortly after the week of the measles peak.

Table 2. *Period of year at which maximum mortalities of infants from broncho-pneumonia and measles take place*

Epidemic year	Week of the peak in mortality: Broncho-pneumonia	Week of the peak in mortality: Measles	Interval in weeks
1923–4	8th (1924)	11th (1924)	3
1925–6	48th (1925)	5th (1926)	9
1927–8	11th (1928)	13th (1928)	2
1929–30	4th (1930)	15th (1930)	11
1931–2	50th (1931)	15th (1932)	17
1933–4	8th (1934)	14th (1934)	6
1935–6	6th (1936)	17th (1936)	11
1937–8	1st (1938)	13th (1938)	12

Whooping cough. (i) The absence of such well-defined periodicity in the epidemics of whooping cough makes it more difficult to estimate the extent to which its misdiagnosis affects the accuracy of the recorded mortality from broncho-pneumonia. Some indication, however, may be obtained by determining the excess mortality from broncho-pneumonia in those years with elevated whooping-cough mortalities. If the whole 16 years be divided into four equal periods, and the recorded data for the 2 years showing high and for the 2 years showing low whooping-cough mortalities in each quadrennium be segregated, and the data for the 8 years in each of the two large resulting groups summated, the average mortalities, per 100,000, of infants

* Throughout this study the epidemic year has been regarded as that between the 27th week of one calendar year and the 26th week of the next. By so doing, all the major outbreaks of respiratory diseases lie about the middle of the epidemic year.

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under 2 years from whooping cough and broncho-pneumonia have the following values.

	High whooping-cough years	Low whooping-cough years
Whooping cough	312	137
Broncho-pneumonia	897	822

There thus appears to be a slight excess, of the order of less than 10 %, in the mortality of infants from broncho-pneumonia in those years in which whooping cough was particularly prevalent.

(ii) As would be expected from the higher average value of the coefficients of correlation between the weekly deaths from whooping cough and from broncho-pneumonia in those years in which major epidemics occurred (0·671* as compared with *0·435* for broncho-pneumonia and measles), the peaks of the 5-week moving averages of the mortality from broncho-pneumonia are much nearer to those for whooping cough than to those for measles.

Influenza. (i) As with whooping cough, no regularly recurring cycle of influenza epidemics occurred during this 16-year period. The same procedure has therefore been adopted to determine the extent of the excess mortality of infants from broncho-pneumonia in those years in which influenza was notably prevalent. Since the number of infants recorded as dying from influenza is generally small, the estimate of prevalence has been based upon the mortalities of adults aged 25–44 years—that part of the population with whom the infants are likely to come into close contact. The average mortalities, per 100,000, of infants and adults in the years of high and low adult mortalities from influenza are as follows:

	High influenza years	Low influenza years
Influenza (adults, 25–44)	15·5	5·4
Broncho-pneumonia (infants, 0–2)	927	790

The likelihood of misdiagnosis between influenza and broncho-pneumonia in infancy appears to be greater than that with either of the two preceding specific diseases. Should the worst interpretation be placed upon the data, it would seem that rather more than 10 % of the deaths of infants in winters in which influenza was prevalent were wrongly attributed to primary broncho-pneumonia.

(ii) In conformity with the relatively high value (0·697) of the average of the coefficients of correlation between weekly deaths from broncho-pneumonia amongst infants and from influenza amongst adults for the epidemic years, it is found that the peaks of mortalities, as shown by 5-week moving averages, from broncho-pneumonia amongst the former and from influenza amongst the latter are seldom far apart. Indeed, the influenza peak as often as not preceded that of broncho-pneumonia.

From this short analysis, it is possible to reach certain conclusions as to possible confusion in certification between these four diseases. There seems to be no basis for the fear that deaths of infants that should properly be attributed to measles are being recorded incorrectly as broncho-pneumonia. Nor do the data for London during the period studied provide any grounds for the misgivings expressed by Smith that the records of deaths from broncho-pneumonia may be affected by 'late' pneumonias developing and terminating fatally in the period of debility following an attack of measles.

On the other hand—possibly because the main specific distinguishing feature of whooping cough, the whoop, is less consistently present than the rash of measles—failure to identify this characteristic cough appears to lead to some exaggeration of the number of deaths recorded from broncho-pneumonia. Only the roughest of estimates can be made of the size of such an error, and even this estimate is probably only applicable to the whole series of 16 years taken collectively, because the ease of recognition of the characteristic cough varies from one epidemic to another, especially in very young infants. From the excess mortality from broncho-pneumonia in those 8 years in which whooping cough was prevalent, it would seem that rather less than 10 % of the deaths in this age group that are now attributed to broncho-pneumonia should more correctly be assigned to whooping cough.

Possibly because its clinical manifestations are the least readily distinguishable of these three specific diseases, there appears to be rather more confusion between influenza and broncho-pneumonia, but as with whooping cough it is impossible to make more than the roughest estimate of the resulting error. From comparisons of the excess mortality in influenza years, it was estimated that the mortality of infants from broncho-pneumonia might be exaggerated by more than 10 % when influenza was prevalent.

Errors due to single specific diseases are likely, of course, to become additive in those years in which two or more of them reach epidemic proportions. As a rough indication of the magnitude of these cumulative errors, the series of 16 years was divided into three groups according to the number of these specific diseases that happened to be epidemic. In the 2 years when none was prevalent, the mortality of infants from broncho-pneumonia, making a correction for the estimated annual decline in the mortality from this disease, was 777 per 100,000; in the 5 years in which only one specific disease occurred, it was 821; and in the 9 years in which

* Here, and in later sections, those coefficients having a value of less than $2/\sqrt{n}$ are italicized.

two or three attained epidemic size, the mortality rose to 908. These estimates of error are probably liberal, because all four diseases are partially conditioned by common non-specific etiological factors, such as meteorological conditions, and some of those which are likely to promote the extension of an epidemic of measles, whooping cough or influenza, are also likely to augment the numbers of infants dying from primary broncho-pneumonia. Nevertheless, it is perhaps safest to assume that the figures recorded for broncho-pneumonia deaths amongst infants probably exceed the true figures for primary broncho-pneumonia by some 10–15%. The origins of such discrepancies, however, are far too complex for it to be possible to attempt any modification of the recorded data for individual years or parts of years, so that in the following sections these data have been used for the calculation of the mortalities of infants from broncho-pneumonia without alteration.

