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THE INFLUENCE OF SOCIAL CONDITIONS UPON DIPHTHERIA, MEASLES, TUBERCULOSIS AND WHOOPING COUGH IN EARLY CHILDHOOD IN LONDON

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(With 1 Figure in the Text)

Before the war diphtheria, measles, tuberculosis and whooping cough were the most important of the better-defined causes of death amongst young children in the London area. The large numbers of deaths registered from these four diseases in the age group 0–4 years in the Metropolitan Boroughs alone between 1931 and 1938, together with the deaths recorded under bronchitis and pneumonia, are set out in Table 1. These records

Table 1. *Deaths from diphtheria, measles, tuberculosis (all forms), whooping cough, bronchitis and pneumonia amongst children,* 0–4 *years, in the Metropolitan Boroughs from* 1931 *to* 1938

Year	Diphtheria	Measles	Tuberculosis	Whooping cough	Bronchitis	Pneumonia
1931	148	109	184	301	195	1394
1932	169	760	207	337	164	1009
1933	163	88	150	313	101	833
1934	232	783	136	277	167	1192
1935	125	17	108	161	119	726
1936	113	539	122	267	147	918
1937	107	21	100	237	122	827
1938	90	217	118	101	109	719

for diphtheria, measles, tuberculosis and whooping cough fail, however, to show all the deaths that should properly be ascribed to these specific diseases. For the most part, the figures represent the deaths occurring during their more acute stages, and necessarily omit some of the many instances in which these infections, after giving rise to chronic disabilities, terminate fatally from some less well-specified cause. Moreover, statistical evidence indicates that many deaths that should be attributed to these specific diseases, notably to measles, are now concealed under some sequela such as bronchitis, pneumonia or other anatomical, non-etiological, category of registration. In Glasgow, Smith (1927–8) found that 'when measles or whooping cough is characterized by an unusually high mortality, pneumonia mortality is also invariably increased. The measles winter epidemic in 1921–2, by far the most severe in the period reviewed, is accompanied by the highest mortality from pneumonia in the years considered. Similarly, when epidemics of measles and whooping cough occurred together as they did in the winter of 1923–4, the mortality from pneumonia reached its second highest point.' From Table 1 it can be seen that, in the London area also, oscillations in the bronchitis and pneumonia rates coincide with those in the measles rate. A redistribution of the large number of deaths at present classified anatomically under bronchitis, pneumonia and enteritis, into categories defined etiologically, would undoubtedly add to the sinister reputation of these four specific

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diseases. The public health problem they present is, therefore, greater than the above-tabulated specific figures would seem to show.

When the distribution of each of these four specific diseases in various parts of London is examined separately, it can be seen that their incidence differs considerably from one borough to another. These variations provide a means for analysing the factors affecting local endemic prevalence by determining how far conditions, which on other grounds might be expected to possess some predisposing influence, exhibit concomitantly varying local differences. The limitations surrounding this method of induction are now well recognized, but on the principle that no two phenomena can be causally related which vary independently, it at least eliminates non-correlating variables from any part in their causation. More positively also, the method may be used to test deductively the general applicability of hypotheses based upon field observations, by finding how far inferences made from relatively restricted evidence are supported by statistical findings from larger sources of data.

In the present investigation, variations in the secular prevalence of diphtheria, measles, tuberculosis (all forms) and whooping cough amongst young children in the London Boroughs since 1924 are examined in relation to the widely different standards of their social conditions. In it an attempt is made to analyse more particularly the extent to which these conditions affect the factors of transmissibility and non-specific resistance in the population at risk, and thus operate as contributory causes determining the secular prevalence of these diseases.

The endemicity of diphtheria, measles, tuberculosis and whooping cough in London Boroughs

Before examining the degree of association between particular social conditions and these specific infections, some estimate is needed of the reliability with which averages made from yearly morbidity or mortality data, grouped in arbitrarily selected periods, represent the local endemic incidences of these diseases. Local epidemics, especially if they occur in different boroughs in different years,* are the main source of aberrations, and the distortions they may introduce can only be minimized by the use of data averaged for a period of some years. The choice of the length of such a period presents a dilemma. Long periods tend to give more consistent representative data for epidemic prevalence, but may result in secular trends being more easily overlooked, while short periods may lead to just those distortions by migrating epidemics which it is hoped to avoid. Attention must also be paid to the periodicity of some of the infectious diseases of children.

The number of years to be included in such a period is usually decided somewhat arbitrarily. It is sometimes determined by the time needed for a particular number of cases or deaths (generally twenty) to occur in each of the smaller population units. More often in statistical studies on the commoner diseases, 5-year averages are used, though adequate consideration is seldom given to possible shortcomings in this widely adopted practice. It is important, however, to find out how satisfactorily such quinquennial averages serve the purpose, for no attempt should be made to investigate associations

* According to Newsholme (1898), diphtheria epidemics may take several years to complete their spread over the enormous area of London. This slow migration was observed in the epidemic that took place shortly after the last war. Measles epidemics, on the other hand, are estimated to take only 6–7 months for their spread throughout the Metropolitan area (see L.C.C. Measles Report (1933) on the epidemic of 1931–2).

between relatively stable social conditions and the endemic incidence of a disease unless the degree of confidence that can be placed in the latter data is properly appreciated. Since the purpose of using averages is to damp down epidemic oscillations and so produce representative data for each borough, an estimate of success is provided by the value of the coefficient of correlation between the data for successive 5-year periods. The greater the value of such a coefficient, the more satisfactorily do the quinquennial averages represent the endemic incidence of the disease in the areas concerned. Such coefficients for diphtheria, measles, tuberculosis (all forms) and whooping cough mortalities for both sexes combined for the age group 0–4 years, and for diphtheria and tuberculosis (all forms) for persons of all ages, for the quinquennia 1924–8, 1929–33 and 1934–8 in the London Boroughs* are set out in Table 2. From the variations in the values of the

Table 2. *Coefficients of correlation between the mortalities from diphtheria, measles, tuberculosis (all forms) and whooping cough, both sexes combined, for the quinquennia* 1924–8, 1929–33 *and* 1934–8 *in the London Boroughs*†

Quinquennia	Diphtheria All ages	Diphtheria 0–4	Measles 0–4	Tuberculosis All ages	Tuberculosis 0–4	Whooping cough 0–4
1924–8 and 1929–33	0·514	*0·323*	0·736	0·900	0·393	0·570
1929–33 and 1934–8	0·565	0·585	0·698	0·925	0·459	0·586
1924–8 and 1934–8	*0·349*	*0·054*	0·481	0·875	0·426	0·528

coefficients it can be seen that there are wide differences in the degrees of confidence that can be placed in these quinquennial averages as representing the endemic incidences of these diseases. Tuberculosis (all forms at all ages) shows, as perhaps might be expected, remarkably high coefficients; tuberculosis (all forms in the age group 0–4 years), on the other hand, is much lower—a difference that may be due to the far fewer deaths in this subgroup. From the comparatively high and uniform value of its coefficients, it seems that whooping cough can be satisfactorily represented by quinquennial averages. For measles, the coefficients are high for the consecutive quinquennia, but that for the two separated ones, though still significant, is substantially lower—a fall which might indicate a divergency in the secular trends of this disease in the different boroughs. For diphtheria, the coefficients are on the whole lower than for the others. Those at all ages are generally higher than those at 0–4—a finding which again may be due to the larger numbers used to calculate the former rates. In this connexion it may be noted that of the diseases considered, diphtheria alone has been attacked in the London Boroughs in the past 20 years by prophylactic immunization schemes. It is possible, though unlikely, from the small proportions immunized (see Sorsby, 1938), that such local schemes have affected the endemic levels that would otherwise have been found.

