DIPHTHERIA

A SUGGESTED EXPLANATION OF THE RELATIVE CHANGE IN AGE INCIDENCE

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Although the mortality from diphtheria amongst children has declined appreciably since the beginning of the century, the decline has not been uniform at each age. The death-rate, which is still greatest in early childhood, 0–4 years, has decreased more rapidly in this age group than at 5–9 years. The result has been that the recent mortality statistics indicate a relative shift in the age distribution, and the disease is now represented as concentrating on children of school age.

England and Wales

The tendency is clearly indicated when the death-rates at ages during 1930–2 are compared with those which existed 30 years previously. The results are as follows:

	Ages in years				
	0–	1–	2–	5–	10–14
1900–2					
Death-rates per million	1565	4390	5258	2245	386
Death-rates as percentages of the rates at ages 5–9	70	196	234	100	17
1930–2					
Death-rates per million	497	1070	1481	1029	279
Death-rates as percentages of the rates at ages 5–9	48	104	144	100	27
Death-rates of 1930–2 as percentages of those of 1900–2	32	24	28	46	72

These rates are calculated upon the average annual number of deaths in each triennium and the census population. The later period has a lower mortality level than in 1900–2, but it is evident that the greatest improvement has occurred in the ages under 5 years. If the percentage distributions for each period are examined, it is clear that the disproportionate fall in mortality has, as has been suggested, resulted in the earlier ages being less significant than they were formerly, when compared with the early school ages 5–9 years.

The relatively smaller decrease in the death-rate at ages 5–9 years as compared with that at ages 0–4 in the whole country has not been due to any particular impression made upon the aggregate by the mortality in the large towns. While it is true that the death-rates from the disease in the county boroughs are larger than those in the rural areas, the shift in the ratio of the pre-school to that of the early school mortality has been characteristic of both town and country. This fact is clearly demonstrated by the following ratios:

		Ages in years		
		0–4	5–9	10–14
County boroughs:	1911–14	147	100	15
	1928–30	126	100	22
Rural districts:	1911–14	102	100	27
	1928–30	89	100	30

From this it will be seen that in 1911–14 the death-rate at ages 0–4 years in the county boroughs was 47 % greater than that at ages 5–9, but in 1928–30 the excess was reduced to 26 %. In the country districts the disease is mainly one of school ages, and its tendency to increased concentration at this period of life is clearly manifested. In the early period the pre-school mortality was only 2 % greater, whereas in the later period, 1928–30, it was actually 11 % in defect of that at ages 5–9 years.

Scotland

A change in the age incidence of the disease has also taken place in Scotland. The indices are:

		Ages in years		
		0–4	5–9	10–14
Scotland:	1900–2	320	100	21
	1931–3	149	100	29
Principal towns:	1900–2	414	100	18
	1931–3	165	100	23
Rest of Scotland:	1900–2	279	100	22
	1931–3	129	100	28

In the whole of Scotland the mortality at ages 0–4 years, during 1900–2, was 220 % in excess of that at ages 5–9, but 30 years later the excess was barely 50 %. As regards the experience in the "principal towns", it must be understood that we are not comparing cities which have remained constant either in size or number (there were, in point of fact, many more towns included in the later period), but broadly speaking the areas designated "principal towns" and "rest of Scotland" represent the urban and rural divisions of the country respectively. According to this classification the ratio has changed more rapidly in the towns. In 1900–2 it was as high as 414 %, but in 1931–3 it declined to 165 %. In contrast the comparable rural indices were respectively 279 and 129 %.

Ireland

The inclusion of Ireland is particularly desirable because the birth-rate in that country has declined only very slightly and, as a consequence, the age constitution of the child population has not undergone any change commensurate with that in either England and Wales or Scotland. The ratios were:

		Ages in years		
		0–4	5–9	10–14
Ireland:	1899–1903	222	100	28
	1924–8	143	100	28

(N.B. The most recent census of population in the Irish Free State and in Northern Ireland at the time of writing this report was that taken in 1926.)

The initial magnitude of the index, 222%, or its subsequent decline to 143% was not of the same dimensions as in either of the two home countries, but, in explanation, it must be remembered that Ireland is much more rural in character than is either England and Wales or Scotland, although its mortality experience can never fully accord with that for purely rural areas.

LONDON AND GLASGOW

So far we have described the correlation between the respective mortality rates at ages 0–4 and 5–9 years in different countries; we will now illustrate their relationship in two large cities, London and Glasgow, which differ appreciably in their respective environmental conditions. In Glasgow, owing to the tenement nature of its housing, existence is much more congested and infection is thereby spread more easily. The indices, or ratios, for the two cities are:

		Ages in years		
		0–4	5–9	10–14
London:	1900–2	228	100	14
	1927–30	195	100	19
Glasgow:	1900–2	487	100	16
	1927–30	277	100	14

The ratio has declined in both cities during the period examined, but the shift which has taken place in Glasgow is much greater than that in London.

PREVIOUS INVESTIGATIONS

The relative age shift in the incidence of diphtheria has been commented upon by several investigators. Murphy (1907) reviewed the trend of the mortality from the disease in London during the period 1859–1905. By a series of graphs, representing the deviations of the mortality at ages from the mean at all ages, he demonstrated that in the early epidemic years, 1859–65, the death-rate at pre-school age was high in relation to that at ages 5–15; during the ensuing 20 years, when the prevalence declined, a reduction in the age mortality occurred, but chiefly amongst the younger children, and, when the disease reverted to epidemic proportions, as in 1891–5, the increased mortality "was most marked at ages 5–10 and 10–15". His conclusions were:

> There has, therefore, been a change in age-incidence, which there is reason for thinking is rhythmical; but the whole story is not yet complete, for we need the periods 1906–10 and 1911–15, or indeed still later periods, to enable us to see whether the lines which they will provide will resemble those of 1866–70 and 1871–5. Possibly, however, there will be less conspicuous curves in these years, owing to the greater aggregation of children in school leading to increased incidence of mortality at the school age.

Chalmers (1913) from a study of the age mortality in Scotland as a whole, for triennial periods, of which the census year was intermediate, beginning at 1860–2 and ending at 1909–11, demonstrated the relative change which took

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place in the age incidence of the disease. He also examined notifications according to age for each year between 1903 and 1912 in Glasgow and described his results in the following terms:

> The changed age-incidence, which began here in the year 1906, is, I think, significant, because it has been maintained in each of the subsequent years, and raises questions which concern age-immunity on the one hand, and the acquisition of a greater infecting power of the organism on the other. With the increasing prevalence there has been a relatively greater invasion of the age period.
>
> The "infectious diseases of childhood" is a convenient phrase whereby to express the increasing immunity to these diseases which individuals acquire on passing through childhood to maturity. Here, however, we have illustration of the spread of an epidemic associated with an alteration in the age-incidence of attack, and selecting not an earlier, but a later age-period. It may be that a new page has been opened in the natural history of disease.