Table 3. *Bacteria recovered from the respiratory tracts of infants, aged under 2 years, suffering from broncho-pneumonia*

Author, place	Nature of organism recovered (numbers, with percentages in brackets)			
	Pneumococcus	Streptococcus	Staphylococcus	*H. influenzae*
Nemir, Andrews & Vinograd (1936); Chicago (1931–5)	445 (86)	57 (11)	18 (3)	1 (—)
Trask (1942); New Haven (1927–33)	186 (64)	16 (6)	12 (4)	74 (26)
Hendry (1942); Glasgow (1939–40)	97 (81)	8 (7)	11 (9)	3 (3)

The bacteria responsible for broncho-pneumonia in infants and their distribution in the general population

(*a*) *The bacterial species present in the respiratory tracts of infants suffering from broncho-pneumonia.* Progress in the epidemiological analysis of a disease, particularly one of an infectious nature, is usually rendered easier when its specificity becomes definable in etiological rather than in merely clinical or morbid anatomical terms. When first introduced, the word broncho-pneumonia was used to denominate the anatomical conception of a 'bronchogenous pulmonary inflammation consisting of more or less numerous small foci in lobular or peribronchial arrangement' (Kaufmann, 1929). But this form of pulmonary disease was met with so often, that the name became freely borrowed by physicians and has now long been accepted in the nomenclature of clinical medicine. Modern bacteriological analysis, however, has shown that broncho-pneumonia as recognized clinically can be resolved into a group of diseases, each of which results from infection with one or more of a number of well-recognized bacteria, and it is to the heterogeneity of its bacterial etiology that the attention of epidemiologists should as far as possible be directed.

Several modern studies provide information upon the bacterial species recoverable from the respiratory tracts of children suffering from broncho-pneumonia, and the summarized findings of three recent investigations are set out in Table 3.

Several other authors have published observations which are in general conformity with those given in this table.

Practically all the so-called 'higher types' described by Cooper have been found in the sputum of infants with broncho-pneumonia, but two or three of these types are now known to be particularly associated with this disease. Their relative frequency, together with an indication of their approximate case-fatality rates, can be seen in Table 4.

Additional observations have confirmed these findings. Butler and his collaborators, working in Chicago in 1939–40, also found that types I, VI, XIV and XIX were particularly prevalent in broncho-pneumonia amongst infants: together these four types accounted for nearly half the cases that they studied. Long, McKhann & Cheney (1939) found that types XIV and VI were the most common of all those causing bronchitis and pneumonia in Boston children in 1935–6. That the predominance of the higher types under these circumstances is not peculiar to the United States, is shown by the investigations of Hendry in Glasgow, and by the study made by Neufeld & Etinger-Tulczynska (1932) in 1931 on the nasopharyngeal flora of Berlin infants suffering from acute respiratory catarrh. Types VI and XIX were much the most common in both these series.

The bacteriological findings in broncho-pneumonia in infants may be summarized for the present purpose as follows: (i) the largest proportion of cases are caused by pneumococci, and especially by those higher types that are common inhabitants of the nasopharynx of normal persons of all ages, but only infrequently associated with lobar pneumonia in

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adults; (ii) the case-fatality rates from infections with the lower and higher types are similar in infancy, although for adults the virulence of the former is known to be much the greater; and (iii) an important fraction, notably in infants under 1 year, is caused by haemolytic streptococci, staphylococci and *H. influenzae*, and with them the case-fatality rates tend to be higher than with pneumococci (see Trask, 1942).

(*b*) *Seasonal variations in the carrier rates for pneumococci and streptococci in the population of London*, 1930–6. From the epidemiological standpoint, one of the most important of the environmental changes which takes place in the early winter is the exacerbation of overcrowding. Some evidence upon the extent to which the greater opportunities for the dissemination of droplet-borne micro-organisms actually lead to their wider distribution in the community, can be found in the survey carried out by Straker, Hill & Lovell (1939) upon the nasopharyngeal flora of a large group of London adults at frequent intervals during the period 1930–7.

(i) *Haemolytic streptococcal carrier rates.* The nasopharyngeal carrier rates in Straker's group of London adults fluctuated irregularly during the 7 years of the survey, but only exceptionally did it fall much below 5 % or rise much above 15 %. The variations between these limits, however, showed little consistent relationship with the seasons, although when the means for the bi-monthly records for the 7 years are compared, there is found to be a small autumnal rise (see Fig. 1), followed by a slow fall throughout the winter months. It is also significant, in confirmation of these findings, that the averages for the monthly morbidity rates for scarlet fever for the same 7 years show that this disease exhibits the same seasonal fluctuations as those of the haemolytic streptococcal carrier rates. From this evidence it seems clear that the early winter rise in the mortality of infants from broncho-pneumonia cannot be due to any rise in the reservoir of infection of haemolytic streptococci. Indeed both sources concur in indicating that throughout the period of rising broncho-pneumonia mortality, the level of the reservoir of infection of this bacterium in the community is steadily falling.

(ii) *Pneumococcal carrier rates.* From the observations made by Straker, Hill & Lovell (see Fig. 1), it seems unlikely that there is any important seasonal fluctuation in the percentage of naso-pharyngeal carriers of pneumococci in their group of London adults. Nor did they find much in the children they examined in large public residential schools. There was, however, a tendency for the carrier rate to be rather lower in the late summer amongst both groups, and this association is borne

Table 4. *Main types of pneumococcus found in the respiratory tracts of infants, under 2 years, suffering from broncho-pneumonia*

Author, place and date		Types of pneumococcus I, II, III	VI	XIV	XIX	Others
Nemir, *et al.* (1936); Chicago (1931–5)	Cases	42	68	125	46	164
	Percentage	10	15	28	10	37
	Deaths	11	20	21	19	—
Bullowa & Greenbaum (1937); New York (1928–34)	Cases	27	34	47	19	89
	Percentage	12	16	22	9	41
	Deaths	6	8	7	3	23
Hendry (1942); Glasgow (1939–40)	Cases	4	18	2	17	56
	Percentage	4	19	2	18	57
	Deaths	1	1	1	1	17

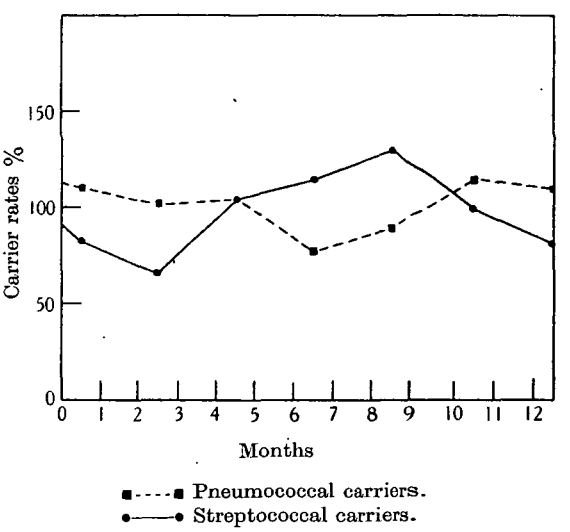

Fig. 1. Carrier rates for pneumococci and haemolytic streptococci in a London group. (Straker, *et. al.* 1939).

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out by a significant negative correlation between the monthly carrier rate and the hours of sunshine, both in the same and in the preceding months. It is significant also that the seasonal variations in the carrier rates applied more or less equally to pneumococci of lower and higher types, so that, whatever might be the respective pathogenic potentialities of these two groups of types, there was nothing to indicate that there were any important differences in their propensities for spreading amongst adults or children at different times of the year.