For the main purpose of drawing inferences upon etiology from comparisons with certain social conditions, it seems that quinquennial averages of mortalities from whooping cough and tuberculosis can be used satisfactorily, those for measles fairly confidently, while those for diphtheria require greater caution. For all four diseases it is advisable to keep a general check on the results obtained with quinquennial averages by using averages based on the whole 15-year period as a single unit.

* The term 'London Boroughs' is used to comprise the twenty-eight Metropolitan Boroughs in the County of London, and the two County Boroughs of East Ham and West Ham in the County of Essex.

† In this and later tables those coefficients less than $2/\sqrt{n}$ are italicized.

Social conditions in the London Boroughs

Data for social conditions in London have been obtained from two sources: the census for 1931 and the *New Survey of London Life and Labour*, carried out between 1929 and 1931. Since these data were collected in very different ways, it is necessary to determine how far they substantiate one another before selecting those that seem to be of particular significance in the present problem.

(*a*) *Housing.* The census questionnaire returnable by all householders made specific inquiry as to the number of rooms and the number of persons accommodated, and from this a substandard housing estimate, expressed as the percentage of the population living more than two persons per room, was made for each borough. The *New Survey* estimates were based on inquiries carefully distributed to about 500 families in each borough, and recorded in a form rather different from that of the census, since they were intended primarily for comparison with Charles Booth's survey of London in 1891. This standard, based on the percentage of the population living with two or more persons per room, has naturally resulted in all the *New Survey* figures being higher than those of the census*: in some boroughs only slightly so, but in others more than three times as high. This wide variation in the ratios between the two estimates is largely due to the fact that in the *New Survey* 'the main purpose of the enquiry was to study the relative amount of actual poverty and sufficiency in wage-earning households', so that the higher standards prevailing in the middle-class residential areas tended to be disregarded.

The averages of the two estimates made for all thirty boroughs were: census, 13·9%; *New Survey*, 28·6%. The coefficient of correlation between the two had the moderately high value of 0·769. Since this was smaller than it should have been had both sets of data adequately surveyed the same social condition, it was necessary to adopt one or other for comparison with the disease statistics. Since the census data had been obtained for all the private families living within the boroughs, rather than for samples only, they seemed preferable for the present purpose.

(*b*) *Economic resources.* Recent census occupation tables, accompanied by a simple form of social grading, has made possible the calculation of a 'Social Index' figure for each borough. This index, devised and named by Stocks, is based on the proportion of the male working population in the lower-paid occupations. It thus provides a valuable estimate of the mean economic status of the population in each borough. Amongst the London Boroughs, for which it was calculated by Hart & Wright (1939), it varied from 155 per thousand in Hampstead to 547 in Bermondsey.

The *New Survey* data on economic resources are based on two kinds of widely distributed samplings in each borough, though the two sampling methods differ radically in principle. From these primary observed data two series of derived data have been calculated: (i) the average income per head after deduction of rent (see Hart & Wright, 1939, p. 162), and (ii) the incidence below the poverty line. The primary observations for the former, like those for housing, were collected after extensive 'house sampling', while those for the latter, which covered a much larger proportion of the population in every borough, were obtained by 'street sampling' with the help of trained observers familiar with their districts. The former was the more intensive, the latter the more extensive, collection of data, and the coefficient of correlation between them is −0·591.

* For further discussion of this difference, see Census Housing Volume 1931, p. xxxiii.

It is difficult to select the most suitable of these diverse economic data for the purpose of investigating the effects of economic resources on these four infectious diseases. Although the primary data of the census cover the entire population, the assignment of all occupations to five social grades is not without pitfalls. The *New Survey* 'street sampling' estimate of the incidence below the poverty line was almost as widely based as the census, for in making it there was no special selection of working-class and exclusion of middle-class districts. This large body of data from the *New Survey* forms a valuable, and fairly satisfactory, check on that from the census, for social index was highly correlated with the incidence below the poverty line (0·876). The *New Survey* estimate of the average income per head after deduction of rent is based on the smallest collection of primary data of the three, and although it purports to represent directly the average economic resources in a borough, it probably reflects the circumstances of too selected a fraction of the population for this inherent advantage not to be outweighed. The correlation between social index and average income per head after deduction of rent had distinctly less significance, its coefficient being −0·724.

(*c*) *Number of children in the family.* Because of considerable differences in the average size of families in different boroughs, and of the likelihood that some infectious diseases might have a higher incidence in larger families, the average number of children below 14 years of age, in each family of four or more members, was calculated for each borough from the census. Hampstead had the smallest (1·41), while Shoreditch had the highest average (2·26). The remaining boroughs were well distributed in a normal manner about an average of 1·92. As might be expected, substandard housing and size of family were strongly correlated (0·742), and incidence below the poverty line and size of family nearly as strongly (0·672).

Table 3. *Coefficients of correlation between various forms of social data*

1.	Housing (C) and incidence below poverty line (*N.S.*)	0·733
2.	Housing (C) and social index (C)	0·741
3.	Incidence below poverty line (*N.S.*) and average income less rent (*N.S.*)	−0·591
4.	Social index (C) and children per family (C)	0·859

The coefficients of correlation between some of the social data from both the census and the *New Survey* are given in Table 3. Of the various data available for social conditions in the London Boroughs, the incidence of substandard housing (census), the social index (census), the incidence below the poverty line (*New Survey*) and the number of children in the family (census) were selected for comparison with the medical data.

SOCIAL CONDITIONS AND THE INCIDENCES OF DIPHTHERIA, MEASLES, TUBERCULOSIS AND WHOOPING COUGH AMONGST YOUNG CHILDREN IN THE LONDON BOROUGHS

Specific mortality returns provide only an incomplete idea of the harm done by these diseases, for, apart from chronic disabilities, these infections often lead to fatal complications that are registrable in other categories. Yet in spite of this drawback, the care with which these returns have been compiled, as well as the compulsory notification of death, makes them the most complete data available on the distribution of these diseases. Although the absolute values of the figures must be regarded with caution, the relative mortalities in the different boroughs are reliable so long as comparisons are restricted

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to periods sufficiently short for standards of diagnosis not to have changed greatly. The use of secular statistics for some diseases is becoming complicated, however, by the increasing use of specific prophylactics.

In the present investigation only short-term mortality data have been used. The period mainly considered has been the quinquennium 1929–33, because for three of the four diseases it appears to provide a fairly good indication of their endemicity, and also because it falls equally on either side of 1931, the year in which most of the data on social conditions were collected.

The degree of association between particular social conditions and mortalities was determined by correlation. The coefficients of simple correlation between the different variables are given in Table 4.

Table 4. *Coefficients of correlation between certain social conditions in or about* 1931 *and the mortalities of young children,* 0–4 *years, both sexes combined, from diphtheria, measles, tuberculosis* (*all forms*) *and whooping cough in the London Boroughs in the specified quinquennia*

Social conditions	Years of mortality data	Coefficients of correlation: Diphtheria	Measles	Tuberculosis	Whooping cough
Housing (1921)	1924–8	0·393	0·678	0·580	0·731
Housing (1931)	1924–8	0·382	0·624	0·573	0·717
	1929–33	0·490	0·865	0·749	0·515
	1934–8	*0·197*	0·753	0·397	0·600
	1924–38	0·503	0·838	0·670	0·729
Housing (1931):					
Families all sizes	1929–33	0·490	0·865	0·749	0·515
Families 7 and over	1929–33	0·548	0·721	0·766	0·490
Families 9 and over	1929–33	0·528	0·497	0·690	*0·207*
Social index (1931)	1924–8	0·490	0·402	0·648	0·474
	1929–33	0·487	0·434	0·659	*0·280*
	1934–8	*0·272*	0·702	0·472	0·397
	1924–38	0·591	0·589	0·746	0·452
Poverty line (N.L.S.)	1929–33	0·482	0·469	0·522	*0·148*
Children per family (1931)	1929–33	0·476	*0·173*	*0·167*	*0·126*

(*a*) *Substandard housing.* The correlations between the substandard housing incidence in each borough and the mortalities of young children from measles and whooping cough are of a high order. That between substandard housing and tuberculosis is of a high order for the quinquennium 1929–33, of rather lesser value for 1924–8, and falls to a very moderate one for 1934–8. It must be recalled, however, that the mortality of young children from all forms of tuberculosis, like those from the other three diseases, has been showing a tendency to fall in recent years. When boroughs having less than twenty deaths from tuberculosis in this age group in the 1934–8 quinquennium are excluded, the coefficient of correlation for the seventeen remaining boroughs rises slightly to the value 0·448. The correlation between substandard housing and diphtheria is of a distinctly lower order than that for any of the other diseases.