The most interesting and most recent contribution to the subject was made by Picken (1937). From a very careful study, particularly of the morbidity and fatality in London, Manchester and Glasgow, he indicated that the shift was not one of morbidity, but rather of fatality and suggested as a possible explanation, "...changes of strain of *Corynebacterium diphtheriae*".

Present investigation

It seemed to us that the question of the relative change in the age distribution of the disease might possibly be explained on grounds other than of a change in the type of organism. During the last 30 or 40 years there has been undoubtedly a decline in the average size of family in this country. The reasons which prompted it and the methods which produced it are immaterial issues. In all probability the reduction is attributable largely to the increasing practice of limitation amongst the lower rather than amongst the higher social grades because the latter during the last fifty years always tended to have small families. Arising from this contention are certain considerations, which, in themselves, may shed some light on the relative change in the age incidence of the mortality not only of diphtheria but also of scarlet fever.

Where the family is small there is obviously less chance of the pre-school children acquiring partial or complete immunity. They live a rather sheltered existence and reach school as a "virgin" population susceptible to infection. The vital statistical experience of children living in residential districts is in complete accord with this hypothesis. Their morbidity rates from infectious diseases at ages 5–9 years are invariably higher than those of children of the same age in the lower social scale, whereas the converse is true for the pre-school population. If, as we contend, the size of families in the lower social grades has become smaller in course of time and housing conditions have also improved, then it follows that the children born in such communities are approximating to those in the higher social classes as regards liability to infection and age of attack. Proportionately more of them will reach school age without a latent immunity and become infected in the "herd" environment of the school classroom. The present investigation was undertaken with the idea of ascertaining the extent to which this hypothesis will explain the age shift which has occurred.

DATA

The official statistics published in this country will not permit an answer because the morbidity records of the disease are not given in age groups for the appropriate social grades and this information is necessary for a complete examination of the problem. By the courtesy of the Medical Department of the London County Council we were given access to the weekly notification registers of infectious diseases covering the period 1901–34 inclusive. We extracted for each week in specific groups of years, 1901–5, 1909–13, 1919–23 and 1929–33, particulars of age, sex and borough in which the patient lived. It will be readily appreciated that this amount of extraction involved considerable labour. We next calculated the social index for each London borough by a method which is akin to that of indirect standardization. With the introduction of a genuinely occupational tabulation in the census of population of 1921 the late Dr Stevenson grouped the nine hundred odd occupations in this country into five social classes, where I–V represented a well demarcated gradient in the social scale. We made a similar tabulation of the occupied males in London as a whole and then measured each of the five London classes as a mean deviate on the normal scale. These deviates were then applied to the corresponding occupational groupings for each London borough and the required index of its social status was thus obtained. An example will clarify the explanation:

	London		Battersea	
Social class	Occupied males (1)	Mean deviate on the normal scale (2)	Occupied males (3)	(2) × (3)
I	42,116	2·2630	991	2,242·63
II	287,765	1·1591	10,636	12,328·19
III	581,538	0·1378	21,806	3,004·87
IV	231,179	−0·6543	8,731	− 5,712·69
V	243,103	−1·4716	9,851	−14,496·73
		Totals	52,015	− 2,633·74

$$\text{Index of social status for Battersea} = \frac{-2{,}633{\cdot}74}{52{,}015} = -0{\cdot}0506$$

When the index for each Metropolitan borough was estimated, the results were finally classified into four broad categories which have been adopted in this paper, class I representing the best and class IV the worst social class. The boroughs listed in each category were:

Class I	Class II	Class III	Class IV
Hampstead	City of London	Battersea	Bermondsey
Holborn	Camberwell	Deptford	Bethnal Green
Kensington	Chelsea	Greenwich	Finsbury
Lewisham	Fulham	Hammersmith	Poplar
Paddington	Hackney	Islington	Shoreditch
Stoke Newington	Lambeth	Stepney	Southwark
Wandsworth	St Marylebone	Woolwich	
Westminster	St Pancras		

For each of these categories the necessary morbidity and mortality rates at ages were calculated. Their trend, both secular and within the social class, their relationship to size of family and its change and to size of epidemic, all form the basis of our present discussion.

Incidence in London generally

The case rates per 1000 of the population for males, females and persons are given in Table I. It will be observed that the incidence has increased appreciably

Table I. *Diphtheria case rates per* 1000 *of the population by age and sex. London*

	1901–5 Ages in years				1909–13 Ages in years			
	0–4	5–9	10–14	0–14	0–4	5–9	10–14	0–14
Males	7·15	5·68	2·06	5·11	5·62	5·06	1·76	4·25
Females	6·59	6·89	2·59	5·44	5·15	6·01	2·29	4·55
Male incidence as percentages of females	108	82	80	94	109	84	77	93
Persons	6·87	6·29	2·33	5·28	5·38	5·54	2·03	4·40

	1919–23 Ages in years				1929–33 Ages in years			
	0–4	5–9	10–14	0–14	0–4	5–9	10–14	0–14
Males	10·75	10·91	4·63	8·71	12·08	11·21	3·45	8·84
Females	9·90	12·42	5·84	9·33	10·61	12·08	4·66	9·09
Male incidence as percentages of females	109	88	79	93	114	93	74	97
Persons	10·33	11·66	5·24	9·02	11·35	11·64	4·05	8·96

in the course of time as the case rates in the later periods are much higher than those existing 30 years earlier. This, however, does not necessarily imply that the disease itself has actually increased. Possibly, there was a growing tendency on the part of medical practitioners to play for safety and to notify doubtful cases as diphtheria, the diagnostic error being approximately 20%. Supplementing this is the inclusion in official returns of an increasing number of bacteriological cases of diphtheria, the importance of which, in relation to social class, will be discussed later. The table reveals a marked difference in the sex ratio of the case rate at various ages. Briefly it is this, amongst the pre-school population the incidence of diphtheria is greater for boys, whereas at school ages the rate is higher amongst girls. The higher incidence amongst females as compared with males at ages 10–14 years is understandable inasmuch as girls of this age often act as nurses to their younger brothers and sisters and get infection from their wards. The sex difference between the case rates at the younger ages is a further manifestation that the environmental response of boys is different from that of girls in the immediate post-natal period. The mortality from all causes amongst males aged 0–4 years is always higher than that amongst females at the same age, but, in the next age group, 5–9 years, the female death rate is usually equal to or in excess of that for males. The sex ratio of the mortality in England and Wales exemplifies this fact:

	Age in years	
	0–4	5–9
Period	F./M.	F./M.
1891–1900	84	101
1901–10	84	103
1911–20	83	99