The associations between certain social conditions and the mortalities of infants from broncho-pneumonia in the Metropolitan Boroughs

There were considerable differences between the mortalities of infants from broncho-pneumonia in the twenty-eight Metropolitan Boroughs in the quinquennium 1929–33. That such local differences in this quinquennium were not fortuitous, is shown by the high values of the coefficients of correlation between the mortalities in that 5-year period and in those immediately preceding and succeeding it (1924–8 and 1929–33, 0·872; 1929–33 and 1934–8, 0·837). It is evident, therefore, that the broncho-pneumonia mortalities in these boroughs, although falling slowly as a whole, are not subject to wide relative variations, but that they reflect some of the continuously operative hygienic characteristics of the areas.

Since the stability of the mortality data thus warranted it, coefficients of correlation were calculated to ascertain how closely broncho-pneumonia was associated with housing and some other indices of economic conditions in these boroughs. The period 1929–33 was chosen because it both centred upon 1931, the year of the last census, and lay close to the middle of the period of collection of much of the data for the *New Survey of London Life and Labour*. During this quinquennium, 6240 deaths from this cause occurred amongst London infants under 2 years, and in only five boroughs were less than 100 such deaths recorded.

The criteria used for the local severity of overcrowding were both the percentage of the population living more than two persons per room, and the average number of persons per room. Because certain boroughs, notably Camberwell, Deptford, Kensington, Paddington, St Marylebone and Westminster have widely differing housing densities in their different wards, an additional coefficient of correlation was calculated using the average number of persons per room in that half of the population that lived in the worst-housed wards of each borough. The effect of using these more restricted populations is to emphasize the less favourable end of the housing-density scale, much in the same way as that which follows the use of the percentage of the population living more than two persons per room (see Hart & Wright, 1939).

Stock's Social Index (the proportion of males aged 14 and over whose occupation places them in the lowest social classes—nos. IV and V; see Census, 1931, Occupation Tables, Part II) and the Proportion of the Population below the Poverty Line, as estimated by the *New Survey of London Life and Labour*, were used as indices of those local economic conditions that might not be fully represented by housing. Such an index of social conditions as infant mortality, which was used by Smith in his Glasgow study, clearly suffers, as he pointed out, from the disadvantage that it is itself greatly dependent upon, and almost certainly highly correlated with, the mortality of infants below the age of 2 years from broncho-pneumonia. In London, during the period 1931–8, more than one-fifth of all recorded deaths in this age group were attributed to this condition.

Table 5. *Coefficients of correlation and regression between mortalities of infants under 2 years from broncho-pneumonia, 1929–33, and certain social conditions in the Metropolitan Boroughs*

Social condition	Coefficient of correlation	Coefficient of regression	Intercept on ordinate	Mean of variable
Housing:				
(1) More than two persons per room	0·751	0·37	5·14	13·89
(2) Persons per room, whole borough	0·653	7·40	2·70	1·02
(3) Persons per room, worst wards	0·777	9·28	−0·50	1·16
Social index	0·741	0·20	3·50	34·32
Incidence below poverty line	0·741	0·34	6·97	9·66
Children per family	0·644	11·22	−11·52	1·91

A further coefficient of correlation was calculated between broncho-pneumonia mortality of infants and the average number of children below 14 years of age for each family of four or more members. Although this variable is closely correlated with both social index (0·859) and sub-standard housing (0·742), it does possess some independent value as a guide to the demands that families of young children impose upon their parents, especially in times of sickness.

The degree of association between the above social conditions and infant mortality from broncho-pneumonia is shown by the coefficients of correlation and regression set out in Table 5. The mean values

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of the independent variables, together with the intercepts of the regression lines upon the ordinate, are also given. The mean value of the dependent variable, broncho-pneumonia, during this quinquennium was 9·91 per 1000 per annum.

It can be seen from the values of these coefficients that sub-standard housing incidence and those economic indices that represent poverty more directly, are all closely associated with the broncho-pneumonia mortality of infants. For housing, the values are not dissimilar to that (0·795) found by Woods (1927) for the twenty-eight Metropolitan Boroughs for the mortalities from 'pneumonia' of children aged 0–5 years in 1921–3 and overcrowding also measured by the percentage of the population living more than two persons per room. Moreover, it is not very different from those obtained by us (1942) between sub-standard housing and the mortalities of London children, aged 0–4 years, from tuberculosis and whooping cough, though less than that for measles. The regression coefficients for the estimates of housing, however, are much smaller than that suggested by Smith's findings for various parts of Glasgow, where the mortality of infants from broncho-pneumonia in certain parts of the city was four to seven times as great as in others. A possible reason for this lesser regression is discussed below.

Since there seemed to be an indication of curvilinear relationship between sub-standard housing and the broncho-pneumonia mortality of infants, the correlation ratio between these two variables was also calculated. Its value, after the application of Pearson's correction, was 0·783, which does not differ significantly from that of the coefficient of correlation. Also by Fisher's test, these two variables show no significant deviation from a rectilinear regression. Nevertheless, the appearance of the spot diagram for the two variables seemed to make a trial of Brownlee's (1924–5) adsorption formula $y = ax^n$ worth while. On trying various values for n, the values of the coefficients of correlation were maximal when n had the value 0·143 ($\frac{1}{7}$th). This value of n is only slightly higher than that found many years ago by Farr (1885*b*) for the closest association between overcrowding and general mortality at all ages, viz. 0·12 ($\frac{1}{8}$th). That the greater severity of the overcrowding in the poorer boroughs is not directly reflected in a proportionately greater mortality of their infants from broncho-pneumonia is hardly surprising. As the personal contacts between individuals become increasingly close, the likelihood of recontamination with bacteria of the same species or type becomes correspondingly greater.

It can be seen from the following table that the coefficients of correlation between broncho-pneumonia mortality and both social index and percentage below the poverty line have considerably larger values than those which we found before (1942) between these two estimates of economic resources and the mortalities of young children from measles and whooping cough.

	Housing	Social index	Poverty line
Broncho-pneumonia	0·751	0·741	0·741
Measles	0·865	0·434	0·469
Whooping cough	0·515	*0·280*	*0·148*

For broncho-pneumonia, the similarity between the coefficients for housing and those for the other economic indices might well imply that inadequate means for the purchase of food, clothing and fuel are of greater consequence in causing deaths in this disease than they are in these two acute specific fevers. This point is of some interest in relation to the association of low external temperature with deaths from broncho-pneumonia (see below).

The influence of seasonal conditions upon the mortality of infants from broncho-pneumonia in the Metropolitan Boroughs

Epidemiologically, the outstanding characteristic of broncho-pneumonia in infants is the remarkably consistent seasonal variation in its incidence as shown by mortality returns. In Fig. 3 are set out the mortalities for each month of the 16 years 1923–39, and from this curve the strikingly cyclical nature of the epidemics can be well seen. Every autumn, usually about the thirty-third week of the calendar year, the mortality begins to rise, and continues to do so until it attains a maximum, some seven times greater than the minimum, about the fifth week of the following year.