Since it has been suggested by Young & Russell (1927) that substandard housing might be proportionately more important in the etiology of such infectious diseases below a certain standard of overcrowding—in short, that this relationship might sometimes be a curvilinear one—correlation ratios have also been calculated between substandard housing incidence and the mortalities from the four diseases for the sesquidecennial period. Their values are given in the following table:

	r	η
Diphtheria	0·503	0·571
Measles	0·838	0·880
Tuberculosis	0·670	0·641
Whooping cough	0·729	0·815

Only for whooping cough does the difference between the correlation coefficient and the correlation ratio approach borderline significance, so that only for this disease does the relationship appear to be even slightly curvilinear.

As some changes had taken place in local housing standards between 1921 and 1931, chiefly through an outward drift from the inner boroughs, coefficients of correlation were also calculated between the mortalities in the quinquennium 1924–8 and the substandard housing incidence in 1921. The resulting coefficients are all slightly higher than those based on the housing data of 1931.

As a check on the correlations found with quinquennial averages, the averages of the mortalities for the whole 15-year period 1924–38 were correlated with the housing figures for 1931, the mid-year of this sesquidecennium. These coefficients are all somewhat greater than the respective means of the coefficients obtained for the three constituent quinquennia, which suggests that 5-year periods may be rather short for ascertaining endemic mortality data for the present purpose, and that the longer period of 15 years should be used in addition.

Although the values of the coefficients all indicate a connexion between substandard housing and the endemic mortalities of young children from each of these diseases, the closeness of the association clearly differs considerably from one to another. It is much the closest with measles, less close, in descending order, with whooping cough, tuberculosis and diphtheria.

A subsidiary series of correlation coefficients was calculated between mortalities from these diseases in 1929–33 and the incidence of substandard housing found amongst large-sized families only. With families of seven and over, there was little change in the values of the coefficients, but when families of nine and over were taken, there was a very marked fall in value for measles and whooping cough, much less fall for tuberculosis and an unchanged value for diphtheria. The reason for the diminution for measles and whooping cough may be that in large families a greater proportion of members will be adolescents or adults—when liability to these diseases is much less—who are therefore unlikely to infect their younger relatives. The morbidity period for diphtheria persisting further into adolescence, and that for tuberculosis extending throughout adult life, older members of the family remain potential sources of infection for the younger, so that the coefficients of correlation between the mortality of young children from these latter two diseases and the overcrowding in the larger-sized families persist at almost undiminished, or even at slightly raised, values.

(*b*) *Social index.* This estimate of social conditions also shows in general significant correlations with the mortalities of young children from all four diseases. As with substandard housing, the coefficients are greater when the entire sesquidecennium is taken as a single unit than as three separate quinquennia. This feature is again most noticeable for diphtheria, and is probably ascribable to the same cause.

When the numerical values of the coefficients are compared, however, it is seen that the four diseases separate into two pairs: measles and whooping cough are decidedly more closely associated with substandard housing than with social index, whereas the reverse is found for diphtheria and tuberculosis. This distinction between the two pairs of diseases is more evident when the mortality for the entire 15-year period is used. For diphtheria and tuberculosis there has been some falling away also in the values of the coefficients for both social index and substandard housing in the period 1934–8, which would seem to imply that recently some additional etiological factor, as yet unrecognized, has been increasing in relative importance.

The comparative importance of the social conditions typified by the incidences of substandard housing and social index in the etiology of tuberculosis in young children will be discussed below in connexion with the further analysis of the results by partial correlation.

(c) *Incidence of persons below the poverty line.* This incidence, obtained from the *New Survey*, was previously found to be highly correlated with the social index derived from the almost contemporary census. The values of the coefficients of correlation between this estimate of social adversity and the mortalities from the four diseases show a general similarity to those previously found with the social index, and thus supports the conclusion that some etiological factor inherent in poverty, but distinct from that measured by substandard housing incidence, operates more strongly in diphtheria and tuberculosis than in measles and whooping cough.

(d) *Number of children in the family.* Diphtheria alone of the four diseases shows a significant correlation between the mortality of young children and the mean number of children below 14 years in each family of four or more members. The insignificant correlations between these variables for measles and whooping cough support the conclusion reached above on substandard housing, that transmission from a considerably older school child to an almost infant brother or sister is not typical of these two diseases. On the other hand, diphtheria, in which the mean age at which the disease is contracted in the London area is well above the 'young child' age group of 0–4 years, is more likely to spread from such a school child to a much younger relative. Tuberculosis differs from the other three in being a disease of relatively low morbidity and still lower infectivity in childhood and early adolescent life, and is thus unlikely to be transmitted from children of school age and under to younger brothers and sisters. The domestic reservoir of infection in this disease exists almost entirely in adult members of the family. The matter is discussed more fully below.

Evidence from morbidity data

The morbidity records of these four diseases are much less complete than those for mortality. Compulsory notification of diphtheria in the whole London area has been in force for many years, but for measles and whooping cough it was only required in certain Metropolitan Boroughs under local orders until 1 October 1938, when a general order was put into operation. Under this order, as at first issued, it was unnecessary, however, for the notifier to report second and subsequent cases of either measles or whooping cough occurring in a household within 2 months of the first. Later, in the year 1939, this general order was amended to require the notification of all cases, irrespective of

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whether they were first or subsequent ones. The result of the provision ruling in the earlier months of the order was to render the notifications for the last quarter of 1938 and the early part of 1939 somewhat defective. The evacuation of many children from London to the country in September 1939, added to the unsatisfactoriness of the returns for statistical purposes.

Not only are the published morbidity data for these two diseases incomplete, but even had the administrative procedure been different, the figures must be inherently less accurate than the corresponding mortality data. Infectious diseases vary widely in severity in different persons. In general, the more severe the case, the more definite are the clinical manifestations on which the notification is based. Consequently, fatal cases,