The relationship between the rates is more clearly depicted in Table II, where for each of the four periods, the rates at ages 0–4 and 10–14 years are expressed as percentages of the corresponding values at 5–9 years. This table illustrates very distinctly the sex difference as regards age of attack. For boys the highest incidence is at 0–4 years, for girls the age group 5–9 takes precedence. In each period the proportion at ages 10–14 is almost constant, although in 1919–23 there is evidence of an increase. At ages 0–4, however, the index for each sex declined appreciably between 1901 and 1923. The male ratio dropped from 126 to 99% and the female from 96 to 80%. In the final period there was an increment, a possible explanation of which is given in a later section. These results are almost identical with those found by Picken, who concluded from them that the age shift was not due to morbidity because,

Table II. *Diphtheria case rates by ages expressed as percentages of the case rate at ages* 5–9 *years for each sex. London*

	1901–5 Ages in years			1909–13 Ages in years			1919–23 Ages in years			1929–33 Ages in years		
	0–4	5–9	10–14	0–4	5–9	10–14	0–4	5–9	10–14	0–4	5–9	10–14
Males	126	100	36	111	100	35	99	100	42	108	100	31
Females	96	100	38	86	100	38	80	100	47	88	100	39
Persons	109	100	37	97	100	37	89	100	45	98	100	35

When the case rates in the age group 0–5 are compared with the corresponding case rates at ages 5–10 practically all the differences lie within the errors of random sampling.

It is perfectly true to say that the observed differences are not statistically significant, but the relevant consideration is that for a period of 20 years there had been a progressive decrease in the size of the ratio—the case rate at ages 0–4 years had been growing less important relative to that at school ages. We can most aptly measure the importance of this downward trend by testing the significance of the differences between the mean age of attack of children under 15 years of age at different intervals of time—the age of each notification was stated in the original records. The mean ages of males, females and persons, with standard errors, were as follows:

Mean age of attack in years under age 15

Period	Males	Females	Persons
1901–5	5·56	6·07	5·82 ± 0·018
1909–13	5·72	6·23	5·98 ± 0·020
1919–23	6·37	6·90	6·65 ± 0·016
1929–33	5·99	6·51	6·25 ± 0·016

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In each period the mean age of attack of females is higher than that of males by a constant difference of half a year. For each sex and the sexes combined the mean age of attack increases throughout the first three periods and falls between 1919–23 and 1929–33, but it is finally at a level higher than that of either of the first two periods. When the differences between mean ages of persons in the first three quinquennia were tested for statistical significance it was found that they were greater than would be expected in mere chance events. In a subsequent discussion upon mortality we have produced evidence to explain the lowered age incidence during 1929–33. Assuming our explanation to be correct we then have demonstrated a statistical increase in the age of attack during the period under investigation.

Age of attack and size of epidemic

We have seen that the incidence of the disease has increased, the case rates in 1929–33 being almost double those 30 years earlier. Likewise there has been a tendency for the mean age of attack to increase—the disease now attacking older children. This suggests a time correlation between the two variables. Turner (1923) in his paper on scarlet fever examined this particular aspect. He showed that, in most epidemic years, the mean age of all patients was high, but he failed to establish a general relationship, since the coefficients which he obtained between the annual number of cases and the mean age of attack over a series of years were:

$$\text{Males:}\quad r = +0{\cdot}17 \pm 0{\cdot}13,$$

$$\text{Females:}\quad r = +0{\cdot}13 \pm 0{\cdot}13.$$

Our problem is slightly different because we desire to know if the suggested shift in the incidence from ages 0–4 years to 5–9 is in any way governed by, or dependent upon, the annual amount of the disease. We accordingly took as our index the maximum weekly case rate in each year from 1897 to 1930—omitting the war years—and we correlated this with the corresponding ratio of the cases at ages 0–4 years to those at ages 5–9 years. We were unable to use the ratio of the *case rates* as it was impossible to make an estimate of the populations at the required ages. The post war population at this period of life was unduly disturbed in consequence of the serious fluctuations in the birth rate. The value of the correlation obtained was:

$$r = -0{\cdot}559 \pm 0{\cdot}128.$$

This indicates that in epidemic years, or in years of more or less abnormally high incidence, the children of the school ages are more affected than is the pre-school population. Why should this be so? The obvious answer is that there is a relatively greater proportion of susceptible children at the higher ages. But this answer involves the further question—why was the susceptibility postponed until school age?

There are either or both of two possibilities:

(*a*) The entrance into school life of relatively more children with no previous immunity in consequence of the improvement in the environment in which they lived.

(*b*) Children reaching early school life with a loss of the temporary immunity which they had previously acquired.

We know from the experimental work upon mice by Greenwood (1934) and Topley (1921) and from the epidemiological study of measles by Stocks & Karn (1928) that both mice and children do lose their temporary immunity and develop an attack on reintroduction of infection.

CASE RATES ACCORDING TO SOCIAL CLASS

The conditions under which children live must undoubtedly play a part in determining the age at which they acquire immunity, either partial or complete. Attendance at school involves the herding together of large numbers of children and thus facilitates the spread of infection. But this presupposes a non-immune population. The existence of such a population depends in its turn upon the domestic environment of the child during its pre-school life. Arising out of these considerations it is obviously necessary to study first the incidence of a disease like diphtheria in different types of environment. For this reason we have grouped the London boroughs into the broad social categories, which we have previously described, and the case rates are now presented in Table III. For purposes of reference the case rates at individual years of life up to age 14 are given for each social class and sex in the appendix tables.

There are two outstanding features of Table III:

(*a*) The nature of the correlation between incidence and social class. At ages 0–4 years for persons the case rate is negatively correlated with ascent in the social scale in every quinquennial period, the children in the poorest boroughs having the highest morbidity. The experience at ages 5–9 is quite different. Between 1901 and 1913 the incidence amongst children living in more or less residential districts, class I, is higher than that in the poorer type of neighbourhood, but after 1913 the positive changes to a negative relationship. This reversal in trend according to social class is characteristic of both males and females.