The relative amplitude and the time of year of these seasonal fluctuations in mortality in the urban and rural districts surrounding the Administrative County of London are much the same as those in the Metropolitan Boroughs. The proportion of deaths in each quarter from 'pneumonia'—most of which is broncho-pneumonia—for (i) persons of all ages, (ii) infants under 2 years, and (iii) persons over 55 years, in the Metropolitan Boroughs; and for persons of all ages in (iv) the urban, and (v) the rural districts of the Home Counties (Buckinghamshire, Essex, Hertfordshire, Kent and Surrey) are shown in Table 6.

From this table it seems clear that whatever factors are responsible for the seasonal variations in mortality must be operating in much the same manner upon persons of very different ages and living under widely differing hygienic conditions. Long clinical experience with respiratory diseases has impressed upon physicians that accounts of recent exposure to cold are frequently found in the histories of pneumonia patients. Farr (1885*c*), in

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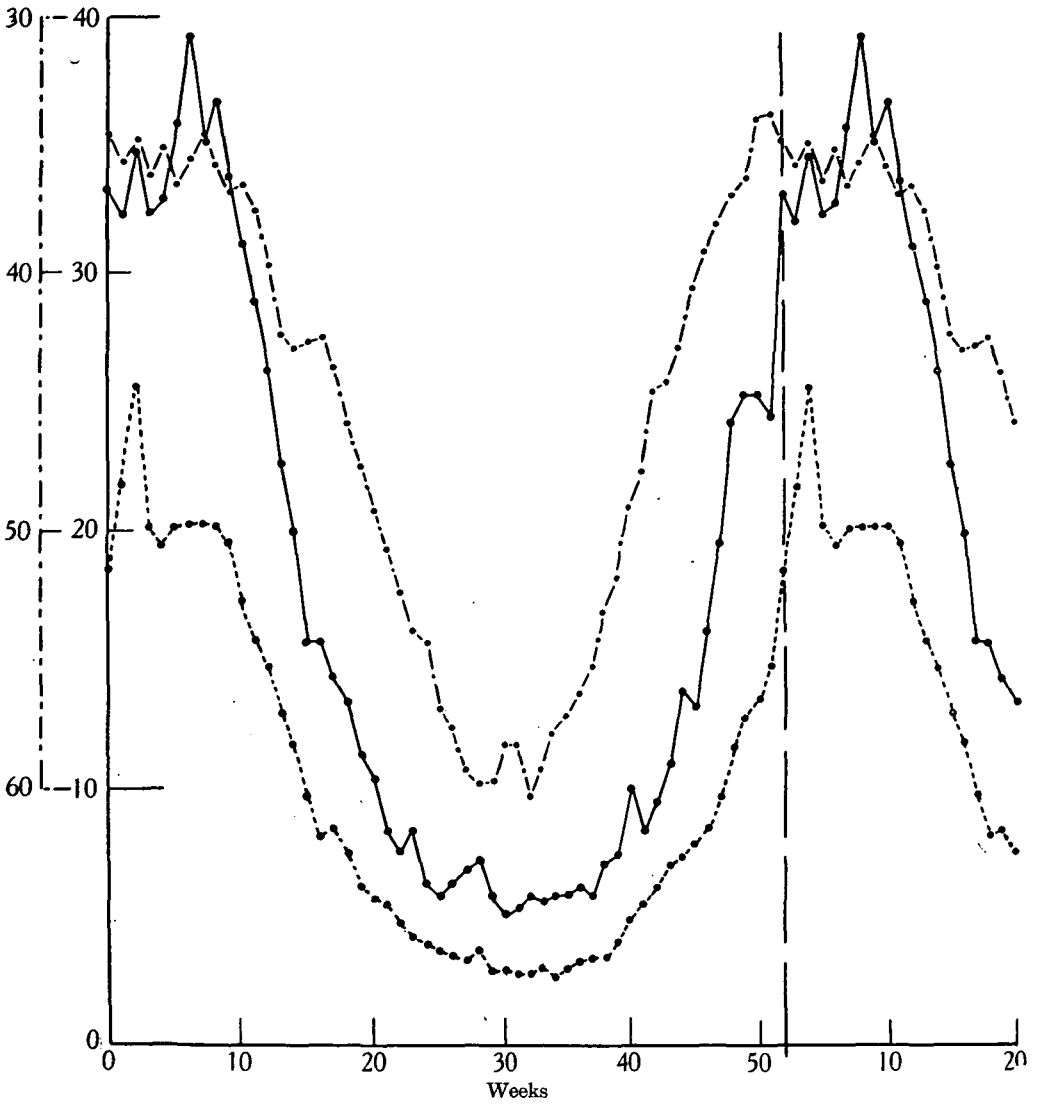

Fig. 2. Weekly averages of mortalities from broncho-pneumonia between 1923–39 of infants under 2 and persons over 55 years, together with mean temperature of coldest day of week. •——• Mortalities per 100,000, infants under 2 years. •----• Mortalities per 100,000, persons over 55 years. •—•—• Temperatures: mean of coldest day in week.

Table 6. *Seasonal mortalities from 'pneumonia' in London and the Home Counties, for various ages, for* 1929–33, *expressed as percentages of that for the entire year*

	Metropolitan Boroughs			Home Counties	
Quarter	All ages	Under 2	Over 55	Urban all ages	Rural all ages
1st	49·4	51·6	56·2	52·2	56·5
2nd	17·6	16·1	15·4	18·8	19·2
3rd	9·2	8·3	7·3	8·8	8·2
4th	23·8	24·0	21·1	20·2	16·1

a discussion upon the value of weekly bills of mortality, recalls Heberden's (1796) notable paper on the 'Influence of cold upon health', which was based upon the two exceptionally contrasting winters of 1795 and 1796. It is not surprising, therefore, that the etiological factors common to persons of such widely diverse types as those included in the above table, should be sought in meteorological conditions, and more particularly in variations in external temperature.

The most complete study of the effects of various

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weather conditions upon the mortalities of London children from bronchitis, pneumonia and both conditions combined, has been made by Young (1924). For the colder halves of the years between 1876 and 1919, he calculated for all the 45 first weeks, all the 45 second weeks, etc., *seriatim*, the coefficients of correlation between the mortalities of children under 5 years from these diseases and the mean weekly temperature, the relative humidity and the recorded rainfall. From the averages of the coefficients for these 'time-series', he concluded that these diseases were most closely associated with temperature. For bronchitis, which had much the higher death-rate of the two diseases, the average values of the coefficients for the 26 winter weeks were: mortality with mean temperature of the *same week*, $-0{\cdot}218$; for 1 *week before*, $-0{\cdot}327$; for 2 weeks before, $-0{\cdot}263$. (The greater values of the coefficients of correlation between temperature and these respiratory conditions when a lag of one or more weeks has been allowed, has been noted by several authors (Russell, 1924, 1926; Huntington, 1924; Greenwood, see Woods, 1928).) The associations of the mortalities from bronchitis and pneumonia with relative humidity and recorded rainfall were all less strong than those with mean temperature.