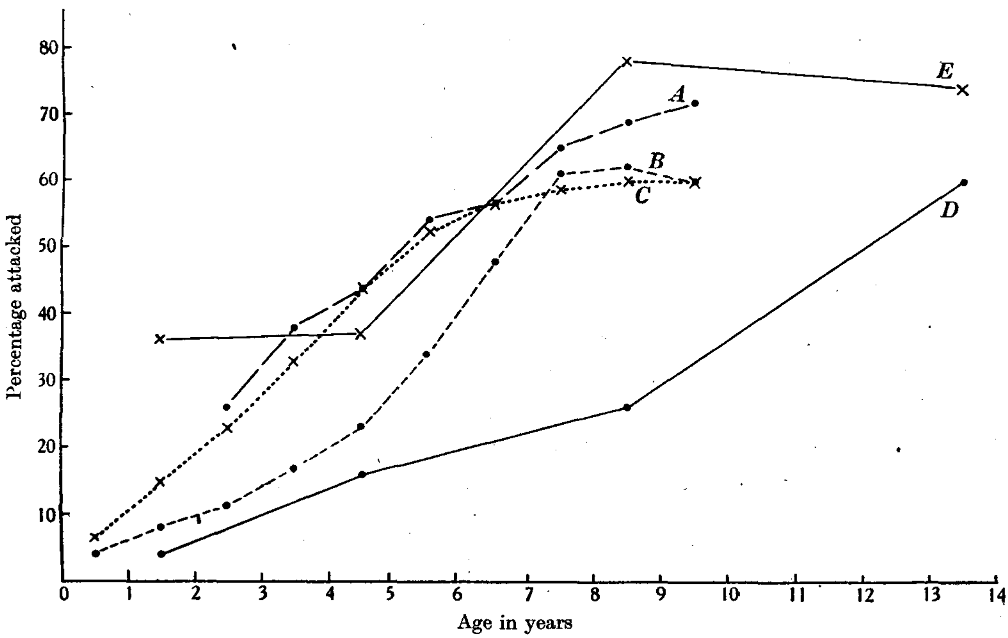

Fig. 1. Morbidity curves for diphtheria, measles, tuberculosis and whooping cough by ages for children in the London area. *A*, Schick-negative reactors in L.C.C. children (1932–6). *B*, Average percentage of children 'not at risk' to measles in St Pancras (1924–7) (Stocks & Karn, 1928). *C*, Percentage of children 'not at risk' to whooping cough in Battersea (1925–9) (Stocks & Karn, 1932). *D*, Tuberculin-positive reactors in families with no open case of tuberculosis (1930) (Hart, 1932). *E*, Tuberculin-positive reactors in families with an open case of tuberculosis (1930) (Hart, 1932).

which usually show the most marked clinical features, are least likely to be misdiagnosed. In most diseases the subclinical cases are seldom recognized and hardly ever reported, and the frequency with which certain infectious diseases take this mild form in a community can only be inferred from such indirect sources as Schick test surveys, tuberculin test surveys and examinations for changes in susceptibility amongst sections of the populations such as those made for measles by Stocks & Karn (1928). Curves derived from such data are shown in Fig. 1. But in spite of deficiencies, recent London morbidity data, if used with caution, throw some light on certain aspects of these diseases in the Metropolitan Boroughs.

For diphtheria only are the data sufficient to compare the local morbidities with the corresponding social conditions. By permission of the Public Health Statistics Department of the London County Council, we have extracted from their weekly returns of the notification of this disease the number of cases of each sex, in separate yearly age groups, for each Metropolitan Borough. (The corresponding data for East Ham and West Ham were not obtained.) As with measles and whooping cough, there are errors of notification of diphtheria, but whereas with the two former the notifications tend to be incomplete, with diphtheria it seems that the incidence of clinical attacks may be exaggerated. After stating that the errors of notifications of deaths from diphtheria are probably not large, Shone, Tucker, Glass & Wright (1939) point out that the crude notification rate for clinical cases in their large Liverpool series is too high by about 40% as judged by bacteriological examinations. Below the age of 10 years the error was about 30%, but it rose rapidly with increasing age: in those above 15 years it was 70%. Difficulties in swabbing the infected area in cases in which the membrane was not readily accessible, may account for part of the discrepancy between the clinical and bacteriological diagnoses, but as Woods (1933) has stated, 'there is no doubt that in recent years there has been a greater tendency to notify cases as diphtheria on slender clinical evidence or on purely bacteriological grounds than in former years, so that notifications have been considerably increased by the inclusion of mild cases'.

Morbidity rates for diphtheria in each Metropolitan Borough for children aged 0–4 years have been calculated for the period 1929–33 from the number of 'corrected' L.C.C. notifications. The correlation coefficients between these rates and substandard housing and social index have the high values of 0·893 and 0·742 respectively. Both coefficients are much greater than the corresponding ones for diphtheria mortalities given above—a result which may be due to the lesser liability of the much larger numbers used for the morbidity rates to chance distortions in the smaller boroughs (16,980 cases notified to 919 deaths notified). It appears likely, however, from the generally lower values of the corresponding correlation coefficients for the other two quinquennia and for the entire sesquidecennium, that the mortality rates are less significantly correlated than the morbidity rates with the incidence of substandard housing. A possible reason for this difference is discussed below.

From the statistical aspect it is unfortunate that the autumn of 1938 and the year 1939 were not periods in which either whooping cough or measles were prevalent: 9059 cases of the former, and only 853 cases of the latter were notified during that period in the age group 0–4 years. In view of the fewness of the cases, particularly of measles, the short period over which the data for both diseases were obtained and uncertainties about the local child populations, the local morbidity figures are not sufficiently reliable to permit a satisfactory comparison of the endemicity of these diseases with substandard housing and social index in the same way as for diphtheria.

It has been possible, however, to calculate for each Metropolitan Borough from the L.C.C. records of notification, the mean ages at infection with diphtheria, measles and whooping cough of all cases aged 15 years and under. The mean age at infection is of great importance in the epidemiology of all three diseases because of the great variations in their case-fatality rates at different ages. The dependability of such calculated estimates depends mainly upon the absence of serious inconsistencies in the extent to which cases occurring at different ages are notified. The discrepancies in the diagnosis of diphtheria at different ages has already been discussed, but some evidence on this point is also available for both measles and whooping cough.

It has already been stated that during the earlier part of the 15-months' period beginning in October 1939, not every case of measles in the Metropolitan Boroughs was compulsorily notifiable. Since the first case to appear in a family is most often amongst the children aged 5–9 years (see Top, 1938), owing to their opportunities for contact at school and elsewhere, it seems fair to assume that the effect of any omission of second and subsequent cases would be to raise somewhat the calculated mean age at which infection took place. Further, it is possible that for other reasons there tends to be more completeness of notification at some ages than at others. Chope (1940) has examined the factors affecting the notification of measles in the residential suburb of Newton near Boston in Massachusetts, and came to the same conclusion as that reached earlier by Sydenstricker & Hedrich (1929), that the reporting was particularly defective for very young children but was better for those of school age. In London, however, there seems

Table 5. *Age distributions of notified cases of measles in Newton, Baltimore, London, St Pancras and the Metropolitan Boroughs*

Age	Newton (1924–38) (1) Notified		Newton (1924–38) (1) Corrected		Baltimore (2) (1908–17)		London (3) (1935–6)		St Pancras (4) (1924–7)		Met. Boros. (5) (1938–9)	
–1	86	1·4	448	4·2	1,069	5·1	1,927	4·3	460	7·6	227	19·3
–2	336	5·6	1,037	9·6	1,109	5·2	4,109	9·1	795	13·1	216	18·4
–3	443	7·5	1,136	10·6	2,572	12·2	4,113	9·1	850	13·9	139	11·8
–4	534	9·0	1,197	11·2	2,963	14·0	6,342	14·1	891	14·5	131	11·1
–5	628	10·6	1,366	12·7	3,195	15·1	9,034	20·1	1,022	16·8	140	12·0
–6	1,191	20·0	1,851	17·3	2,965	14·0	10,776	23·9	1,180	19·4	138	11·7
–7	1,495	25·1	1,967	18·4	3,405	16·0	6,730	15·0	699	11·5	108	9·2
–8	1,235	20·8	1,717	16·0	3,916	18·5	1,986	4·4	192	3·2	76	6·5
	5,948		10,719		21,194		45,017		6,089		1,175	

For data see: (1) Chope, 1940; (2) Fales, 1928; (3) L.C.C. Measles Report (1938); (4) Stocks & Karn, 1928; (5) present data.

reason to believe that the deficiencies in all age groups are much smaller than those found by Chope. Whereas he estimated that only 50% of all cases below the age of 9 years in Newton were notified, Stocks & Karn (1928), after examining the notifications in St Pancras* between 1924 and 1927, concluded that the true incidence of measles (although at times there might have been some confusion between measles and German measles) was only about 10–15% higher than that actually recorded. Even were this deficiency to be largely concentrated in the pre-school years, it is clear that notifications for children under 5 years are likely to be more nearly complete than those in Newton. The recorded and corrected figures given by Chope for Newton, together with various figures for Baltimore, St Pancras and London, and the notifications in the Metropolitan Boroughs from the last quarter of 1938 to the end of 1939, are set out in Table 5.