(*b*) The increased incidence of the disease in the latter periods as compared with the earlier periods. When the rates in 1929–33 are expressed as percentages of those in 1901–5 the results are:

Persons

Social class	1901–5 Ages in years		1929–33 Ages in years	
	0–4	5–9	0–4	5–9
I	100	100	149	165
II	100	100	151	155
III	100	100	180	212
IV	100	100	187	219

Table III. *Diphtheria case rates per* 1000 *of the population by age, sex and social class. London*

Social class*	1901–5 Ages in years 0–4	5–9	10–14	1909–13 Ages in years 0–4	5–9	10–14
Males:						
Social class I	5·76	5·60	2·02	4·82	6·06	2·20
Social class II	7·28	6·28	2·22	5·20	4·78	1·62
Social class III	7·08	5·58	1·90	6·06	5·54	2·02
Social class IV	8·28	5·08	2·06	6·36	3·78	1·16
All classes	7·15	5·68	2·06	5·62	5·06	1·76
Females:						
Social class I	4·92	6·64	2·42	4·32	6·94	2·78
Social class II	6·84	7·60	3·00	4·82	6·04	2·04
Social class III	6·76	6·42	2·34	5·70	6·30	2·40
Social class IV	7·48	6·76	2·52	5·62	4·68	2·00
All classes	6·59	6·89	2·59	5·15	6·01	2·29
Persons:						
Social class I	5·34	6·12	2·22	4·58	6·50	2·50
Social class II	7·05	6·95	2·61	5·00	5·40	1·84
Social class III	6·92	6·00	2·13	5·89	5·91	2·20
Social class IV	7·88	5·92	2·29	5·99	4·24	1·59
All classes	6·87	6·29	2·33	5·38	5·54	2·03

Social class*	1919–23 Ages in years 0–4	5–9	10–14	1929–33 Ages in years 0–4	5–9	10–14
Males:						
Social class I	8·28	10·68	4·50	8·34	10·04	3·04
Social class II	9·62	10·32	4·16	11·64	10·38	2·88
Social class III	11·24	11·38	5·22	13·36	12·20	4·16
Social class IV	14·00	11·32	4·60	15·18	12·22	3·64
All classes	10·75	10·95	4·63	12·08	11·21	3·45
Females:						
Social class I	7·68	11·56	5·26	7·54	10·14	3·80
Social class II	8·66	11·40	5·26	9·60	11·18	3·92
Social class III	10·04	13·32	6·22	11·50	13·30	5·36
Social class IV	13·54	13·44	6·74	14·24	13·72	5·66
All classes	9·90	12·42	5·84	10·61	12·08	4·66
Persons:						
Social class I	7·98	11·12	4·89	7·94	10·09	3·42
Social class II	9·15	10·86	4·71	10·63	10·77	3·40
Social class III	10·64	12·34	5·71	12·43	12·74	4·75
Social class IV	13·78	12·38	5·67	14·72	12·97	4·64
All classes	10·33	11·66	5·24	11·35	11·64	4·05

* Social class I is the best social class and social class IV the worst.

There have been substantial increases in all classes for both age periods, but particularly at ages 5–9 years in the lowest social class, in which the increment has been 119%. It is the large increase in the case rates at this age period amongst the poorer children in the two post-war periods that has altered the trend of the incidence according to social class. It may be that there are more wrongly diagnosed cases in this section of the community

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generally but this hypothesis cannot explain the age differentiation within this class, the percentage increase at ages 0–4 being 87 as compared with 119 at ages 5–9 years. Of course there is the possibility that bacteriological diphtheria cases occur more frequently in the lower than in the better class type of district. Woods (1928) has shown "that non-clinical cases appear to come mainly from the poorer districts". The correlation coefficient which she obtained between the variables (i) the percentage of the bacteriological cases to the total and (ii) the percentage of overcrowding in the London boroughs, for the period 1923–6, was

$$r = +0{\cdot}479 \pm 0{\cdot}100.$$

The inclusion of such cases in the London statistics was not, however, confined to the post-war period. In 1909 the bacteriological cases were tabulated separately in the reports of the Metropolitan Asylums Board. Their inclusion was accompanied by the following note:

It has been suggested that the decline in the mortality amongst cases of diphtheria, which follows the introduction of antitoxin-serum treatment of the disease, might largely be accounted for by the inclusion of numbers of cases which were certified as diphtheria after bacteriological test only. Therefore such cases have been shown this year in a separate column from those exhibiting the usual clinical signs of the disease.

Until 1922 the bacteriological cases formed approximately 5–9% of the total and afterwards from 8–11%.

All admissions of diphtheria cases to the Metropolitan Asylums Board Hospitals

Year	All cases of diphtheria	Bacteriological cases	Bacteriological cases as percentage of total cases
1909	4,603	210	4·56
1910	3,856	222	5·76
1911	5,390	356	6·60
1912	5,219	375	7·19
1913	5,475	399	7·29
1914	7,113	522	7·34
1915	7,251	475	6·55
1916	7,695	494	6·42
1917	7,391	600	8·12
1918	7,026	392	5·58
1919	7,741	557	7·20
1920	11,679	1,043	8·93
1921	13,369	937	7·01
1922	12,752	1,015	7·96
1923	8,350	828	9·92
1924	8,188	619	7·56
1925	10,251	1,004	9·79
1926	11,635	1,108	9·95
1927	10,320	1,165	11·29
1928	10,018	1,037	10·35
1929	9,890	881	8·91

In the reports, bacteriological cases of diphtheria and negative cases are combined, the latter being those in which there was no evidence of diphtheria beyond the admission certificate. The bacteriological cases were not tabulated by age and sex for the individual boroughs.

The effect of the bacteriological cases on the general trend of the case rate can only be slight, since this factor was operating during the whole of the period under discussion. Their incidence was never greater than 12% of the total cases and hence the very large increase in the case rates in the later as compared with the earlier quinquennia cannot be attributed to the inclusion of these particular types of cases.

If, however, the bacteriological cases were drawn mainly from certain age groups and particular boroughs, the rates, particularly the case rates, would be modified. Although the correlation found by Woods was large enough to justify her conclusion that the non-clinical cases seem to come largely from the poorer boroughs, the size of the correlation coefficient, 0·479, allows of a great deal of variation within the boroughs.

Since the age and sex in bacteriological cases are not given for the individual boroughs we cannot say whether the age incidence of such cases varies from district to district or even differs from that of ordinary diphtheria admissions to hospital within the same district. The only data available are those given for London as a whole. Comparing the percentage age distribution of the ordinary admissions with that of the bacteriological cases during the period 1925–9 in all fever hospitals, we arrive at the following results:

Age period in years	Ordinary admissions	Bacteriological cases
0–4	38·4	32·6
5–9	42·9	40·1
10–14	13·7	20·0
15–19	5·0	7·3
	100·0	100·0

The bacteriological cases are, on the average, older than the ordinary admissions, that is, there is a higher proportion of these at age 10 and over, but, since we are only concerned with the relative age shift of the incidence from ages 0–4 to 5–9 years, it is obvious that their inclusion in the total admissions could not materially influence the issue as regards London as a whole. It may be argued that this is no answer to the question as we are solely concerned with their influence at a specific age in specific districts or boroughs. We can only say that, in view of the age distribution we have demonstrated for London as a whole and the correlation found by Woods between the incidence of diphtheria bacteriological cases and overcrowding, the inclusion of such cases, while presumably increasing the diphtheria case rates at ages 0–4 and 5–9 years relatively more in the poorer areas, cannot alter their ratio to any significant extent.