The risks involved in drawing inferences from coefficients of correlation calculated for 'time-series' are now well recognized (see Yule & Kendall, 1940), and it is possible that the relatively low numerical values that Young found for these coefficients were due at least in part to the fact that no allowance had been made for the trends of bronchitis and broncho-pneumonia mortalities in children over this long period, either by the method devised by Hooker (1905, 1907), or by that of excluding 'time' by the use of partial correlation as has been recommended by Fisher (1941).

In the present study the degree of association between low external temperature and high broncho-pneumonia mortality amongst infants has been examined in a different way. For the 16 years that it covers, the average 'daily mean temperature' for the coldest day of each week has been calculated from Greenwich observations. The choice of data for the coldest day of each week, instead of the more usual mean for the entire week, receives a certain sanction from the clinical belief that even a short period of exposure may precipitate acute respiratory diseases, especially those forms due to infection with pneumococci. For each week of the period, the mean broncho-pneumonia mortality of infants under 2 years (and of persons over 55 years) has been calculated. The results can be seen in Fig. 2. The values of the coefficients of correlation between the two series of mortalities and the temperatures of the same and various preceding weeks, both for the whole year and for the coldest 26 weeks, are set out in the following table:

	Infants under 2		Persons over 55	
Temperature	Whole year	26 coldest weeks	Whole year	26 coldest weeks
Same week	$-0{\cdot}896$	$-0{\cdot}780$	$-0{\cdot}869$	$-0{\cdot}699$
One week before	$-0{\cdot}909$	$-0{\cdot}879$	$-0{\cdot}902$	$-0{\cdot}858$
Two weeks before	$-0{\cdot}910$	$-0{\cdot}919$	$-0{\cdot}910$	$-0{\cdot}937$
Three weeks before	$-0{\cdot}893$	$-0{\cdot}878$	$-0{\cdot}902$	$-0{\cdot}940$
Four weeks before	$-0{\cdot}867$	$-0{\cdot}835$	$-0{\cdot}878$	$-0{\cdot}885$
Five weeks before	$-0{\cdot}830$	$-0{\cdot}790$	$-0{\cdot}846$	$-0{\cdot}810$

The values of the coefficients pass smoothly through maxima such that, were the necessary data available, the closest association would probably be found between the weekly mortality of the infants and the temperature some 12–14 days earlier. In this respect, the present results are in reasonably close agreement with those found by Young.

The existence of such high values for the coefficients of correlation between temperature and mortality from broncho-pneumonia does not of itself suffice for the demonstration of the influence of the former upon the latter, for, quite apart from the limitations inherent in the method of correlation as an instrument of logical induction, the influence of other seasonal variables of the kinds discussed by Worringer (1928) and Madsen (1930) are not excluded. But taken in conjunction with the results obtained by Young's modification of Greenwood's method, which has many of the advantages of the method of partial correlation in which the operation of other independent variables is excluded, the present findings strengthen the evidence that short spells of low temperature greatly raise the incidence in broncho-pneumonia in infants. In this connexion it may also be of some significance that the mortality of elderly persons over 55 years from broncho-pneumonia is also closely associated with temperature as recorded in this way, and that these coefficients pass through a maximum slightly later than that of the infants.

In spite of the high values of the coefficients of correlation between broncho-pneumonia mortality and temperature, both for infants under 2 years and for persons over 55 years, it is evident from the curves shown in Fig. 4 that the relationships are not strictly rectilinear. This is borne out by the application of Fisher's test for the straightness of regression lines both to the data for the whole year and to that for the first 32 weeks of the epidemic year during which the mortalities are steadily rising. This twofold test was made because, with both age groups, the mortalities from broncho-pneumonia at any particular temperature tend to be rather lower in the later than in the earlier part of the winter. These lower values are probably due partly to

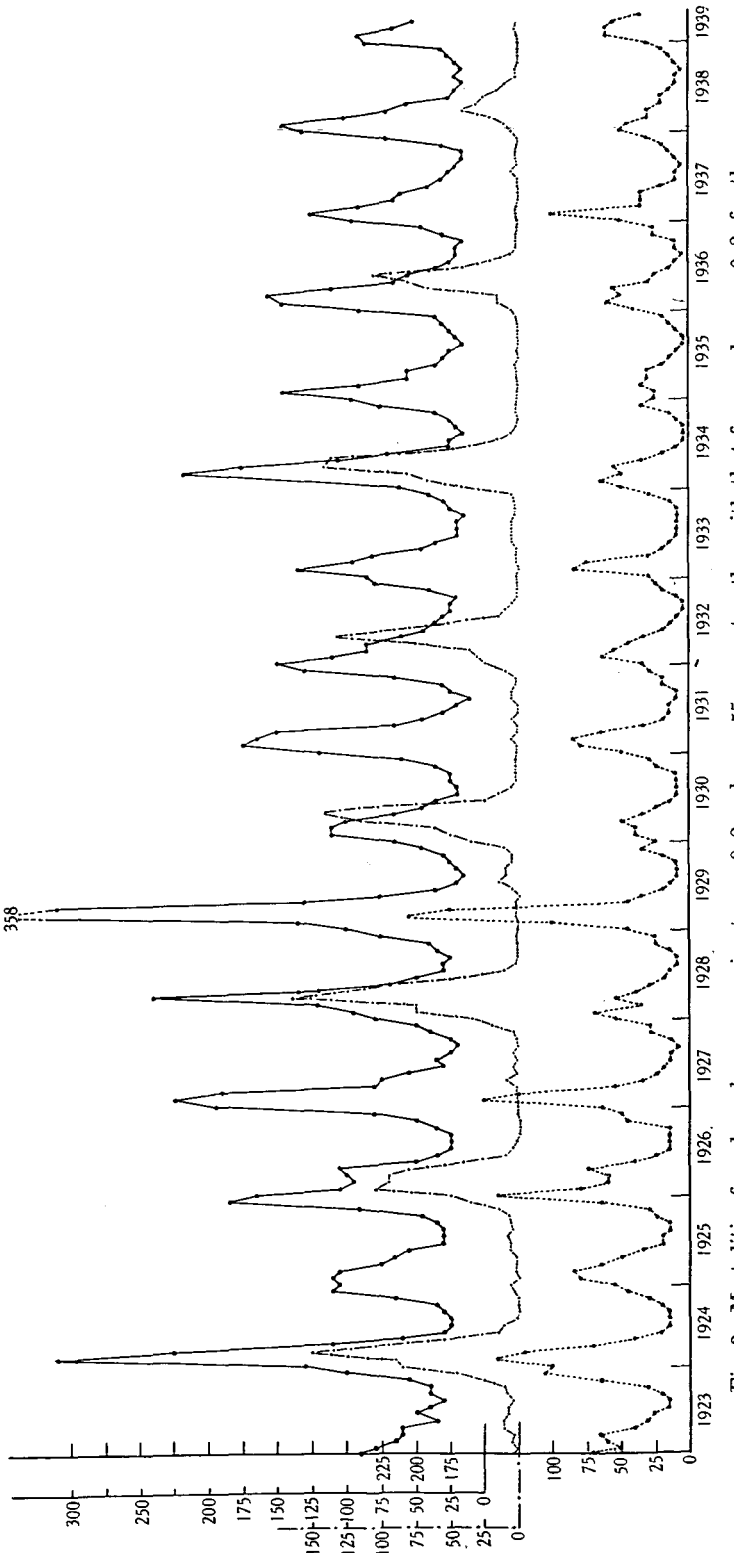

Fig. 3. Mortalities from broncho-pneumonia at ages 0–2 and over 55 years, together with that for measles, age 0–2, for the Administrative County of London, 1923–39.