Deficiencies in the notification of whooping cough were believed by Stocks & Karn (1932) to be more serious than for measles. In conjunction with C. J. Thomas, they compared the number of cases of whooping cough notified in Battersea in 1925–9 (economically considered, an average Metropolitan Borough) with those later ascertained through the

* St Pancras is, economically considered, an average London Borough, having a social index of 34% and a substandard housing incidence of 18%; the means of all the Metropolitan Boroughs in 1931 were: social index 34·2%, substandard housing 13·9%.

use of a special questionnaire to parents at the time that their children first entered school. They estimated that about one-third of the cases below 10 years were not notified, and also that, as with measles, the deficiencies were greatest in the earlier years, when they reached a proportion of about two-fifths. As a result of this comparison, Stocks & Karn estimated a corrected attack rate at various ages. It seems possible that the notifications of whooping cough in the Metropolitan Boroughs in 1938–9 may not have been so deficient as a decade earlier in Battersea, since, as can be seen from the following table, there is fairly good agreement between the notified cases in 1938–9 and Stocks & Karn's corrected rate when both series are expressed as a percentage of the maximal incidence in the age group 3–4:

	Age groups									
	–1	–2	–3	–4	–5	–6	–7	–8	–9	–10
Battersea (1925–9) (corrected)	71	79	86	100	99	88	45	18	7	3
Met. Boros. (1938–9)	72	89	86	100	90	81	43	18	7	3

In a later communication Stocks discussed variations in the deficiencies of notification from one borough to another, and concluded that, as with measles in Newton, they were more serious in the poorer localities. Such an unequal distribution would again tend to raise falsely the calculated mean age at infection in boroughs of this type.

Although the evidence pointed to an unequal distribution of the errors of notification of these diseases in the Metropolitan Boroughs, the likely direction of these errors seemed to make it safe to compare the mean age at infection and certain social conditions for those boroughs for which the morbidity data were adequate. For diphtheria and whooping cough the calculations were based on all twenty-eight boroughs, but owing to scantiness of data, two boroughs (Holborn and Stoke Newington), where the cases had been particularly few, were omitted for measles. The calculated mean age at infection, together with the coefficients of correlation between this variable and the incidence of substandard housing and social index, are set out in Table 6.

Table 6. *The mean age at infection for diphtheria, measles and whooping cough in the Metropolitan Boroughs, and the coefficients of correlation between these means and the incidence of substandard housing and social index*

	Diphtheria (1929–33)	Measles (1938–9)	Whooping cough (1938–9)
Number of notified cases ...	42,621	1,408	12,324
Mean age at infection	6·29	4·38	3·60
Coefficient of variability	5·9	19·8	10·6
Coefficients of correlation:			
Substandard housing (1931)	–0·704	–0·509	–0·790
Social index (1931)	*–0·099*	*–0·248*	–0·399

The average mean age at infection for measles for the twenty-six Metropolitan Boroughs used was 4·38 years, which corresponds fairly well with the value of 4·26 calculated from Stocks & Karn's data for St Pancras; for whooping cough, for all twenty-eight boroughs, it was 3·60 years, which again corresponds adequately with the values of 3·78 for Holborn in 1929–33 and of 3·56 for Greenwich in 1931–3 (these figures were calculated from published notifications made under local orders in these boroughs; although notification in the period prior to 1932 was also compulsory in Wandsworth, the discrepancy between the L.C.C. records and those published by the Medical Officer of Health in his annual reports is too great to make their use possible). For all three diseases the mean ages are lower than those that can be calculated from the notifications in Baltimore in 1908–17 (see Fales, 1928); the order into which the diseases fall in the two cities is also different. Fales's data provide the following mean ages: measles 5·95 years; diphtheria 5·66 years; whooping cough 4·33 years. The particularly discrepant figures for measles may be due to notification failures for children below school age—omissions which seem to be more frequent in American cities than in London. In the present series, the mean age at infection with diphtheria is the highest, even though its computation was based on records collected several years before those for the other two diseases. Had contemporaneous data been used, it might well have been higher still, since, as Cheeseman, Martin & Russell (1939) have shown for London, and Wright (1939) for other large English cities, the mean age at infection with diphtheria has been tending to rise slowly during the past 30 years.

There is a consistent difference between the high values of the coefficients of correlation between the mean age at infection for all three diseases and the incidence of substandard housing on the one hand, and the low values for social index on the other. The close association of high diphtheria incidence amongst the younger children and overcrowding has been previously observed by de Rudder (1928) in Würzburg and other large German cities. For whooping cough, on the other hand, the conclusion to be drawn from the present data is the reverse of that reached by Stocks (1933), who found a remarkable inverse relationship between overcrowding and this disease, which he summarized in a coefficient of correlation (based on 3330 cases) between the number of persons per room and the percentage of children attacked below the age of 5 years in twenty-two areas of London, which had the value $-0{\cdot}189 \pm 0{\cdot}139$. Although this coefficient is not significant, the finding of any inverse relationship between these two variables is surprising, and it seems possible that the use of a questionnaire to parents might have led in some way to greater selection of data than happened when information was collected more impersonally. The implications of the present finding of a strong association (which might well have been stronger for measles and whooping cough but for the disproportionate notification deficiencies for young children in the poorer boroughs) between early infection and overcrowding will be discussed later in relation with the notoriously high case fatality in infancy from these diseases.

In recent years much attention has been paid to the variations with age in the case-fatality rates in these diseases. Such rates depend upon both deaths and cases, and are thus liable to error from inaccuracies in the notification of either. Owing to the widespread occurrence of very mild and subclinical attacks of all three of these diseases, and of tuberculosis also, it is apparent that notifications of cases, especially in young children, are likely to be the more misleading of the two. In spite of such errors, the figures for London and other places, which have been collected in Table 7, show that although the steepness of the gradient of case-fatality rate with age might be lessened by more complete notification, no correction of the figures could ever leave it otherwise than very pronounced.

Even adopting a conservative attitude, it is clear that the case-fatality rates in childhood both for measles and whooping cough fall rapidly with increasing age—a fundamentally important characteristic of these diseases that was first pointed out by Butler (1913) and later stressed by Brownlee (1920). It would seem, therefore, that the combination

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of a high case-fatality rate in the very young from measles and whooping cough with a marked correlation between substandard housing incidence and the mean age at infection might partly account for the high correlations found earlier between the mortalities of children, aged 0–4 years, from these diseases and the overcrowding in the thirty London Boroughs. Infection at an early age, which Brownlee so much feared, is largely brought about by inferior housing. With diphtheria, although mean age at infection is strongly correlated with substandard housing incidence, the case-fatality rate in young children has a much less steep gradient,* so that the earlier mean age at infection resulting from overcrowding has less effect on the mortality from this disease than from the other two.