Ratio according to social class

(*a*) *Persons*

When the attack rates at ages 0–4 years are expressed as percentages of those at ages 5–9 years there is, as is shown in Table IV, a steady decline during the first three periods in the relative importance of the pre-school incidence for

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the combined classes and for each social class except class IV. This tendency for the age of attack to be higher and the consequent diminution of the relative importance of the pre-school ages is distinctly checked in the period 1929–33, when the attack rate of all classes under age 5 is only slightly lower than that at ages 5–9 years. Although the ratio in the last quinquennium, 1929–33, is proportionately more important in the preceding period, it still remains below that of 1901–5.

Table IV. *Diphtheria case rates at ages expressed as percentages of the case rate at ages 5–9 by sex and social class. London*

	1901–5 Ages in years			1909–13 Ages in years		
Social class*	0–4	5–9	10–14	0–4	5–9	10–14
Males:						
Social class I	103	100	36	80	100	36
Social class II	116	100	35	109	100	34
Social class III	127	100	34	109	100	36
Social class IV	163	100	41	168	100	31
All classes	126	100	36	111	100	35
Females:						
Social class I	74	100	36	62	100	40
Social class II	90	100	39	80	100	34
Social class III	105	100	36	90	100	38
Social class IV	111	100	37	120	100	43
All classes	96	100	38	86	100	38
Persons:						
Social class I	87	100	36	70	100	38
Social class II	101	100	38	93	100	34
Social class III	115	100	36	100	100	37
Social class IV	133	100	39	141	100	38
All classes	109	100	37	97	100	37

	1919–23 Ages in years			1929–33 Ages in years		
Social class*	0–4	5–9	10–14	0–4	5–9	10–14
Males:						
Social class I	78	100	42	83	100	30
Social class II	93	100	40	112	100	28
Social class III	99	100	46	110	100	34
Social class IV	124	100	41	124	100	30
All classes	99	100	42	108	100	31
Females:						
Social class I	66	100	46	74	100	37
Social class II	76	100	46	86	100	35
Social class III	75	100	47	86	100	40
Social class IV	101	100	50	104	100	41
All classes	80	100	47	88	100	39
Persons:						
Social class I	72	100	44	79	100	34
Social class II	84	100	43	99	100	32
Social class III	86	100	46	98	100	37
Social class IV	111	100	46	113	100	36
All classes	89	100	45	98	100	35

* Social class I is the best social class and social class IV the worst.

The trend indicated by these ratios can be illustrated concisely by the mean age of attack for each social class. The means ages are as follows:

Mean age of attack in years of cases under age 15. *Persons*

Social class	1901–5	1909–13	1919–23	1929–33
I	6·19	6·57	7·01	6·52
II	5·98	5·99	6·66	6·12
III	5·66	5·95	6·73	6·34
IV	5·53	5·37	6·25	6·08
All	5·82	5·98	6·65	6·25

It will be noted that in confirmation of the deductions drawn from Table IV that up to the third period there is a tendency for the age of attack to increase, whereas between 1919–23 and 1929–33 the mean age of attack falls. In the first two periods the mean age of attack increases as the social class improves, but in the last two periods the sequence is broken by the interchange of position of classes II and III. Thus, throughout, the best social class has a higher mean age of attack than the worst, the differences ranging from 0·44 to 1·20 years during the four periods.

(*b*) *Males and females*

So far the discussion upon the influence of social conditions upon the incidence of the disease has been restricted to the combined sexes, but the attack rates show some variation between sexes.

Referring to Tables III and IV generally, with few exceptions the rate at ages 0–4 years declines in importance within each period as the social class improves. For males in 1901–5 the rate at ages 0–4 years in each class is greater than that at ages 5–9 years; in 1909–13 and 1929–33 the three lowest social classes have a rate in the pre-school ages in excess of that at ages 5–9 years, but, in 1919–23, only the lowest social class has a rate which is larger at the earlier age group. For females, the lowest social class has the highest rate at ages 0–4 years in each period but, for all other classes except the second lowest social grade in 1901–5, the rate at ages 5–9 years is more important. Of the sixteen observations the male rate at ages 0–4 years exceeded that at ages 5–9 years on eleven occasions and was in defect five times. These numbers are reversed for females as their rate at ages 0–4 years was lower upon eleven occasions and higher five times.

Thus while the change in the relative importance of the age groups occurred at an earlier period for the females than for the males, the latter are following the female trend, although there exists a definite time lag. The result is that the statistical experience of the combined sexes does not reflect the change as clearly as does that for the females alone.

(*c*) *General*

One point does, however, stand out clearly from the two tables, namely children in the lowest social class have larger case rates in the pre-school ages than do children in the highest social grade and as the social status improves the pre-school ages lose their relative importance to the school ages. This influence of environment upon the attack rate and the age of attack can be demonstrated briefly by correlation coefficients between the relevant variables. Woods found that the morbidity rate and certain social environmental indices in the London boroughs for the period 1923–6 were correlated as follows:

	r
Diphtheria attack rate and infant mortality	$+0{\cdot}443 \pm 0{\cdot}104$
Diphtheria attack rate and poverty	$+0{\cdot}573 \pm 0{\cdot}087$
Diphtheria attack rate and prosperity	$-0{\cdot}716 \pm 0{\cdot}063$

Her poverty index was based upon the percentage overcrowding, while for prosperity the percentage of the population in the social classes I and II—the Registrar-General's occupational classification—was used. It will be seen that all these correlations are statistically significant and indicate that high attack rates are associated with poor social conditions.

We assessed the relationship between the mean age of attack of cases under age 15 years and (i) the legitimate birth rate and (ii) overcrowding, for three different periods in the London boroughs and the results were:

	Mean age of attack under age 15 years and	
Period	(i) The legitimate birth-rate r	(ii) Overcrowding r
1909–13	$-0{\cdot}609 \pm 0{\cdot}119$	$-0{\cdot}830 \pm 0{\cdot}059$
1919–23	$-0{\cdot}526 \pm 0{\cdot}137$	$-0{\cdot}702 \pm 0{\cdot}096$
1929–33	$-0{\cdot}382 \pm 0{\cdot}161$	$-0{\cdot}679 \pm 0{\cdot}102$

The sign and size of these coefficients indicate that, in overcrowded areas where large families are usual, diphtheria infection occurs mainly at an early age.