●——● Mortality per 100,000, infants under 2 years [4-weekly figures]. ●----● Mortality per 100,000, persons over 55 years [4-weekly figures].
●—●—● Mortality per 100,000, measles. Infants under 2 years [4 weekly figures].

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acclimatization and partly to the elimination in the earlier part of the epidemic year of those members of both groups that are most susceptible to this disease, so that the inclusion of data for the decrescent part of the epidemic would tend, perhaps unfairly, to exaggerate the curvature of the regression line. This difference between early and late winter mortalities is rather less marked for infants than for elderly persons, possibly because, as the succumb from it during the period for which the data are collected.

For both age groups, the mortality from broncho-pneumonia rises disproportionately to the fall in temperature. Both curves in Fig. 4, however, appear to be smooth, and both when plotted upon a double logarithmic scale approximate reasonably to straight lines. They may thus be expressed by the formula $y^n = k(a-t)$, where y is the mortality, t is the tem-

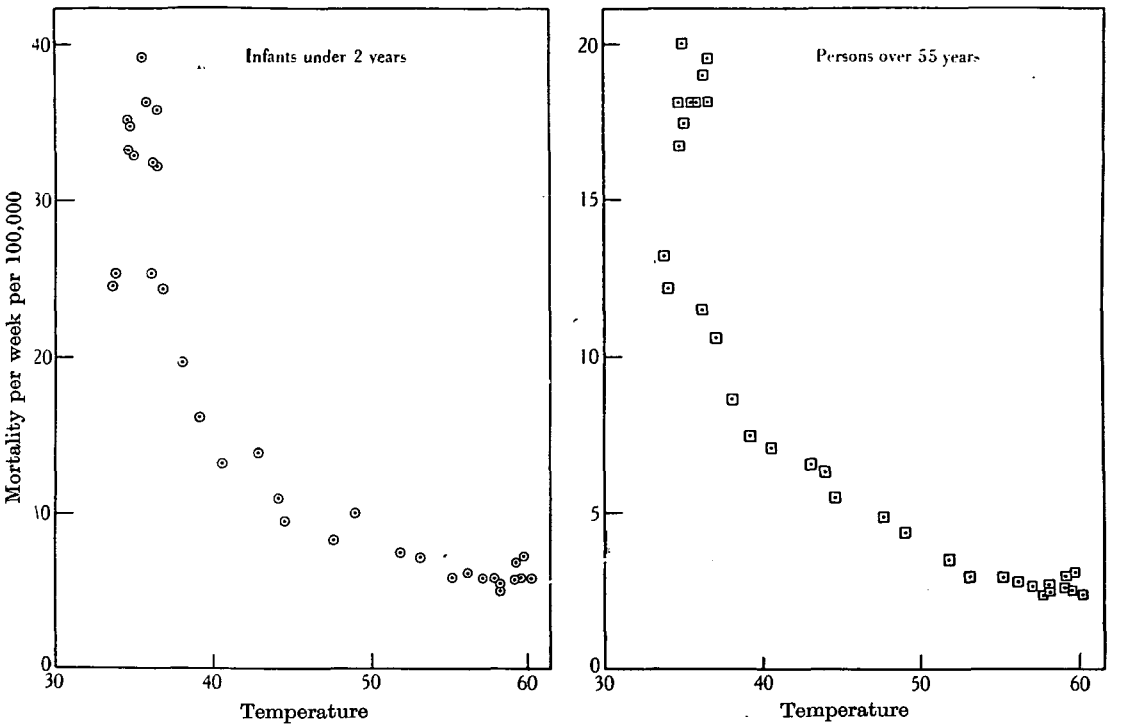

Fig. 4. Mortalities of infants under 2 years and persons over 55 years from broncho-pneumonia at various temperatures in autumn and winter weeks.

epidemic year advances, this age group is being continually recruited with relatively susceptible newly born infants who contribute disproportionately greatly to the average mortality of the group as a whole.* On the other hand, the additions to the older group are persons of 55 years who are still relatively resistant to this disease and unlikely to

perature, n is a constant of fractional value, and k and a are constants.

For immediate purposes, three points emerge from these correlations. (i) The mortalities from broncho-pneumonia, both of infants and of elderly persons, rise rapidly when the mean daily temperature for the coldest day of the week falls below 40° F. (ii) A close association exists between the mortalities of infants and of elderly persons from this disease: the coefficient of correlation between the weekly death-rates for the two groups for the period of 16 years had the value 0·821. (iii) The fact that the mortalities of both groups from broncho-pneumonia at any particular low temperature tend to be less in the later than in the earlier part of the epidemic wave, does not support

* Between 1931 and 1935, the average monthly mortalities per 1000 live births from broncho-pneumonia at various ages in early infancy in Greater London were: 0–3 months, 1·21; 3–6 months, 0·99; 6–9 months, 0·76; 9–12 months, 0·66. Were these proportions to hold also for the Administrative County of London, the mortalities at various ages there would be: 0–3 months, 2·12; 3–6 months, 1·74; 6–9 months, 1·33; 9–12 months, 1·16; 12–24 months, 0·49.

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the view that a progressive depletion of the body of protective nutrient substances, acquired under more favourable summer conditions, renders the subject increasingly susceptible to this disease as the winter advances.

DISCUSSION

For the Administrative County of London, the fullness of the available statistical material allows the problem of broncho-pneumonia in infancy to be examined from two distinct aspects. The first relates to those factors that are responsible for the differences in the secular mortalities that exist in the twenty-eight constituent Metropolitan Boroughs. The second concerns the causation of the remarkably constant winter exacerbations in mortality which are recorded for the area as a whole, and which would undoubtedly be found to occur also in each of the boroughs were the necessary data available. These two problems are distinct—both theoretically and practically—a point which has not always been made clear in earlier discussions in which attempts have been made to distinguish the relative importance of social and meteorological conditions in the etiology of this disease.

1. *Social factors associated with the different secular mortalities found in the individual Metropolitan Boroughs*

The close association between overcrowding and excessive mortalities from the commoner respiratory diseases has long been recognized. Broncho-pneumonia in infancy is no exception to this general experience, for a strong correlation exists between housing conditions, even when assessed in several ways, and the mortalities from this disease in the twenty-eight boroughs. How far this association is directly ascribable to the closer physical proximity of persons in overcrowded areas, and how far it is indirectly dependent upon the almost invariable association of overcrowding with poverty, is never easily determined. With broncho-pneumonia, however, in which the causative organisms are both relatively resistant to exposure (see Wells & Stone, 1934), and very widely distributed throughout the year in the noses and throats of healthy persons, there seems to be no reason to hesitate to accept the simpler interpretation that overcrowding contributes by allowing greater opportunities for the spread of these organisms. At the same time, the closely similar numerical values of the coefficients of correlation between broncho-pneumonia mortality in infants and each of the three independent variables, housing (0·751), social index (0·741) and the percentage below the poverty line (0·741), give a less clear indication of the primary importance of overcrowding in this explicit sense than that which we formerly found for measles and whooping-cough mortalities in London children.