Table 7. *Case-fatality rates, based on notifications of deaths and cases, at ages under* 5 *years, from diphtheria, measles and whooping cough*

	Ages in years				
	–1	–2	–3	–4	–5
Diphtheria					
London (1895–1914) (Goodall, Greenwood & Russell, 1929)	39·2	29·4	20·5	15·5	14·4
				16·5	
New York State (places under 200,000) (1915–24) (Godfrey, 1928)	26·9	28·1	18·6	14·1	12·8
Liverpool† (1936–7) (Wright, 1939)			6·8		
London (1929–33) (present data)	9·4	7·8		4·6	
Measles					
Birmingham (1916–19) (Halliday, 1928)	6·5	6·3	3·2	1·3	0·6
New York State (places under 200,000) (1915–24) (Godfrey, 1928)	7·9	4·6	1·3	0·6	0·3
St Pancras (1915–26) (Stocks & Karn, 1928)	8·6	7·6	2·9	1·2	0·6
London (1931–2) (L.C.C. Measles Report, 1933)	8·6	8·4	2·8	0·8	0·4
London (1935–6) (L.C.C. Measles Report, 1938)	6·2	5·8	2·1	0·5	0·4
Whooping cough					
New York State (places under 200,000) (1915–24) (Godfrey, 1928)	20·1	8·0	2·3	1·0	0·7
Battersea‡ (1925–9) (Stocks & Karn, 1932)	6·6	5·5		1·1	
London (1938–9) (present data)	7·4	1·7	0·3	0·4	0·1

† This rate was based on notified cases; if only bacteriologically confirmed cases were used this rate rose to 10·2. The Liverpool and London rates may also differ somewhat owing to the different frequencies with which the three main types of *C. diphtheriae* occur as pathogens in the two cities (see Mair, 1936; Shone *et al.* 1939).

‡ These rates were based on notifications uncorrected for any estimated deficiencies, and are consequently rather higher than those published by Stocks & Karn.

This perhaps partly explains the lower values of the coefficients of correlation found earlier between the mortality of young children from this disease (even using the longer, sesquidecennial, period) and the incidence of substandard housing conditions.

Unfortunately our knowledge of tuberculous infection in childhood is too incomplete for any statistical treatment along these lines at the present time. There seem good grounds for believing (see Hart & Wright, 1939) that the incidence of this disease is closely affected by housing conditions. It is also believed (see below) that the case-fatality rate from tuberculosis, like those for measles and whooping cough, is particularly high in early infancy. There thus seems to be prima facie reason to believe that the strong

* For a discussion on case-fatality rates in diphtheria, see Picken (1937).

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association between tuberculosis in young children and overcrowding is again dependent upon bad housing conditions causing particularly early infection, and that this disease in this respect falls into line with the other two droplet-borne infections—measles and whooping cough. The question is more fully discussed below.

DISCUSSION

Although these four diseases, diphtheria, measles, tuberculosis and whooping cough, all have in common droplet transmission as their main means of spread, and are thus nosologically kindred diseases, they have certain dissimilarities which make it desirable to review their epidemiological characteristics separately. In the following discussion the incidence of each disease in children under 5 years will be considered from three aspects: the main reservoir of infection, the facilitation of transmission by certain social conditions, and the influence that these conditions may have on the specific and non-specific resistance of the population at risk.

Diphtheria. There are two main sources from which young children in London become infected with diphtheria: (i) actual clinical (notified) cases, which occur mostly amongst children of school age and under—the age period of maximum incidence in the Metropolitan Boroughs in 1929–33 being from 3 to 7 years; (ii) carriers of virulent organisms, who may be of any age, but whose maximal incidence, to judge from the Baltimore observations of Doull & Fales (1923), is between 7 and 9 years. The relative importance of these two sources varies from time to time, for although carrier rates tend to rise when clinical cases are prevalent (as Forbes (1932) found for L.C.C. school children in 1921–2), there may sometimes be considerable divergencies between the two (see Dudley, 1932). A rough estimate of the relative importance of the two sources may be made, however, by comparing the incidence of clinical (notified) cases with that of carriers of virulent organisms.

Shortly after the last war, Forbes found a carrier rate for London school children of about 6%; a proportion nearly the same as that found by Dudley for the boys in Greenwich Hospital School. About half the organisms found in each series were toxigenic. Forbes's figures were obtained, however, at a time when diphtheria was more than usually prevalent in London, and his rate is thus probably higher than that prevailing from 1929 to 1933, the period with which the present study is mostly concerned. Between 1934 and 1937, the examination of 1467 crippled or debilitated, but otherwise normal, London children, swabbed as a precaution before going to convalescent homes, disclosed a total carrier rate of 1·6%, and a virulent carrier rate of 0·75%. This rate was probably lower than that of the general child population, for such invalid children had probably not been mixing freely with others for some time before examination. If a virulent carrier rate of 1·5% for the general child population during this period be assumed, there would be roughly 15,000 cases of subclinical infection or carriers of virulent bacilli amongst London school children at any one time. Since Dudley has found that the carrier state in such children usually persists for about 5–6 weeks, about 120,000 such children would become infected in the course of a year. This estimate agrees reasonably well with one that can be made from the proportion of Schick-negative reactors amongst a sample of London school children of various ages in 1932–6 (L.C.C. 1936, 1937). Amongst 4335 children below the age of 10 years, there was an average annual conversion rate from Schick-positive to negative of 13%. Were the sample tested to represent adequately the 950,000 children aged 14 years or under in the Metropolitan Boroughs in 1931, this observation would indicate that more than 100,000 such children acquired and were partially immunized by virulent bacilli yearly.

Between 1929 and 1933, when the prevalence of diphtheria in London was somewhat lower than shortly after the last war, there was an annual average of 8500 cases of clinical (notified) diphtheria amongst children below the age of 15 years, so that the incidence of such notified cases was probably about one-fifteenth of that of the children who, at one time or another, had virulent diphtheria bacilli in their throats in each of those years.

The comparative risks of incurring infection from home contact with clinical cases and with carriers has been estimated by Doull (1930), who concluded from observations in Baltimore that it is about three times greater from exposure to clinical cases (removed to hospital after diagnosis as is the procedure in London) than to a carrier of virulent bacilli. If such an estimate of comparative risks applied equally in London, it would mean that the source of infection in any particular case is likely to be found about five times more frequently amongst subclinically infected persons or carriers than amongst clinical (notified) cases. The greater importance of subclinical cases and carriers in spreading diphtheria might explain Elderton & Pearson's (1914–15) failure to demonstrate any important result from the isolation of clinical cases upon the prevalence or mortality from diphtheria.

Since the reservoir of infection, whether case or carrier, is so largely concentrated in the child population, particularly amongst younger school children, it is hardly surprising that a correlation exists between the incidence of diphtheria amongst children aged 0–4 years and the average size of the family—the coefficients for mortality and morbidity for the quinquennium 1929–33 being 0·476 and 0·703 respectively.

The transmission of infection from the school child to his younger brothers and sisters is clearly made easier by inferior housing conditions: the correlation coefficients between substandard housing and the mortality and morbidity of children aged 0–4 years in 1929–33 were 0·490 and 0·893 respectively. The former value may be somewhat high, however, for the calculation of a representative quinquennial mortality figure for the endemic prevalence of this disease was not very satisfactory, and the coefficients of correlation between mortalities and housing in both the preceding and succeeding quinquennia were definitely lower.

From the values of the correlation coefficients for 1929–33, it seems possible that inferior housing conditions may be more closely associated with morbidity than with mortality from diphtheria. It may have been that the stronger correlation with morbidity was due to more complete, and sometimes erroneous, notification of diphtheria in the poorer boroughs, and that, as Woods (1928) has stated, 'non-clinical cases appear to come mainly from the poorer districts'. On the other hand, it is possible that this difference in the values of the coefficients represents some distinction of epidemiological significance. If this be so, the difference may be due to the earlier age at infection in poor districts (the coefficient of correlation between substandard housing incidence and mean age at infection was $-0·704$) which curtailed the duration of the gap between the decline in the congenital passive immunity, which is so marked in this disease, and the rise in active immunity developing from subclinical infections. Children in the poorer districts become infected more frequently, and consequently have a higher morbidity than children in better-housed areas, but the infection falling on them at a time when their immunity, either congenital or acquired, is higher, their mortality is proportionately lower. This suggestion is compatible with the finding that the case-fatality rate (based on notified deaths and cases in the Metropolitan Boroughs) for diphtheria in 1929–33 was significantly, but negatively, correlated with substandard housing—the coefficient being −0·467. In interpreting this coefficient, however, Wood's caution, noted above, should again be borne in mind.