We can adduce additional information to support this correlation. If we take the three cities, London, Glasgow and Dublin, and calculate for each, (i) the infant mortality as an index of environment, (ii) the birth rate and (iii) the ratio of the diphtheria case rates at ages 0–4 and 10–14 years to that at ages 5–9 years, then we obtain the following particulars:

		Infant mortality deaths under one year per 1000 births	Birth-rate per 1000 females aged 15–45 years	Diphtheria case rates as percentages of the rates at ages 5–9 years		
	Period			0–4	5–9	10–14
London	1927–30	64	609	195	100	19
Glasgow	1927–30	105	861	277	100	14
Dublin	1924–8	119	1084	321	100	11

In Dublin where the environment is much worse and the families much larger—deducible indirectly from the high birth-rate—than in London, the relative incidence of diphtheria in the pre-school, to that at school age, is much higher.

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Influence of improved environment and smaller families

We have shown that in the poorest areas of London the case rate is highest at ages 0–4 years whereas in residential areas it is greatest at ages 5–9 years. If, then, the general conditions of life in the lowest social grade be improved—less overcrowding, more cleanliness and smaller families—it follows that the morbidity history of the slum children as regards infectious diseases may approximate to that of children in the highest social classes and, as a consequence, there will arise a tendency towards a relative age shift in the incidence.

There is no standard sufficiently adequate to represent what is termed "environmental conditions", but there are approximate indices, some of which we have previously used. The principal of these are:

(i) the percentage of the population living more than two in a room,

(ii) the infant mortality,

(iii) the standardized death-rate from all causes.

Although these measurements are highly interrelated we have made the necessary calculations of each at two different periods, 1911–13 and 1930–2, and accepted the difference in the size of the particular index as indicative of environmental improvement. We have no official statistics which will enable us to evaluate the change which has occurred in the size of family within the social grades, but, as an indication, we have submitted the alteration in the legitimate birth rate between 1911 and 1932. The results for the social classes I and IV, at opposite ends of the social scale, will afford the most satisfactory test of our hypothesis. These were as follows:

	Social class I	Social class IV
Standardized death-rate per 1000 of the population (1911–13)–(1930–2)	2·81	6·21
Infant mortality, deaths under 1 year per 1000 births (1911–13)–(1930–2)	30	64
Percentage of the population living more than two in a room (1911)–(1931)	3·0	4·8
Legitimate birth-rate, per 1000 married women aged 15–45 (1911–13)–(1930–2)	63	100

It will be seen that the reduction both in the birth-rate and in the environmental indices was greater in the lowest social grade. The standardized death-rate declined 6·21 per 1000 as compared with 2·81 in class I, the corresponding decreases in the infant mortality were 64 and 30 per 1000 births.

As a consequence of this relatively greater improvement in their hygienic life and a relatively larger reduction in their birth-rate, we should expect to find a larger age shift in the morbidity amongst the lower than the higher social class. This is exactly what has occurred, as will be seen from the differences between the ratios of the case rates at ages 0–4 years to that at ages 5–9 years in 1929–33 and 1909–13, which for classes I and IV are as follows:

	Social class I	Social class IV
Diphtheria case rate aged 0–4 years as a percentage of that aged 5–9 years (1929–33)–(1909–13)	8	20

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The interesting point now arises as to which of the two variables—the improved environment or the decrease in size of families—had the greater influence in producing the relative age shift in the disease. To apportion the responsibility we have calculated correlation coefficients between the following variables:

(1) The decrease in infant mortality (1911–13)–(1930–2), as representing improved environment.

(2) The decrease in the legitimate birth-rate (1911–13)–(1930–2), as indicating the existence of smaller families.

(3) The change in the ratio of the case rates, case rate at ages 0–4 years as a percentage of that at ages 5–9 years (1909–13)–(1929–33).

The total correlation coefficients were:

$$r_{13} = +0{\cdot}479 \pm 0{\cdot}146, \qquad r_{23} = +0{\cdot}573 \pm 0{\cdot}127.$$

The total coefficients are positive and statistically significant, the value of r_{23} being the numerically more important. The variables (1) and (2) are highly interrelated and hence it is necessary to isolate the importance of the one when correlating the other with the variable (3). This has been done by calculating the partial or first order coefficients which are:

$$r_{13.2} = +0{\cdot}063 \pm 0{\cdot}188, \qquad r_{23.1} = +0{\cdot}363 \pm 0{\cdot}164.$$

The influence of the smaller families is the more important factor, the total correlation between this and the change in the case rate ratio was $+0{\cdot}573$; when "environmental improvement" was made constant this correlation was reduced to $+0{\cdot}363$, but the value is still statistically significant. When a similar allowance was made for the influence of the birth-rate on the correlation between the change in the ratio of the case rates and "environmental improvement" the coefficient, $r = +0{\cdot}063$, which is less than its standard error, was obtained.

Hence the increasing tendency of diphtheria to concentrate relatively more upon early school ages has arisen partly as a result of the families becoming smaller in the lower social grades and the morbidity experience of children in this section of the community plays a large part in determining the ultimate case rate and its age shift for London as a whole.

MORTALITY ACCORDING TO SOCIAL CLASS

We come finally to a study of the mortality according to social class. The essential information is given in Table V, into which the case rates have also been introduced so that the trend of the morbidity and mortality rates can be easily compared. We could not obtain the rates for the separate age groups 5–9 and 10–14 years because the deaths for the individual boroughs are published only for the composite group 5–14 years. This fact is, however, not of very great importance because previous investigators have shown that mortality at the higher school ages also exhibited a relative increase. The figures which Picken published for England and Wales were:

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Diphtheria mortality at ages 0–5 and 10–15 years as percentages of that at 5–10 years. Persons

Period	Ages in years 0–5	5–10	10–15
1909–13	145	100	17
1919–23	131	100	24
1929–33	112	100	26

Table V. *Diphtheria case and death-rates by age and social class showing the rates at ages 0–4 years as percentages of the rates at ages 5–14 years. London. Persons*

Social class*	1909–13† Ages in years 0–4	5–14	Ratio‡	1919–23 Ages in years 0–4	5–14	Ratio‡	1929–33 Ages in years 0–4	5–14	Ratio‡
				Case rates per 1000 of the population					
Social class I	4·58	4·58	100	7·98	7·94	101	7·94	6·76	117
Social class II	5·00	3·68	136	9·15	7·76	118	10·63	7·10	150
Social class III	5·89	4·14	142	10·64	8·97	119	12·43	8·75	142
Social class IV	5·99	2·96	202	13·78	9·02	153	14·72	8·92	165
All classes	5·38	3·85	140	10·33	8·41	123	11·35	7·87	144
				Death-rates per 10,000 of the population					
Social class I	5·51	2·61	211	11·09	4·98	223	5·23	2·42	216
Social class II	5·99	1·90	315	12·42	4·98	249	6·58	2·61	252
Social class III	7·25	2·07	350	13·53	4·84	280	5·90	2·13	277
Social class IV	9·36	1·47	637	19·05	4·37	436	7·23	1·93	375
All classes	6·97	2·01	347	13·88	4·81	289	6·20	2·29	271

* Social class I is the best social class and social class IV the worst.