Even though there is a strong correlation between sub-standard housing incidence and broncho-pneumonia mortality in London, the present observations provide little ground for the expectation that any readily attainable improvement in metropolitan housing could bring about a great reduction in the mortality of infants from this disease. On the justifiable assumption that the incidence of sub-standard housing and of broncho-pneumonia in the Metropolitan Boroughs can be represented by a rectilinear regression line, it becomes possible to predict the fall in mortality for the Administrative County as a whole that would be likely to follow if the mean level of sub-standard housing incidence throughout the area were to improve until it had attained to that now existing in the six best-housed boroughs. Instead of the mean mortality for all twenty-eight boroughs being 9·91, as in the years 1929–33, it would be 6·80 per 1000 infants. Thus, although the coefficient of correlation is large, that of regression, which in this case forms the best guide to the amelioration that can be expected from improvements in housing, is relatively small. In this respect, therefore, the problem of effecting improvements in the broncho-pneumonia mortality of infants in London seems to differ from that in Glasgow (see Smith, 1928).

The relatively low value of the coefficient of regression of mortality on overcrowding was rather unexpected, but there seems to be several reasons which might account for it. The seasonal incidence of broncho-pneumonia mortality is associated with external temperature in such a way that when the mean of the coldest day of the week falls below about 40° F., the mortality rises disproportionately sharply. A fall of 2° F. in this lower range is accompanied by a striking increase in mortality. In reaching these conclusions, the meteorological data used were those recorded at Greenwich, but from the less complete monthly records compiled by the Meteorological Office from observations made at various London stations, it is evident that variations in temperature are found in different parts of the metropolitan area which are likely to have highly significant effects upon their broncho-pneumonia mortalities. Broadly, for no refined treatment can be applied to these data, it can be stated that the minimum temperatures in the central and more densely populated parts of London do not fall as low as those in the periphery. Probably the most important reason for this radiating temperature gradient is that London lies in a large shallow basin, and most of the outer parts of the Administrative County lie at higher elevations than

the older more centrally situated boroughs. Less important, but still significant, factors which moderate the winter fall in temperature in the more congested districts are the large proportion of the ground surface in such areas which are drained, and the local consumption of fuel in factories and houses. The slope of the housing-mortality regression line is therefore determined by two conflicting factors—the ill-effects of overcrowding and its accompanying evils, and the beneficial effects of the less rigorous temperature conditions that in part result from it.

2. *Factors associated with the seasonal exacerbation in mortality in the administrative county as a whole*

Disturbances in the balance between host and parasite that initiate an epidemic of infectious disease may arise: (i) from circumstances that lead to a numerical expansion of the parasite population in close contact with that of the host, or to the natural selection of certain varieties of the parasite to which the host is less well adapted; (ii) from changes in external conditions that suddenly facilitate the transmission of parasites to new hosts, so that large numbers of susceptibles amongst the latter become exposed to infection in quick succession; and (iii) from a deterioration in the effectiveness of those physiological adaptations to this communal life that collectively comprise the resistance of the host, so that the parasite, without any initial increase in numbers or virulence, is thus given greater opportunities for displaying its latent pathogenic powers. Such a deterioration in the host's defences may affect all its tissues indiscriminately, or it may be limited to that portal of entry through which the particular parasite usually begins its invasion. Our present task is to assess the relative importance of these sources of disequilibrium in the genesis of the seasonal epidemics of broncho-pneumonia in London infants.

(*a*) *Seasonal changes in infection potential.* Although the haemolytic streptococcus and the pneumococcus are nearly related bacteria, there appears to be a definite ecological difference between them. The carrier rate for the former organism, which is the less common but the more lethal cause of broncho-pneumonia in infants, attains its maximum in the early autumn. It also shows seasonal variations in prevalence which are less in amplitude than, and occur at different times of the year from, those of the disease. The carrier rate for pneumococci shows wider seasonal fluctuations than does that for the streptococcus as judged by the London School of Hygiene survey. But even these fluctuations in the pneumococcal carrier rate, although more closely coincident with those of broncho-pneumonia, are much smaller than the seasonal variations in mortality from this disease amongst London infants.

Since infants form a segregated part of the population, variations in their carrier rates for these bacteria may or may not rapidly reflect those observed in older children and adults. Probably the best guide on this point is the time needed for the flora of the nasopharynx of newly born infants to come to resemble that of adults. The most complete study of this rate of transference was made by Gundel & Schwarz (1931) in Heidelberg: within 14 days of birth the species recovered from the noses and throats of newly born infants and their mothers had become closely similar, even to the types of pneumococcus present in both. A similar series, studied by Kneeland (1930) in New York, showed that after 2 weeks the infants had acquired a nasal flora comparable to that of adults, except that potential pathogens were absent. During the ensuing months potential pathogens were found to appear without giving rise to symptoms, and by 8 months the nasopharyngeal flora of the infants closely resembled that of their adult contacts. From these observations, it seems unlikely that any serious barrier tends to dissociate infants from those seasonal fluctuations in carrier rates that have been found in older children and adults. It seems improbable, therefore, that the sharp winter epidemics of broncho-pneumonia, both in infants and elderly persons, can be accounted for adequately by a rise in the carrier rate for these organisms, first in the community generally, and secondly in the two age groups themselves.

There is little evidence concerning any seasonal variations in the virulence of pneumococci and streptococci. Powell, Atwater & Felton (1926), studying pneumococcal infections amongst schoolboys, students and nurses in Boston, carried out virulence tests on more than 200 strains of pneumococci. For seven consecutive months, the virulence of each newly isolated strain was estimated: those recovered during December had the highest, and those during January the lowest virulence. In no month did the virulence differ at all considerably from the mean. Although the evidence is slender, it seems sufficient to make it unlikely that the winter rise in mortality from broncho-pneumonia in London can be ascribed to an exaltation in the virulence of pneumococci. That there is no seasonal variation in the virulence of staphylococci and haemolytic streptococci seems likely from the steady uniformity of the quarterly returns of deaths from various diseases caused by these two organisms (see below).

From the available information it seems likely that during the winter there is some rise in the infection potential of these organisms—most notably for the pneumococcus—but its extent seems quite incommensurate with that in the mortality of both infants and elderly persons from broncho-pneumonia.

(*b*) *Seasonal changes in host susceptibility.* Adverse seasonal conditions may depress the resistance of the host to infection either by causing a general deterioration in humoral and cellular immunological reactions, or by impairing the efficiency of the defence mechanism at some particular portal of entry. As yet comparatively little is known about this obscure region between general pathology and epidemiology.