The above examination of mortality and morbidity data seems to indicate that the effects of bad housing on diphtheria may not be altogether uncompensated, since the easier transfer of infection, resulting from the enforced closer contact, may maintain a higher level of specific herd immunity in the young child population and so tend to mitigate the effects of inferior social conditions. Not that bad housing operates beneficially upon the mortality from diphtheria in this age group; all that can be said is that were it not for the congenital transfer of immunity at a relatively high level from mothers, themselves doubtless often reimmunized by chance exposure, the mortality of young children from this disease in the overcrowded boroughs might be higher.

Resistance to diphtheria, as to other infectious diseases, may be affected by both specific and non-specific factors, and in poorer districts the non-specific resistance seems to be at a lower level. If the social index be accepted as representing the general level of prosperity in a borough, then diphtheria mortality in young children is definitely associated with poverty: the coefficient of simple correlation between the two for the quinquennium 1929–33 having the value 0·487, and the coefficient of partial correlation, substandard housing being excluded, having the value *0·212*. If the sesquidecennial data be preferred, as giving a better indication of the endemic levels of diphtheria in the boroughs, the corresponding coefficients have the values 0·591 and 0·376 respectively. It seems, therefore, that poverty may lead to a higher mortality amongst young children in the poorer boroughs not only by facilitating the transmission of infection through overcrowding, but also by lowering non-specific resistance to the infecting organism should it be acquired.

Measles. The main reservoir of infection for young children is generally believed to be their rather older brothers and sisters attending school and acquiring the disease there (see Butler, 1913). This view was held by Brownlee (1920), and formed the basis of his proposals for reducing the mortality from measles by quarantining exposed school children if younger susceptible children were living in the same house. It is also supported by Top's (1938) observations on an epidemic in Detroit in 1935, in which he found that in the families affected the primary case was much the most often in the age group 5–9 years. It is not possible, unfortunately, from the data given in his paper to determine the mean age of these primary cases, but it would seem to have been between 6 and 6½ years; the mean age of the secondary cases can be calculated more closely and would seem to have been nearly 4 years. The total number of the secondary cases (1380) given in his sample which developed in houses in which *one* primary case had occurred (home contacts with two or more primary cases formed less than 10% of the whole number of contacts) was not much greater than the number of primary cases themselves (1253), so that during this outbreak each school child seldom, on average, infected more than one brother or sister at home. This mode of spread of infection, in which the donor and the recipient are so nearly of an age, may well account for the low value (*0·173*) of the coefficient of

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correlation between the mortality of children aged 0–4 years from measles and the average size of the family. Halliday (1928), examining the distribution of measles in Glasgow, also regarded the schools as the main source from which infection was introduced into the homes, especially in the more overcrowded parts of the city.

The most important contribution on the relationship between social conditions and measles has been made by Halliday, who found that the severity of the disease in the overcrowded districts was much greater than in the better-housed areas. This finding agrees with that in the present paper, for, of the four diseases examined, measles has the highest coefficient of correlation between substandard housing and the mortality of young children. In Glasgow in 1925–6, the greater seriousness of the disease in the poorer districts seemed to be dependent upon an earlier mean age at infection. This mean age, calculated from the figures given in the table on page 26 of his Report, has the same value (4·34 years) as that found for the Metropolitan Boroughs in 1938–9, but it seems likely that the Glasgow figures were more seriously affected by defective notification than those of London, especially for the younger age groups. When the data for the four separate districts of Glasgow are calculated individually, their mean ages at infection, in descending order of quality of housing, are 4·91, 4·70, 4·26 and 4·00. These figures show less variability than those of the London Boroughs, possibly because the Glasgow areas were fewer and proportionately rather larger.

The subdivision of Glasgow into only four areas on the basis of housing does not allow the application of the method of correlation to determine the degree of association between this social condition and the mean age at infection, but for the larger number of Metropolitan Boroughs this method can be used. The value (−0·509) of the resulting coefficient (based on twenty-six boroughs) shows that the relation between the two is both inverse and significant. Halliday's view that the seriousness of measles in a community mainly depends upon the combination of a low mean age at infection, which results from overcrowding, and an unusually steep gradient of case-fatality rates in the first few years of life, thus seems equally applicable to the Metropolitan area.

From the mortality data there seems little evidence for associating measles with any other factor in poverty than housing. The coefficients of correlation for social index are always below, and mostly well below, those for substandard housing. Coefficients of partial correlation for the whole sesquidecennium between the mortality from measles amongst young children and substandard housing when social index is excluded, and between the first variable and social index when substandard housing is excluded, have the widely different values of 0·741 and *−0·088* respectively. From so great a disparity it is difficult to reach any other conclusion than that substandard housing is the predominant social factor concerned in the transmission of this disease, and that other factors in poverty have little influence upon the outcome of the infection by affecting the non-specific resistance of the children.

Tuberculosis. The main sources of infection from which young children acquire tuberculosis at the present time are contaminated milk supplies and open cases of respiratory tuberculosis in the adult population with whom they come into intimate contact. Although there has not been sufficient typing of tubercle bacilli recovered from clinical cases in the London area to determine the incidence of the bovine type of infection in recent years with any certainty, there can be no doubt that, with the steady expansion of pasteurization or other form of heat treatment of milk in the Administrative County of London in the decade ending 1930, the frequency of infection from this source must have been much reduced and latterly almost eliminated. But although the incidence of respiratory tuberculosis in the adult population of London has declined considerably in the last 20 years, it still remains at a high level, and was undoubtedly the chief source of infection of young children in the period under review. The fairly close association that existed in the period 1924–38 between the mortalities of young children from all forms of tuberculosis and the mortalities of adults aged 25–44 ('parents') from respiratory tuberculosis in the London Boroughs is shown by their having a coefficient of correlation of 0·540. If 'fathers' only, instead of 'parents', be used, the value of the coefficient rises to 0·667.

The closer association of the mortalities of young children with those of males in the middle-adult age group is possibly due to the greater incidence of respiratory tuberculosis amongst men than women, and is interesting in the light of Toussaint & MacIntyre's (1936) field study upon the sources of infection in cases of primary tuberculosis amongst children in the Metropolitan Borough of Bermondsey between 1928 and 1935. In their search for the probable human source of infection of children dying from meningeal or miliary tuberculosis, these authors found that, for the children below 5 years, the father was the probable source in twenty-five cases, the mother in seven cases and both in one case. A similar study made recently in Paris by Bernard, Kreis & Daridan (1939) on the probable source of infection of children under 3 years, led to the same general conclusion: in the eighty-one cases in which the source was identified, the father was implicated thirty-six times and the mother thirty-one times. Bernard *et al.* drew attention to this rather unexpected sex difference, the importance of which in preventive medicine is clearly considerable, and ascribed it to changes that had been taking place in the previous 20 years in the relative tuberculosis mortalities of the two sexes: that for women having fallen more rapidly than that for men in the Département de la Seine. In both the Bermondsey and Paris surveys it was found that the younger the child, the more frequently was the mother the source of infection. Wirtz (1936) also found much the same relative frequencies of infection from the two parents in Frankfort between 1926 and 1933; the probable source was traced on thirty-six occasions to the father and on thirty-two to the mother. In London, Dow & Lloyd (1931) examining the contact children below the age of 15 years of patients treated at the Brompton Hospital, found a rather higher incidence of Mantoux-positive reactors amongst children exposed to a sputum-positive father than to a sputum-positive mother. This observation suggests that for some reason an infected father is a more serious source of infection for the child, a finding which, if generally true, would qualify the suggestion that he is more often the source merely because open tuberculosis is more common amongst adult males. Infection of young children is seldom acquired from other children below or of school age, and this view is in conformity with the low value of the coefficient of correlation found between the mortality of young children from tuberculosis in the London Boroughs and the average size of the family.