† Death-rates based on the years 1911–13 only.

‡ Ratio refers to the rates at ages 0–4 years expressed as percentages of the 5–14 rates.

Hence the death-rate in the combined group 5–14 years, when compared with that in the pre-school ages, will reflect the change which has taken place in the age distribution of the disease.

The mortality figures indicate the necessity of taking social class into consideration when discussing the question of age shift. According to the experience of the combined classes the ratio of the mortality amongst the pre-school to that amongst the school population declined from 347% in 1911–13 to 271% in 1929–33, thus indicating the increasing concentration on the school ages, but there was a considerable class divergence. In social class I —the best districts—the ratio has been almost constant over the whole period under review, 211% in 1911–13, and 216 in 1929–33; whereas in the lowest social group—social class IV—the decline has been considerable, in the first period the index, or ratio, was 637% and it decreased to 375% in the last quinquennium.

Thus the age shift in the diphtheria mortality from pre-school to school ages amongst the child population in London has been solely due to the influence of the trend of the death-rates in the lower social groups. At first it would appear that the movement is one of mortality and not of morbidity because the ratio, 144 %, for the latter in 1929–33 is even higher than the corresponding value, 140, in 1909–13. It was owing to the almost constant size of the morbidity ratio and the decline in the fatality ratio that Picken postulated the change in the type of organism as a possible or probable explanation of the changing age incidence of diphtheria. But a comparison of the actual case rates and death-rates at the various quinquennial periods does not suggest that the disease has changed its type. In 1909–13 the case rates of all classes at ages 0–4 and 5–14 years were 53·8 and 38·5 per 10,000, with associated mortality rates of 6·97 and 2·01 respectively. In the succeeding period the disease was apparently of epidemic proportions and the case rates were doubled. If the killing power of the disease remained unaltered one would expect the mortality at the two age periods during 1919–23 to be almost doubled. This is exactly what occurred, the death-rates being 13·88 per 10,000 at ages 0–4 years and 4·81 at ages 5–14 years. In the last quinquennium the incidence at the younger ages continued to increase but the mortality declined, whereas at ages 5–14 years both the morbidity and the mortality decreased relative to that in 1919–23. Thus the statistical experience of children aged 0–4 years in this period—an increased incidence accompanying a decreased mortality—suggests that the case rate was swollen considerably by the inclusion of mild or non-diphtheritic cases. Consequently, if it were possible to make the necessary adjustment in the case rate by excluding such cases, the revised ratio would probably be less than its present value of 144 % and the morbidity would then indicate the age shift to school years, but, possibly, not so distinctly as does mortality. The reason for the discrimination is this—the transfer of a few cases from one age group to another may not appreciably alter the ratio of the respective case rates but the transfer of a few deaths will certainly have a disturbing effect, because the death-rates in themselves are quite small.

SUMMARY AND CONCLUSIONS

The purpose of the investigation was to examine the reason for the relative age shift in the incidence of diphtheria. The disease has been represented as now concentrating on children of school ages. We analysed, for various quinquennial periods beginning with 1901–5, the statistics of the notifications and deaths according to age and sex in the London boroughs which we classified into four social classes where I to IV represented descending order in the social scale. The conclusions arrived at were:

I. The age shift as represented by the ratio of the mortality at ages 0–4 to ages 5–9 years which has taken place in London has been found to occur mainly in the poorer districts. The ratio in the residential districts has not altered appreciably during the thirty years under review (Table V).

II. The age shift is also indicated by the morbidity statistics for the three quinquennial periods, 1901–5, 1909–13 and 1919–23, as there was a significant increase in the mean age of attack of children under 15 years of age.

The case rate at ages 5–14 during 1929–33 as compared with that in 1901–5 has increased most amongst children in the lowest social group.

III. Each of the variables (*a*) the decrease in the birth-rate between 1911 and 1931 in each London borough—an index of the change in the size of family—and (*b*) the decrease in infant mortality—a measurement of environmental improvement—is positively and significantly correlated with (*c*) the corresponding change in the size of the ratio of the case rates at ages 0–4 to 5–9 years. The coefficients were:

$$r_{ac} = +0{\cdot}573 \pm 0{\cdot}127, \qquad r_{bc} = +0{\cdot}479 \pm 0{\cdot}146,$$

but the partial correlation coefficients

$$r_{ac.b} = +0{\cdot}363 \pm 0{\cdot}188, \qquad r_{bc.a} = +0{\cdot}063 \pm 0{\cdot}164,$$

indicate that the change in the size of family is the more important factor as the value of $r_{ac.b}$ is fairly large and significant, whereas the correlation between the change in the ratio and the environmental improvement when the effects of the decreasing birth-rate are made constant—$r_{bc.a}$—becomes statistically unimportant.

General conclusion

Hence, in consequence of the family becoming smaller the children in the lowest social grades are not being subjected to the same intensity of exposure in their pre-school life as hitherto and it is the morbidity experience of these children which mainly determines the size of the case rate at ages 0–4 in London as a whole. These children are now approximating to those living in residential districts in as much as relatively more of them are contracting the disease during school life.

We wish to express our thanks to the Medical Department of the London County Council for their kindness in allowing us to extract the weekly notifications of the disease from their registers.

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APPENDIX

Average annual attack rates for each social class and age for males, females and persons. London. 1909–13

Social class*	Ages in years														
	0–	1–	2–	3–	4–	5–	6–	7–	8–	9–	10–	11–	12–	13–	14–15
Class I:															
Males	1·4	2·9	4·9	6·5	8·5	9·0	7·4	5·5	4·8	3·3	3·1	2·2	2·2	1·7	1·7
Females	0·9	2·7	4·3	6·2	7·5	9·0	8·7	7·1	5·4	4·4	3·8	3·0	3·0	2·2	1·9
Persons	1·2	2·8	4·6	6·3	8·0	9·0	8·1	6·3	5·1	3·9	3·5	2·6	2·6	2·0	1·8
Class II:															
Males	1·7	4·4	5·7	7·3	7·2	7·5	5·9	4·8	3·1	2·3	2·3	1·9	1·5	1·3	1·0
Females	1·3	3·6	4·9	6·7	7·7	9·1	7·8	5·8	3·8	3·5	3·1	2·1	1·9	1·8	1·2
Persons	1·5	4·0	5·3	7·0	7·4	8·3	6·8	5·3	3·5	2·9	2·7	2·0	1·7	1·6	1·1
Class III:															
Males	2·2	5·6	6·4	8·1	8·2	8·7	6·6	5·1	4·1	2·9	2·8	2·4	2·1	1·6	1·2
Females	1·7	4·8	6·3	7·8	8·0	8·9	8·0	5·9	4·6	3·9	3·4	2·8	2·3	2·2	1·2
Persons	1·9	5·2	6·3	8·0	8·1	8·8	7·3	5·5	4·4	3·4	3·1	2·6	2·2	1·9	1·2
Class IV:															
Males	2·7	7·3	7·0	7·5	7·7	6·5	4·2	3·6	2·7	1·8	1·2	1·4	1·4	1·0	0·9
Females	2·5	5·7	5·7	7·1	7·4	7·8	5·4	4·3	3·2	2·4	2·3	2·1	2·6	1·5	1·5
Persons	2·6	6·5	6·4	7·3	7·5	7·2	4·8	4·0	3·0	2·1	1·7	1·7	2·0	1·3	1·2
All classes:															
Males	2·0	5·1	6·0	7·4	7·9	8·0	6·1	4·8	3·7	2·6	2·4	2·0	1·8	1·4	1·2
Females	1·6	4·2	5·4	7·0	7·7	8·7	7·5	5·8	4·3	3·6	3·2	2·5	2·4	1·9	1·4
Persons	1·8	4·6	5·7	7·2	7·8	8·3	6·8	5·3	4·0	3·1	2·8	2·2	2·1	1·7	1·3