Various authors (see Madsen, 1930) have suggested that part of the winter rise in mortality from respiratory diseases may be due to a decline in non-specific resistance that is assumed to result from the less abundant nutrition and insolation characteristic of the colder and darker months. Not unnaturally, such views have appealed particularly to Scandinavian workers living in high northern latitudes. Even in controlled animal experiments, however, it is difficult to recognize such periodic changes in host-parasite relationships (for a discussion on fluctuating immunity, see Wilson, 1930). In man, the problem can be approached indirectly by ascertaining, by their time of occurrence, the number of deaths from certain acute diseases which are chiefly caused by infection with staphylococci, streptococci or pneumococci. The average numbers of deaths which took place quarterly between 1929 and 1933 in England and Wales from four such diseases are shown in the following table:

	Quarters of year			
	1st	2nd	3rd	4th
Acute infective endocarditis	256	268	266	279
Puerperal sepsis	342	311	252	273
Carbuncle	134	128	135	140
Osteomyelitis	121	126	119	123
Total	853	833	772	815

Since the clinical courses of these diseases is usually brief, these data show that there is little seasonal variation in the mortality from, and thus presumably in the resistance offered to, acute infections with staphylococci and streptococci. It seems hardly credible that the wide seasonal variations in broncho-pneumonia mortality, both of infants and elderly persons, could be attributable to factors that have so little influence upon these four diseases.

There is now considerable evidence to support the clinical-statistical inference discussed above, that exposure to low temperatures has a detrimental effect upon the local defence mechanisms of the respiratory tract. In the course of repeating Lieber's (1931) work, Rosher (1939) studied the seasonal fluctuations in the frequency with which *Haem. influenzae* can be recovered at post mortem from the lower parts of the trachea and main bronchi of persons dying without gross evidence of respiratory disease. He concluded that, while the naso-pharyngeal carrier rate for this organism in town dwellers remains at a steady level of 60–65% irrespective of season, considerable fluctuations take place in the frequency of its occurrence in the trachea and bronchi. In the summer, it appears to be confined mainly to the nasopharynx, but in late winter and early spring it tends to spread downwards into the lower respiratory tract.

Cralley (1942) has experimented upon the rapidity with which rabbits, subjected to various changes of temperature, dispose of inhaled bacteria. He found that the conditions that were most detrimental to the freeing of the respiratory tract from such bacteria were the combination of a high temperature with low relative humidity before infection and a low temperature with high relative humidity afterwards. Such a combination recurs often during the winter in the life of any town dweller. Possible reasons for the occurrence of this lessened local resistance are suggested by the observations of Mudd, Goldman & Grant (1921) and of Nedzel (1935) upon the fall in the temperature of the respiratory mucosa that results from chilling of the body, and Nungester & Klepser (1938) have demonstrated a possible mechanism by which exposure to cold might lead to respiratory infections and pneumonia.

Their incompletely developed control of body temperature renders infants particularly vulnerable to adverse conditions, and it seems probable that any chilling of their bodies would lower the efficiency of the defence mechanisms of their respiratory tracts. Under these circumstances, bacteria that are normal inhabitants of the nasopharynx progressively extend their areas of colonization until they gain access to the smaller bronchi and bronchioles and there set up foci of broncho-pneumonia.

The control of broncho-pneumonia mortality in infants

The heavy death role of infants from primary broncho-pneumonia deserves the close attention of the public health authorities, and in this concluding section some observations will be made upon various counter measures that might profitably be taken to lessen it (for further discussion, see Cruickshank, 1942).

Little can be done to prevent the disease by the use of specific prophylactics. The varieties of bacteria responsible are too numerous, and their distribution in the community too widespread, for any active immunization measures to be practicable even if they were possible. Of various non-specific measures, it is almost certain that progressive improvements

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in social conditions, and particularly in housing, will steadily promote a further fall in the incidence of the disease. In the immediate future, however, the same objective might be more expeditiously attained by appropriate educative measures directed towards the better protection of infants against chilling and exposure. Such procedures would supplement those that have been so successfully employed to improve the standards of infant nutrition. The physiological reactions underlying the susceptibility of infants to cold, together with the kindred problem of designing clothing to guard against its effects, are important questions in infant hygiene that require investigation.

Reduction in the mortality of infants from broncho-pneumonia depends mainly on the more effective treatment of patients. The importance of proper nursing in suitable surroundings has long been recognized, but recently these simpler resources have been greatly fortified by chemo- and oxygen-therapy. To take full advantage of these revolutionary advances, it is essential to have the patients in institutions under continuous observation by persons possessing modern equipment and proper training in its use. Moreover, the likelihood of success in treating pneumonia is largely determined by promptness or delay in its commencement. Were certain hospitals to possess trained personnel specializing in the care of pneumonia on modern lines, and were practitioners encouraged to co-operate by sending patients promptly to hospitals possessing such experienced medical teams, the present mortality might be much reduced.

From the administrative standpoint, the predictability of the times of high morbidity from broncho-pneumonia considerably simplifies the problem of preparing to meet impending epidemics. To this extent, the task is simpler than that of providing arrangements for the treatment of infectious diseases whose epidemics take place at much less regular intervals.

SUMMARY AND CONCLUSIONS

1. In the period 1923–39, more than one-fifth of all deaths in the age group 0–2 years in the Administrative County of London are recorded as having been caused by bronchitis or broncho-pneumonia. It is very unlikely that the returns have been exaggerated by more than 10–15% through the inclusion of deaths from secondary broncho-pneumonia following measles, whooping cough or influenza. In the 8 years in which measles epidemics occurred, the peak of the measles mortality was from 2 to 17 weeks after, and never before, that of the mortality from broncho-pneumonia.

2. The winter rise in mortality from broncho-pneumonia is not associated with any comparable increase in the carrier rates for pneumococci and haemolytic streptococci.

3. The broncho-pneumonia mortality of infants in the Metropolitan Boroughs is strongly correlated with sub-standard housing incidence, social index and percentage below the poverty line. The relatively small value found for the coefficient of regression between broncho-pneumonia mortality and sub-standard housing may be due to the less rigorous winter temperatures occurring in the more overcrowded central areas.

4. Low external temperature appears to be the most important predisposing cause of fatal broncho-pneumonia in infants; their weekly death-rate from this disease in mid-winter is about seven times that in the late summer. This great seasonal fluctuation in mortality is also found for persons over 55 years in the Administrative County, and for persons of all ages in both the urban and rural districts of the Home Counties.

5. The weekly mortalities of infants from broncho-pneumonia in the Administrative County are most strongly correlated with low temperatures 2 weeks earlier. The two variables are so associated that the mortality rises sharply when the mean temperature of the coldest day of the week falls below 40° F. There is no indication that low temperatures in the spring are associated with higher death-rates from broncho-pneumonia than the same temperatures in the autumn, so that the data provide no support for the supposition that susceptibility increases during the winter in consequence of the progressive depletion in the body of protective nutrient substances.

6. Possible measures to reduce the mortality of infants from broncho-pneumonia are discussed.

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