The close association between the incidence of substandard housing in the London Boroughs and the mortality of young children from tuberculosis in the period 1924–38 is shown by the value of the coefficient of correlation (0·670) between the two. This association may partly result from housing conditions affecting the incidence of respiratory tuberculosis amongst those adults (the coefficient of correlation between these

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two variables for the period 1924–38 being 0·593) who form the principal reservoir of infection for young children. That this is not the only cause for the association between overcrowding and tuberculosis in young children, however, and that poor housing also operates by facilitating the transmission of the infecting organisms from adult to child seems likely on commonsense grounds. This belief in the importance of this effect of overcrowding is supported by the significant value (0·519) of the coefficient of partial correlation between the incidence of substandard housing and the mortality of young children from tuberculosis after excluding the incidence of 'parental' tuberculosis. It is also in conformity with Dow & Lloyd's finding that when no tuberculous person was living in the house, there was little difference in the incidence of tuberculous infection in children living in houses classified hygienically as 'good', 'fair' or 'bad', but that when an inmate suffered from tuberculosis there was a gradation between the incidences in the three groups: 68·6% in the 'good', 76·8% in the 'fair' and 86·4% in the 'bad'.

Our knowledge of specific immunity, either natural or acquired, in tuberculosis is at present too fragmentary to make it possible to discuss its bearing on the likely differences in susceptibility of young children living under various social conditions. It is well known that positive tuberculin reactors are more common amongst the children living in overcrowded districts, but whether this signifies any raised herd immunity amongst them is unknown. From a comparison of the mortalities of young children in well and badly housed areas, however, it seems unlikely that any rise in their general level of immunity so acquired is sufficient to compensate for their greater exposure to infection. Rather more is known of the age variations in the natural immunity of children to tuberculosis. Nassau & Zweig (1925), working in Berlin, stated that of twenty children infected during the first 3 months of life all died, of sixteen between 3 and 6 months fourteen died, and of thirteen between 6 and 12 months four died. Other observers have found somewhat lower case-fatality rates at these ages. Gasul (1929), working in Vienna in the period 1920–6, found case-fatalities in children below 6 months of 17%, between 6 and 12 months of 7%, and between 12 and 18 months of 6%. While the number of cases in all these series is very small, the proportions of deaths found support the view that tuberculosis resembles measles and whooping cough in having a steeply declining case-fatality rate with increasing age.

Some information may be gained on local variations in susceptibility to tuberculosis from the coefficients of partial correlation between the mortalities of young children and various social conditions. The greatest interest naturally centres on the possible effects of variations in nutrition in the different boroughs. Since the economic circumstances of the parents are almost certainly reflected in the state of nutrition of the children, there are grounds for accepting the social index (which is highly correlated with the proportion of persons below the poverty line (0·876)) as a trustworthy guide to this aspect of local social conditions.

The coefficient of correlation between social index and the mortality of young children from all forms of tuberculosis in the period 1924–38 had the high value of 0·746, and although in none of the constituent 5-year periods was this high value reached, in all the association was significant. When coefficients of partial correlation were calculated in which in the first instance the incidence of 'parental' tuberculosis alone was excluded, the value fell somewhat to 0·702; but when the more stringent test of excluding substandard housing in addition to 'parental' tuberculosis was applied, the coefficient, though falling lower, still remained significant with a value of 0·578. The persistence of a significant correlation between social index and the mortality of young children from tuberculosis after these exclusions does not necessarily mean that there is an association between the death-rates in this disease in this age group and a lowered general level of nutrition. Deficient economic resources involve a deprivation of many amenities of life in addition to food, and such factors as clothing and heating may be concerned in maintaining resistance to this more chronic infection. At the present time it would be unsafe to infer how poverty operates other than that important factors appear to influence the distribution of tuberculosis amongst young children in addition to the increased physical proximity resulting from overcrowding.

Whooping cough. The main, and probably the only, reservoir of infection in whooping cough is to be found in actual cases of the disease, for the observations of Bjorn Kristensen (1933) and others have shown that chronic carriers of *H. pertussis* are rarely found amongst either healthy persons or patients suffering from chronic respiratory disease. In the Metropolitan Boroughs in the period between October 1938 and December 1939, three-quarters of the notified cases were in the age group 1–5 years. Stocks (1933) believed that this infection was most commonly conveyed to the younger members of their families by children aged from 4 to 6. The co-existence of the main reservoir of infection and the main bulk of susceptibles within the narrow limits of the age group 0–6 years probably accounts for the low value of the coefficient of correlation between the mortality of young children from this disease and the average size of the family.

The very wide variations in the numbers of cases notified month by month in those Metropolitan Boroughs, in which notification of whooping cough has long been obligatory, indicate that almost equally wide variations must take place in the level of the local reservoir of infection. Bacteriological examinations reported by Martin Kristensen (1926) on cases of this disease in Copenhagen showed that there was a sharp fall in the percentage of patients showing *H. pertussis* cultures in the fifth week of the paroxysmal stage, and these findings have since been confirmed by Gardiner & Leslie (1932) and others. Further, the epidemiological studies of Stocks & Karn (1932) indicate that clinical cases rapidly lose their high initial infectivity after the end of the first 4 weeks—the infectivity during each of the first 3 months taken separately being roughly in the ratios 20, 3 and 1 respectively. From such findings it seems that the occasional fall in the incidence of whooping cough to very low levels in two or three consecutive summer months must reduce the reservoir of infection almost proportionately.

The transmission of whooping cough is strongly associated with overcrowding, as can be seen from the high value (0·729 for the period 1924–38) of the coefficient of correlation between the mortality of children aged 0–4 years and substandard housing incidence. A similar association between the number of persons per room and the mortality below 5 years in the London Boroughs from 1911 to 1920 was found by Young & Russell (1927). The values of their coefficients of correlation were 0·758 for males and 0·782 for females. This association has also been commented upon by the Registrar-General (1934) and by Britten & Altman (1941). That poor housing makes the transference of this infection easier can also be inferred from the association of a high substandard housing incidence with an early mean age at infection. It seems that the ease of transmission may be so great in the poorly housed districts that even substantial falls in the level of the reservoir of infection fail to prevent the rapid development of epidemics when the rising level of susceptibility in the population at risk, the meteorological conditions and the indoor aggregation of children again promote their occurrence.

There do not seem to be grounds for believing that non-specific factors of resistance depending upon social conditions determine to any great extent the mortality of young children from whooping cough. The coefficient of correlation between their mortality and social index had a much lower value in each quinquennium and in the whole sesquidecennium than the corresponding ones for housing, and this was further supported by the low value of the coefficient of correlation with the incidence of persons below the poverty line. The preponderant influence of the factors affecting transmission, as compared with those affecting non-specific resistance, in determining the endemic levels of whooping cough can be seen from the coefficients of partial correlations calculated for these three variables. When social index is excluded by this method, the value of the coefficient of partial correlation of mortality with housing for the period 1924–38 falls from 0·729 to 0·657, but when substandard housing incidence is excluded, the coefficient of partial correlation between mortality and social index falls from 0·452 to *−0·192*.

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