* Social class I is the best social class and social class IV the worst.

Average annual attack rates for each social class and age for males, females and persons. London. 1919–23

Social class*	Ages in years														
	0–	1–	2–	3–	4–	5–	6–	7–	8–	9–	10–	11–	12–	13–	14–15
Class I:															
Males	2·6	6·0	12·7	12·6	11·8	13·5	12·2	10·9	9·4	7·8	7·2	5·6	3·9	3·3	2·7
Females	1·9	4·8	11·0	13·4	11·9	14·6	13·4	11·6	9·8	8·9	7·3	5·4	6·3	4·4	3·2
Persons	2·3	5·4	11·8	13·0	11·8	14·0	12·8	11·2	9·6	8·3	7·2	5·5	5·1	3·8	3·0
Class II:															
Males	3·0	6·9	14·9	16·2	12·9	15·5	12·5	10·5	7·8	5·9	6·2	4·9	4·1	3·3	2·2
Females	2·2	5·1	13·0	16·4	12·6	14·7	13·4	11·6	9·3	8·3	6·3	6·4	5·5	4·7	3·4
Persons	2·6	6·0	14·0	16·3	12·8	15·1	13·0	11·0	8·5	7·1	6·3	5·7	4·8	4·0	2·8
Class III:															
Males	3·7	8·3	16·1	17·9	15·4	15·2	13·1	12·0	9·3	7·5	6·0	6·0	5·9	4·8	3·4
Females	2·6	6·5	14·6	17·7	14·4	17·2	15·5	13·1	11·4	9·7	8·5	7·5	6·3	5·1	3·6
Persons	3·1	7·4	15·4	17·8	14·9	16·2	14·3	12·6	10·4	8·6	7·3	6·8	6·1	5·0	3·5
Class IV:															
Males	4·8	10·0	21·9	23·7	18·0	17·4	12·4	11·1	9·3	6·9	6·2	5·5	4·8	4·1	2·4
Females	3·9	9·3	21·0	22·7	19·5	19·7	15·9	12·4	10·6	9·3	8·3	8·1	6·6	6·7	4·0
Persons	4·3	9·7	21·4	23·2	18·7	18·5	14·2	11·7	9·9	8·1	7·3	6·8	5·7	5·4	3·2
All classes:															
Males	3·5	7·8	16·3	17·5	14·5	15·4	12·6	11·1	8·9	7·0	6·3	5·5	4·7	3·9	2·7
Females	2·6	6·4	14·7	17·5	14·4	16·4	14·6	12·2	10·3	9·0	7·6	6·8	6·1	5·1	3·5
Persons	3·1	7·1	15·5	17·5	14·4	15·9	13·6	11·7	9·6	8·0	7·0	6·2	5·4	4·5	3·1

* Social class I is the best social class and social class IV the worst.

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Average annual attack rates for each social class and age for males, females and persons. London. 1929–33

Social class*	Ages in years														
	0–	1–	2–	3–	4–	5–	6–	7–	8–	9–	10–	11–	12–	13–	14–15
Class I:															
Males	3·1	6·1	8·5	12·3	12·2	14·9	12·6	10·0	7·7	6·0	4·2	2·7	3·9	2·8	1·5
Females	1·9	4·7	9·6	10·5	11·4	14·2	13·3	9·9	7·8	6·6	4·6	3·8	4·9	3·9	1·8
Persons	2·5	5·4	9·1	11·4	11·8	14·5	12·9	9·9	7·7	6·3	4·4	3·3	4·4	3·4	1·7
Class II:															
Males	5·0	8·9	14·0	14·8	16·5	16·4	13·5	9·9	7·6	5·8	3·9	2·6	3·2	3·1	1·6
Females	3·9	7·3	11·1	12·6	13·7	16·0	14·5	11·5	8·4	6·5	5·0	3·9	5·0	3·8	1·9
Persons	4·4	8·1	12·6	13·7	15·1	16·2	14·0	10·7	8·0	6·1	4·4	3·2	4·1	3·5	1·7
Class III:															
Males	4·6	9·8	15·7	18·4	19·1	19·3	15·6	11·6	8·5	7·3	5·7	3·9	5·4	3·6	2·0
Females	3·0	8·2	12·8	15·8	18·2	19·2	16·3	12·8	10·6	8·7	7·2	5·3	6·4	5·1	2·7
Persons	3·8	9·0	14·2	17·1	18·7	19·2	16·0	12·2	9·5	8·0	6·4	4·6	5·9	4·4	2·4
Class IV:															
Males	4·7	13·4	17·3	19·8	20·5	19·5	15·3	11·9	8·7	7·1	4·6	3·5	4·0	4·4	1·8
Females	3·8	10·9	16·9	20·2	19·3	21·8	16·6	12·5	10·4	8·4	7·1	4·8	7·5	5·4	3·6
Persons	4·2	12·1	17·1	20·0	19·9	20·6	15·9	12·2	9·5	7·7	5·8	4·2	5·8	4·9	2·6
All classes:															
Males	4·4	9·4	13·8	16·3	17·1	17·5	14·3	10·8	8·1	6·5	4·6	3·2	4·1	3·5	1·7
Females	3·2	7·7	12·4	14·6	15·7	17·7	15·2	11·7	9·3	7·6	5·9	4·5	5·9	4·6	2·4
Persons	3·8	8·6	13·1	15·4	16·4	17·6	14·7	11·3	8·7	7·0	5·3	3·8	5·0	4·0	2·1

* Social class I is the best social class and social class IV the worst.

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